Evaluation of Waste-to-Energy Technology Use by South African Metropolitan Municipalities

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ABSTRACT

This research aimed to assess the implementation of waste-to-energy (WtE) technology in three South African metropolitan municipalities, which are the City of Johannesburg, the City of Tshwane and the City of Ekurhuleni, focusing on its technical, economic, and environmental feasibility. As the push for decentralised electricity generation intensifies, local governments seek alternative energy solutions to lessen their dependence on the national grid. While many metropolitan areas have concentrated on solar and wind energy initiatives, this study explores the potential of WtE technology to tackle waste management challenges and energy production requirements simultaneously. By utilising a mixed-methods approach, the research will offer a thorough understanding of the obstacles, advantages, and sustainability outlook of WtE projects in the context of South African metropolitan areas.

The study's findings highlight that while WtE technology is increasingly recognised as a sustainable solution for waste management and energy generation, its adoption in Gauteng's metropolitan municipalities remains limited. Survey results indicate that approximately 66% of respondents consider WtE crucial for reducing landfill dependence and diversifying energy sources, yet financial, regulatory, and technological barriers hinder large-scale implementation. Johannesburg, Tshwane, and Ekurhuleni have varying levels of adoption, with some operational projects like landfill gas-to-energy plants and biogas facilities contributing modestly to the grid. However, challenges such as high capital costs, lengthy approval processes, and infrastructure deficits necessitate targeted policy interventions and investment strategies to accelerate WtE adoption.

KEYWORDS

Waste-to-energy.

Sustainability

Energy Consumption

Energy production

Local government

Metropolitan

Municipalities

Cities

Renewable energy

DECLARATION

I, **Tembalethu Nomongo**, declare that this research report is my work except as indicated in the references and acknowledgements. It is submitted in partial fulfilment of the requirements for the degree of Master of Management in Energy Leadership at the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination in this or any other university.

Name: Tembalethu Nomongo Signature: *TNomongo*

Signed at ………Johannesburg……………………………………………

On the ……………………………28 day of ……February…………… 2025…..

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CHAPTER 1
INTRODUCTION

1.1 Purpose of Study

The research delves into how waste-to-energy technology is employed in Gauteng’s major urban centres, focusing particularly on the municipalities of Johannesburg, Tshwane, and Ekurhuleni. These cities form a considerable portion of the province's urban environment and act as the central subjects for this study. The core objective here is to understand the extent and manner in which this technology is applied across these urban centres.

1.2 Context of the Study

The research is centred on the three Gauteng metros of South Africa that are Johannesburg, Tshwane, and Ekurhuleni. An energy deficit in South Africa has propelled a move toward localised power production. With a more decentralised approach to power generation, local authorities and municipal governments have become vital players in producing energy from a variety of sources. In many of the big cities, the work of local governments in building large-scale power plants using renewable energy and other alternative generation methods is already well underway and showing successes (Inglesi-Lotz, 2023).

The surge in urban populations within South Africa, alongside the shrinking output from Eskom, the nation's primary electricity supplier, has intensified the power crisis. At the heart of this issue lies the antiquated and inadequately funded state of national infrastructure, which results in a waning capacity for energy delivery. This is not just a South African problem. India and Pakistan often encounter similar situations that lead to numerous blackouts and load-shedding episodes, impacting both companies and homes (Khan & Kabir, 2020).

To address the energy shortfall, a lot of big cities have started embracing renewable energy projects, like solar and wind power. Cape Town aims to be carbon-free by 2050, with solar energy being the major thrust. The big problem is that solar and other renewables are still expensive compared to energy from fossil fuels (Jakeni et al., 2024).

Using WtE technology is a promising way to solve both the waste management and energy generation challenges faced by modern societies. As landfills fill up and space for waste disposal becomes scarcer, WtE can serve as a renewable energy source that reduces the volume of waste. Globally, there is a long way from realising this potential as WtE makes up only a small fraction of the world's energy mix, although its capacity is expected to grow in the future (Komane & Mathonsi, 2023).

Metro urban areas generate a massive quantity of waste, contributing greatly to the overall waste problem of the nation. WtE presents a sustainable option for addressing two major issues: sustainable management of waste and energy supply. But despite the technological advances and the tremendous benefits those advances promise, many environmental organisations oppose WtE because the facilities have potential for environmental harm (Bailey, 2024).

Additionally, the numerous challenges posed by existing regulations make widespread adoption of WtE exceedingly difficult. Research and development in this area are crucial, as well as understanding the current regulatory framework and the possibilities for policy reform (Le, Nguyen & Park, 2020).

1.3 Research Problem

South Africa sees a minimal contribution of just about 1% from renewable energy, including WtE technologies, to its energy mix (Rasmeni & Madyira, 2019). This represents a real challenge for the country's major metropolitan municipalities, as they have to meet a large energy demand with a relatively small share coming from these alternative, sustainable sources. It also means that the limited energy capacity produced in these ways contributes little toward the national goal of 19 gigawatts (GW) of renewables by 2030 (Department of Energy, 2019; Lyons & Gross, 2017). In these large cities, environmental and economic factors certainly favour the use of WtE technologies.

Urban municipalities in South Africa are barely using WtE projects as part of their energy supply. A few metropolitan municipalities, eThekwini (Durban), Ekurhuleni (East Rand), Tshwane (Pretoria) and Johannesburg are beginning to explore WtE as an energy source. According to Ramparsad (2020) and Turpie and Letley (2023), very few WtE projects have been initiated, despite the many options and forms of waste that can be used. Being renewable and locally abundant, WtE has a large potential as a power source. However, its integration into the municipal energy mix is not happening fast enough because of the obstacles mentioned earlier, mainly financial, regulatory, and technical, which will need to be overcome in the coming years.

1.4 Research Objectives

- To evaluate the inclusion of waste-to-energy technology in the current energy mix within the Gauteng metropolitan municipalities.
- To understand the constraints that contribute to the slow rate of adoption and implementation of waste-to-energy technology by the Gauteng metros.
- To propose the relevant technologies that are appropriate for waste-to-energy projects used by the metros in Gauteng.

1.5 Significance of the Study

The WtE approach offers a practical answer to the swelling waste management crisis in South African cities. Landfills are rapidly reaching capacity, making conventional waste disposal untenable. WtE not only lessens the volume of refuse that ends up in landfills but also produces an impressive amount of energy sufficient to supply power to a substantial number of residences. In the current modern era, urban areas are growing at an unprecedented rate, with energy demands rising alongside them. They are also generating more waste than ever before, much of which can be converted into power. WtE is one such answer, and its application is gaining prominence across the globe (Khan & Kabir, 2020).

1.5.1 Waste Volume Reduction

WtE technology diverts amounts of non-recyclable waste away from landfills, which are running out of space at an alarming rate. Already, urban South Africa has too few landfill options, and the old ones are filling up fast. Traditional landfilling not only uses up land but also poses a long-term threat to the environment (Komane & Mathonsi, 2023). Thus, when waste is thrown away, it still has the potential to do harm. South African urban centres generate ever-increasing amounts of waste, and the technology to do WtE is readily scalable and aligns with the broad objectives of sustainable development (Komane & Mathonsi, 2023).

1.5.2 Mitigation of Greenhouse Gas Emissions

WtE technology serves an important environmental function: it curtails greenhouse gas emissions. This is particularly relevant when it comes to methane, which forms as a byproduct when waste materials decay in anaerobic conditions, such as those found in many landfills (Khan & Kabir, 2020). Methane is the second most prevalent greenhouse gas and is 25 times more effective at trapping heat in the atmosphere when compared to carbon dioxide (Khan & Kabir, 2020). Using waste as a source material for energy generation reduces not only the amount of waste but also the amount of methane that might otherwise have been emitted, and that is far more damaging to the atmosphere than an equivalent amount of carbon dioxide (Vincent et al., 2018).

1.5.3 Conservation of Resources

Waste-to-energy technology is important for conserving resources, as it reduces the need for finite natural resources, especially fossil fuels (Narassimhan, 2025). This is because WtE turns waste into renewable energy. It helps to displace energy that would otherwise have to come from coal, oil, and natural gas, which are still the main contributors to South Africa's energy supply (Naicker & Thopil, 2019). By generating energy from waste, WtE lessens the strain on these conventional resources. Using some of the ash from the WtE process in construction materials also contributes to resource conservation by decreasing the demand for new raw materials (Monyai, Chivanga & Katsande, 2023). In this way, WtE can be a large step towards even a society being a circular economy; it can diminish the very idea of waste, turning it instead into a resource, something to be used again.

1.5.4 Economic Advantages

WtE technology offers a dependable and eco-friendly energy solution (Kruger, 2023). In South Africa, where energy problems are rampant, the technology provides a way out. It is used to turn waste into power, serving as a multifaceted tool for municipalities (Nel-Sanders, 2023). Producing local power closes the gap between consumption and the amount of power that a city generates, and the technology is being integrated into the local ecologies of cities and provides more than just a means of power production (Nel-Sanders, 2023). It is the local power plant and is being used to substitute and diversify the energy sources that form part of the power grid (Thaba, 2021).

Besides producing energy, WtE plants offer municipalities a chance to earn income. Local governments can sell the electricity produced at WtE plants, either back to the national grid or directly to local businesses and homes (Leigland & Eberhard, 2018). This income can then be used to compensate for the costs of waste management, making WtE projects financially viable for local government (Kruger, 2023). A major part of the revenue that WtE plants earn comes from what are called tipping fees paid by the waste producers (Leigland & Eberhard, 2018). In other words, the waste producers pay the WtE plants to take their waste to work on it. The plants take the kind of waste that would normally be landfilled and make it yield a far better, more sustainable result (Leigland & Eberhard, 2018).

The development and running of WtE plants provide numerous employment opportunities, greatly benefiting local economies (Leigland, 2020). Building these facilities calls for skilled workers in several areas engineering, project management, and construction, being just a few (Oelofse & Muswema, 2020). When the plants are up and running, they promise long-term jobs in plant management, operation, maintenance, and administration (Leigland, 2020). They also create jobs in sectors that support them: waste collection, transportation, and recycling (Kruger, 2023). These are particularly relevant to South Africa, a country where unemployment is high. In a way, WtE is not only about achieving energy and waste management goals but also about giving people jobs (Oelofse & Muswema, 2020).

1.6 Delimitations of the Study

This study zeroes in on WtE systems now being used, or at least contemplated, in the Gauteng towns of Ekurhuleni, Tshwane, and Johannesburg. These three cities, all of them with large populations, also boast of outputs of waste. The main reasons are that its large metros produce a lot of waste, and the technology is already available to convert that waste into energy. The metros involved have the assets to make WtE work, and the technical expertise to see it through to fruition. They produce enough municipal solid waste (MSW) to keep such projects running and to make them a consistent producer of electricity. That is important, not just because the country needs more energy sources, but also because it needs more electricity and because Gauteng (the heartbeat of South Africa's economy) is already suffering from the dual problems of energy supply disruptions and an insecure energy future.

1.7 Definition of Terms

The study defines the following key terms as follows:

1.7.1 Sustainability

Sustainability emphasises fulfilling current needs while ensuring that future generations have the resources they require to meet their own needs.

1.7.2 Renewable Energy

Renewable energy is conceptualised as energy sources that are inexhaustible and continually replenished (Twidell, 2021). These energy sources are naturally occurring, often produce minimal to no carbon emissions, and are replenished more quickly than they are utilised (Ehrlich, Geller & Cressman, 2022). Notable examples of renewable energy sources include wind power, solar energy, bioenergy (derived from burning organic materials), and hydroelectric energy, which includes tidal power.

1.7.3 Energy Mix

The concept of energy mix describes the distribution of final energy consumption across various primary energy sources within a specific geographical area (To & Vo, 2020).

1.7.4 Waste-to-Energy

It is a process of transforming waste through primary treatment into usable energy, such as electricity. Waste-to-energy represents a method of energy recovery.

1.8 Assumptions

The researcher makes the following assumptions:

- The respondents are expected to provide accurate and truthful information regarding the transition during the interviews. Those chosen for participation in this research occupy roles in their respective fields and possess relevant knowledge on the topic at hand.
- The respondents from metros understand the policy aspects related to the energy sector, specifically the waste-to-energy sector.
- The respondents from the industry are going to be willing to take part in this study and provide critically relevant information for the research.

CHAPTER 2
LITERATURE REVIEW

2.1 Introduction

As early as 2005, the South African metro municipalities intentionally used their capacity and amount of waste. However, up to now, the metros are still facing energy challenges just like the rest of the nation, despite the local authority having modern plans of converting waste to energy. South African metro faces unique challenges regarding the composition and quantity of its waste and the infrastructure required to convert waste into energy (Sithole, 2021). The chapter will discuss the waste-to-energy production processes, the energy production levels, and the energy crisis that affects South Africa in general and, subsequently, the South African metros.

2.2 Overview of Waste-to-Energy

WtE technology plays an important role in the sustainable management of waste and the production of energy. It transforms non-recyclable waste into energy, thus reducing the burden on landfills and enhancing energy security. WtE is a key component of both the circular economy and the sustainability paradigm. These ecologically pragmatic principles relegate waste to the status of an interim resource that, through several strategies and processes, can be rerouted into economic and energy systems (Tsui & Wong, 2019).

WtE is a method for producing energy, whether electricity or heat, from waste. This applies to non-recyclable MSW that is processed to extract as much energy as possible (Mayer, Bhandari & Gäth, 2019). This dual-purpose approach integrates effective waste management with energy production, mitigating the volume of waste directed to landfills while enhancing urban energy supply. The main goal of WtE is to use waste as a valuable source of energy. It is an attractive option for urban areas, where waste generation is high and landfill space is at a premium, as a potential solution to achieve both better waste management and energy security (Mayer, Bhandari & Gäth, 2019).

WtE is a method that creates electricity or heat from waste treatment, predominantly using non-recyclable municipal solid waste. This technique serves a dual function, reducing the amount of waste directed to landfills and boosting the urban energy supply. The technology is designed to capture the maximum amount of energy with minimal emissions, and it is particularly useful in dense urban areas where available landfill space is small and waste generation rates are high, serving both the waste disposal problem and the energy supply problem (Wienchol, Szlęk & Ditaranto, 2020).

Around the world, WtE has emerged as a promising method for generating power, especially in areas saddled with waste management problems. It has taken hold in Europe, a continent where numerous member states are now relying heavily on WtE to generate power. Denmark and Sweden are two prominent examples. In Copenhagen, the Amager Bakke facility processes around 400,000 tons of waste each year and provides electricity and heat for thousands of households (Wienchol, Szlęk & Ditaranto, 2020). This is an example of a metropolitan region relying on WtE as a means to manage its waste and, in the process, power a lot of the local economy.

Denmark is a leader in the WtE sector, setting a global standard for converting waste into usable energy. This sector is part of a broader strategy that the country has pursued for decades to become one of the world's most environmentally sustainable societies (Johansen & Werner, 2022). Danish law and policy have pushed the nation's recycling rate to among the highest in Europe and have long ensured that only non-recyclable waste ends up in energy-generating WtE plants (Scarlat, Fahl & Dallemand, 2019). Aside from technological innovation, Denmark's waste management policies are forward-looking in their prioritisation of recycling and their focus on the optimal use of resources.

Denmark has minimised its environmental impact while maximising the potential benefits derived from waste (Scarlat, Fahl & Dallemand, 2019). The Danish model serves as a persuasive example of how to incorporate WtE into a broad waste management plan that aims for sustainability. Denmark uses WtE extensively, but in combination with a host of other methods that, together, make up an integrated waste management system. This system is part of Denmark's achievement of a high level of sustainability and is a fundamental pillar of its circular economy (Scarlat et al., 2019).

WtE technology adoption in the United States shows regional differences. Some places have gotten out ahead of the curve, such as Alexandria, Virginia, which has one of the country's oldest WtE plants in Lorton, Virginia. The Alexandria/Arlington energy-from-waste facility has been around since 1988 (Mukherjee et al., 2024). This plant can process about 350,000 tons of municipal solid waste annually, and it provides electricity for 20,000 homes. It does all this while cutting down on almost 90% of the waste that would otherwise go into a landfill. Even so, the growth of WtE plants in the United States runs up against a far tougher regulatory environment than perhaps anywhere else in the world. That is mainly because of renewed attention to the concerns of emissions that these plants release (Badgett & Milbrandt, 2020).

In Hartford, Connecticut, the Materials Innovation and Recycling Authority (MIRA) runs a WtE plant. This facility processes a remarkable 500,000 tons of waste every year, transforming most of it into electricity and recovering recyclable metals (Badgett & Milbrandt, 2020). The Hartford WtE plant is a major component of Connecticut's waste management program. This is because it enables the state to achieve one of the highest recycling rates in the country. Nonetheless, the infrastructure of this WtE facility is ageing and increasingly costly to operate. This situation, as well as the various environmental and public health threats associated with incineration, has prompted many to call for a rethinking of waste-to-energy conversion in Connecticut and across the United States (Badgett & Milbrandt, 2020).

Across Africa, the adoption of WtE technology is picking up speed as countries look for efficient ways to handle their waste management problems and find new sources of power. For many, the nexus of these two issues is urbanisation: Africa is the most rapidly urbanising continent in the world, and its largest cities are growing at rates not seen anywhere else (Asmare & Alelign, 2019). Half of all Africans will live in cities by 2050, according to the African Development Bank, and those cities will produce two to three times more solid waste than they do today (Ngcamu, 2022).

WtE processes use a variety of technologies, with incineration, gasification, pyrolysis, and anaerobic digestion as the most widely used. Incineration, the foremost method, involves burning waste at high temperatures to produce steam, which drives a turbine and generates electricity (Mohammadi & Harjunkoski, 2020). Gasification and pyrolysis are very similar methods. Both decompose waste by charring it in oxygen-poor environments, but there are a couple of differences.

Gasification produces a syngas that can be used directly as a fuel; pyrolysis produces a gas that has more energy and can be used to produce electricity when it is cleaned up (Tsui & Wong, 2019). Anaerobic digestion, meanwhile, is a method ideally suited for organic waste and results in the production of biogas, mostly methane ($CH4$), that can be used directly as a fuel or can be burned in a gas engine to generate electricity.

Economic factors are crucial in deciding whether to adopt WtE technologies. These technologies require an initial investment because of the necessary infrastructure. However, the long-term benefits can make this investment worthwhile (Mohammadi & Harjunkoski, 2020). WtE plants offer many advantages; they reduce reliance on landfills, they generate energy from a constant source, and they emit far less methane than landfills do. The energy produced by WtE plants is also local, often supplying 2% to 5% of a city's electricity requirements. WtE, however, is generally seen as a supplementary energy source to other renewable energies such as solar and wind (Khan & Kabir, 2020).

Despite its benefits, WtE encounters several challenges. WtE facilities are not very efficient at generating electricity; even the most modern plants only convert about 20–30% of their non-recyclable waste into electricity, a serious drawback compared to the efficiencies of renewable technologies like solar and wind (Khan & Kabir, 2020). The efficiency of energy output is limited by the amount of waste that can be processed. Critics also worry that WtE might undermine recycling initiatives because it could diminish the incentive to sort and recycle materials at their source (Khan & Kabir, 2020).

The efficiency of WtE facilities in electricity generation is generally low, with most modern plants achieving only about 20-30% efficiency, a critical drawback when compared to other renewable technologies like solar and wind (Khan & Kabir, 2020). Furthermore, energy output is constrained by the quantity of waste that can be processed since WtE plants typically only manage non-recyclable waste. Critics also raise concerns that WtE might undermine recycling initiatives, as the incineration process could diminish the incentive to sort and recycle materials at their source (Khan & Kabir, 2020).

While WtE may not single-handedly fulfil the energy needs of large urban centres, it plays a crucial role in promoting sustainable urban development. By converting waste into a valuable resource, WtE enables cities to manage waste more effectively while contributing to a diversified energy portfolio. Its utility is particularly pronounced in urban locales where landfill space is scarce and waste generation is high, providing both environmental and economic advantages. The future of WtE is likely to witness further technological innovations, enhanced efficiency, and better integration with other renewable energy sources, paving the way for more sustainable energy systems.

2.2.1 Key Technologies in Waste-to-Energy

Various technologies enable the transformation of waste into energy, each with its specific methods and uses. Incineration is the most common waste-to-energy method. It burns waste at high temperatures to create heat, which directly or indirectly produces steam to drive a turbine that generates electricity. Several leading-edge incineration plants, like those in Copenhagen and Paris, operate at high efficiency and use advanced pollution control systems to minimise the release of hazardous substances to the atmosphere. Even so, incineration has come under heavy fire in recent years as a waste management tool in Sweden and elsewhere, where air quality is taken extremely seriously and where the primary objective is to minimise the release of greenhouse gases (Rezania et al., 2023).

These advanced thermal processes break down waste in oxygen-limited environments. Gasification creates syngas, a blend of hydrogen and carbon monoxide, which serves as a fuel or a basic material for generating electricity or producing chemicals and synthetic fuels (Rezania et al., 2023). It is an especially effective way to use organic waste and offers energy efficiency and emissions reduction when you compare it to incineration (Rezania et al., 2023). Pyrolysis is a method that breaks down organic materials in the absence of oxygen. It produces bio-oil, syngas, and char. Yet, both of these technologies are still emerging and require huge initial capital outlay to get started.

The process of anaerobic digestion breaks down biodegradable waste in the absence of oxygen. This method generates biogas, which is rich in methane and can be used to produce electricity and heat or can be purified to the level of natural gas. Anaerobic digestion is conducted on a large scale in the agricultural sector, where widespread organic waste offers a convenient basis for this low-emission energy solution (Mazzanti, Modica & Rampa, 2021).

The decomposition of organic matter in landfills generates a large amount of gas, about half of which is methane and half carbon dioxide, both of which are potent greenhouse gases. This is why landfill gas is now being collected at many sites and burned for energy recovery. By capturing and burning the gas, it not only generates some modest amount of energy but also prevents a substantial environmental impact. This method is frequently employed in South Africa, where landfilling continues to dominate waste disposal practices.

2.2.1 Applications and Advantages of WtE

WtE technology serves multiple applications, addressing both waste management and energy production. A primary application of WtE is energy production. Cities such as Copenhagen and Paris show that WtE plants can satisfy as much as 5% of their energy needs by using municipal solid waste. Even though WtE will probably never completely substitute conventional energy sources, it already serves a major purpose in making the energy mix more varied and less dependent on fossil fuels (Malinauskaite & Jouhara, 2019). Besides generating electricity, WtE plants can also supply thermal energy for district heating networks.

The Amager Bakke facility in Copenhagen, for example, provides heat to 150,000 homes, demonstrating the plant's efficiency in capturing energy from waste, especially in colder climates (Malinauskaite & Jouhara, 2019).

Energy recovery in WtE is not only about generating kilowatts; it's also about providing warmth. By substituting a combustion process for the landfill, WtE greatly reduces the volume of waste that needs to be disposed of. Landfills can serve more people for a longer time when WtE is employed because they get filled more slowly. WtE eliminates all the traditional harms associated with landfilling, such as groundwater contamination and the release of greenhouse gases like methane (Arena, 2012).

From an economic perspective, WtE presents both opportunities and challenges. On the upside, WtE can generate revenue for municipalities through the sale of electricity, heat, and byproducts like biogas and recyclables. It also reduces costs associated with landfill management and environmental penalties. Additionally, in regions with carbon pricing or emissions trading, WtE can offer financial incentives by lowering greenhouse gas emissions.

WtE offers municipalities a way to earn revenue, and by using WtE facilities, they can sell electricity and heat. In some cases, they can also sell biogas and recyclables, which the facilities generate. This means that a municipality can sell these products and lessen the costs of managing landfills. Moreover, in places that have carbon pricing or emissions trading, WtE facilities can help municipalities avoid paying for their carbon emissions, providing another economic advantage (Reinhart et al., 2022).

On the other side of the coin, building WtE facilities demands intensive initial capital. Crafting today's WtE plants with the latest pollution control technologies is not cheap. For any municipality, especially those in poorer countries, the cost can be intimidating, and these facilities often make sense only if there is a steady stream of waste to feed them, if energy prices remain stable, and if governments support the initiative. The landfill is still a cheaper option than a WtE plant. In places like South Africa, it is hard to make the case for using the facilities in the absence of governmental intervention and incentives (Dlamini et al. 2019).

WtE offers some promise for both managing waste and generating power, yet it has its drawbacks. The proportion of a city's energy needs that WtE meets is relatively small, usually only 2% to 5% in large cities. Mutelo (2023) states that by far the largest WtE company in the U.S. The reason behind this modest share is simple: it is a question of supply and demand. Urban areas have huge energy appetites, and there is simply not enough waste to convert into electricity to satisfy the energy needs (Mutelo, 2023).

2.3 Waste Production in the Metros

It is imperative to first look at waste production levels and the potential and capacity of waste produced by the metros. In South African metropolitan areas, waste production has been on the rise. This can be attributed to fast-paced urban growth and the swift march of industrialisation, especially within cities. Urban areas have increasingly become centres of both population and industry (Zeru, 2025). As a result, the amount of waste generated has grown exponentially. This has, unsurprisingly, put a great deal of pressure on both the waste management systems and the environment (Ayeleru, Okonta & Ntuli, 2021).

The increase in waste generation in South Africa is largely due to the expanding urban population in the country's largest cities. The United Nations projects that more than 70% of South Africans will be living in urban areas within the next two decades (Islam, 2025). Rapid urbanisation, as is well-documented globally, has been associated with a number of environmental problems, the foremost of which, certainly in the developing world, is the generation of waste (Maalouf & Mavropoulos, 2023).

Industries produce a substantial amount of both hazardous and non-hazardous waste, which adds pressure to the already overburdened waste management systems. The improper disposal and treatment of waste from industrial sources result in several problems, notably environmental pollution and associated health risks for communities living near these industrial sites (Adeniran & Shakantu, 2022).

South African metros are increasingly producing more waste, and this is partly because their waste management infrastructure is inadequate, leading to poor levels of waste collection and disposal (Cudjoe & Acquah, 2021). Many of the cities are simply using outdated systems that can't keep up with the amount of waste being generated. The result is waste piled up in public spaces, polluting the environment and posing health risks to residents.

A lack of public awareness and education regarding proper waste disposal and recycling practices also contributes to the high waste production levels (Adeniran & Shakantu, 2022). Many South Africans are not adequately informed about the impact of their waste disposal habits and the importance of recycling, leading to higher levels of waste generation and improper disposal.

Wet, solid and gaseous waste streams present opportunities for the domestic production of biofuels, bio-product precursors, heat, and electricity (Mahadew, 2021). Waste materials hold considerable promise as largely untapped sources of renewable energy and valuable products. Using waste as a feedstock for energy production could reduce the reliance on fossil fuels (Mahadew, 2021). The waste hierarchy is the framework that informs and elucidates the kinds of decisions that must be made if energy is to be extracted from waste, as opposed to the direct incineration of waste for its own sake.

The waste hierarchy sets a well-defined priority for handling and minimising waste. It underscores that recovering energy should come into play only when attempts to reduce, reuse, recycle, and compost have been exhausted. Even then, turning waste into energy stands as a much better option than simply letting it decay in a landfill (Scarlat et al., 2019). The waste-to-energy pathway's sustainability hinges on two main factors: the efficiency of the conversion process and the share of biodegradable matter within the waste stream (Scarlat et al., 2019).

It is imperative to note that within the waste-to-energy, not all technologies fit within the bracket of ‘renewable’, ‘sustainable’ or ‘green’ terms (Hlongwane & Daw, 2022). Some of the technologies, such as combustion, produce carbon monoxide, which is bad for the environment, whilst at the same time gasification technique can be classified as ‘sustainable’ or any other environmentally appropriate and progressive term.

The difference between a "recovery" method and a simple "waste disposal" lies in the techniques used. Numerous ways exist to turn waste into energy. These involve transforming the waste not into harmful by-products but into useful forms of energy (Hlongwane & Daw, 2022). How this is accomplished includes combustion, gasification, pyrolysis, anaerobic digestion, and landfill gas recovery. These methods are used in waste-to-energy plants, facilities that generate energy by incinerating waste to make steam in a boiler that then drives a turbine to produce electricity. The resulting steam is utilised to power a turbine, which generates electricity. Key to this study are the two aspects of combustion and gasification.

2.3.1 Combustion

Combustion is the incineration of waste, which in turn drives a turbine to produce electricity. This indirect method of energy generation currently operates at an efficiency level ranging from approximately 15% to 27%, although there is considerable room for improvement (El Sheltawy et al., 2019). Combustion can be characterised as a high-temperature exothermic redox reaction, involving a fuel (the reductant) and an oxidising agent, typically atmospheric oxygen.

The sustainability of any energy generation approach using waste largely hinges on the ‘net calorific value’ of the waste being processed (El-Shahidy et al., 2019). The process of burning waste is like the process of burning fossil fuels. Rubbish is collected in a facility, either a classic incinerator or a waste energy recovery facility. The difference is that the first device burns waste. In contrast, the second converts it into energy, and the incinerated waste inside meets oxygen and releases heat, a key ingredient of energy production in the form of steam (Tsui & Wong, 2019). The steam powers the turbine and generator for the production of electrical energy. In the context of waste incineration, the energy yield should be approximately 7 MJ/kg. This indicates that materials such as paper, plastics, and textiles are particularly well-suited for energy recovery through combustion.

2.3.2 Gasification

Gasification serves as a flexible waste-to-energy technique that can convert a wide range of waste materials, such as municipal solid waste, industrial byproducts, and biomass, into synthetic gas or syngas (Karemore et al., 2020). Syngas finds application in power generation, particularly in driving gas turbines or engines, which in turn produce electricity. This use case aligns with the broader trend toward renewable energy sources, with syngas itself often seen as a kind of renewable energy. Several pilot plants using syngas to generate electricity are operational around the world, including a few in Japan that are running on landfill gas, the ultimate renewable energy source (Karemore et al., 2020), which could be seen as a kind of "mitigated" landfill waste.

Gasification not only generates electricity but also enables hydrogen production, a clean fuel under serious consideration in places like the U.S. and Europe (Rezania et al., 2023). These regions see hydrogen as a sustainable alternative, especially for refining and chemical production. A principal component of gasification, syngas, can also be used to make biofuels, such as bioethanol and biodiesel. Enerkem, a leading company in Canada, is using municipal waste to make these cleaner energy alternatives (Rezania et al., 2023).

Syngas serves as a direct fuel for generating heat or steam, used in industrial settings or for district heating systems. The method is widespread in a number of European nations, furnishing energy for both the residential and the industrial sectors (Rezania et al., 2023). Beyond this, syngas's main chemical components, carbon monoxide and hydrogen, are very much of industrial interest in sectors of the chemical industry that directly affect everyday life. Both methanol and ammonia, two simple, well-known chemicals made from syngas, are used to make plastics and fertilisers, respectively. And few places in the world have embraced the integration of waste gasification into their circular economies as much as South Korea (Kim et al., 2021).

2.4 South African Energy Context

This section will focus mainly on South Africa’s energy profile, including the consumption

2.4.1 South Africa Energy Consumption

South Africa ranks among Africa's most sizable economies, and energy consumption remains crucial to both its economic progress and its growth potential. Energy fuels the nation's industries and infrastructure, which are already developed, while also catering to the demands of a population that is both poor and increasing in size (Atsu et al., 2021). Although there has been a notable movement towards adopting more sustainable and renewable energy sources in recent years, coal remains the predominant energy source for the nation (Atsu et al., 2021).

The energy consumption profile of South Africa is coal-dominated and is the mainstay of the nation’s energy production (Gabbar & Ahmad, 2024). South Africa is rich in coal, which has long been its main energy source for electricity generation. Coal-fired power stations are the core of its energy framework and play a key role in satisfying the nation’s huge thirst for power (Gabbar & Ahmad, 2024).

South Africa also depends on various energy sources in its energy mix, which includes renewables and non-renewables. The country has one nuclear power plant, which contributes to its energy supply, and natural gas is used in a limited capacity for both electricity generation and industrial processes (Olanrewaju et al., 2019). The expansion of investments in renewable energy, mainly solar and wind energy, has been a topical issue within the energy sector of the country. To encourage investment in green projects and broaden its energy mix, the government has rolled out initiatives such as the Renewable Energy Independent Power Producer Procurement Programme, or REIPPPP (Olanrewaju et al., 2019).

South Africa has been trying to diversify its energy sources; however, its energy system is still chiefly dependent on coal. This has many negative effects on the environment and the health of its citizens (Akinbami, Oke, & Bodunrin, 2021). A very serious problem is the impact coal dependency has on global warming, with all the associated outcomes: more extreme weather events, sea level rise, droughts, and so on.

Its demographic and economic factors also influence South Africa's energy consumption profile. South Africa is witnessing an upsurge in its population and urbanisation, leading to a rise in energy demand. The mining, manufacturing, and agriculture industries are some of the most energy-hungry sectors, and the amount of energy they consume forms a large part of the overall energy profile in the country (Tsaurai & Ngcobo, 2020).

Recently, the state has recognised an immediate necessity to overhaul the energy sector. The aim is to engage a variety of other sources that, while abundant and efficient, are friendly to the environment and do not emit nearly as much in the way of climate-altering substances as coal does (Tsaurai & Ngcobo, 2020). The IRP key initiative is to make a large dent in the share of coal power. By the year 2030, the plan is for coal's share to drop and for the share of green energy to rise considerably. It is quite a substantial dent and expansion that is being planned for the next 10 years (Tsaurai & Ngcobo, 2020).

2.4.2 Energy Crisis in South Africa

South Africa is grappling with a serious and urgent issue related to its electricity supply. For many years, the nation has been dealing with an energy crisis primarily due to poorly managed and underinvested power infrastructure. This has especially affected the state-run power utility, Eskom (Marope & Phiri, 2024). The insufficient oversight and investment in the utility have led to frequent power outages and load shedding, negatively affecting businesses, industries, and households (Naidoo, 2023). The unreliable power supply has scared away investors, too. This is posing a dire threat to the rate of economic growth the country can achieve (Naidoo, 2023).

South Africa boasts the largest electricity grid in the Southern African region, with high electrification levels and per capita energy use (Hlongwane & Daw, 2022). Yet, a deteriorating energy situation has taken hold over the past decade and a half, and the nation has experienced almost two years of rolling blackouts, beginning in November

2022. The situation has resulted in the kind of diminished reliability that is seen nowhere else in the Southern African region, and it has meant that South Africa has become the only country in the region where electrification levels are dropping (Marope & Phiri, 2024). The year 2023 was likely to have been the worst on record, as it is estimated that the country spent at least a few days without some form of load shedding (Eskom, 2024).

The country is facing an energy crisis largely because it relies so heavily on coal to produce electricity. About 90% of its power comes from coal-fired plants. These contribute not only to environmental pollution but also to the emission of greenhouse gases (Inglesi-Lotz, 2023). The coal-fired plants are getting old, with many of them being over 40 years old, and that means they are both inefficient and unreliable (Inglesi-Lotz, 2023). This results in a weak electricity supply that struggles to meet the power demand.

The current energy crisis has impacted the country's mining and manufacturing sectors, both of which are major electricity consumers (Mlambo & Mufandaedza, 2025). Mining production particularly saw a drastic reduction, declining by 4% in the last quarter of 2022 (Ekman & Lawlor, 2024). At a recent mining conference in Cape Town, the platinum mining sector, a major player in the region, noted that they had managed to cope with up to level six load shedding, but that any further escalation would bring about serious challenges. These include the potential closure of shafts and, most critically, the shedding of jobs (Ekman & Lawlor, 2024).

Unreliable electricity supply has caused many businesses to halt production and increase their operational costs. This, in turn, has led to job losses and a reduction in economic output. South Africa’s real GDP is projected to grow by just 0.3% in 2024. The prediction could be revised even lower if the ongoing effects of load shedding are not mitigated. The main obstacle to procuring more energy is the electricity grid itself (Ekman & Lawlor, 2024), the main problem being that it cannot optimally carry all of the energy that the country generates, much less the additional energy that is needed.

South Africa's struggle with a dependable electricity supply has obstructed the emergence of new industries and technologies. This energy crisis makes investors hesitate, stalling any potential area of development. Diversifying the economy and reducing dependence on traditional sectors are just ideas right now because no real change is happening. The Reserve Bank's estimates from 2024 suggest a grim reality: the energy crisis reduced the GDP by 2.1% in the third quarter of 2023. Worst hit are the agriculture, forestry, and fishing industries, which form the core of the new nontraditional export strategy.

2.5 The Role and Opportunities for Local Governments in Solving South African Energy Crises

South Africa's energy crisis is affecting its urban centres, with Eskom required by law to produce and supply electricity to municipalities. In turn, municipalities are crucial to the power system and are positioned as constitutional partners in the electricity supply industry (Hochstetler, 2020). It is important to remember this, especially when considering who is responsible and who should be held to account when there are energy interruptions (Hochstetler, 2020).

The role of the municipality in the power industry is a historical one and is ingrained in the way that the industry has structured itself. It has developed in this way for many reasons, including the influence of the World Bank and the International Energy Agency (IEA) in the utility reform and restructuring processes that have been happening over the past 20 years in many parts of the world. These reasons notwithstanding, a lot of the problems that have been developing in the electricity sector in South Africa can be traced to the level of municipalities and the things that they have or have not been doing.

Municipalities are tremendous customers in the electricity supply industry, both literally and figuratively. In 2019, the 187 municipalities listed as electricity distributors by the National Energy Regulator of South Africa (NERSA) together consumed a little over 40% of all the energy that Eskom produced (Eberhard & Kruger, 2023). They can influence the resolution of the energy crisis by doing several things: They can improve their energy efficiency, they can reduce their carbon footprints, and implement several renewable energy projects such as solar farms (Eberhard & Kruger, 2023).

Municipalities can also help their communities use less energy, and residents of local municipal governments are also taking action to cope with the energy crisis and ensure that their businesses and homes continue to function. From the perspective of law and public administration, municipalities, which are obligated to provide essential services like electricity, could see their revenue streams dry up if too many consumers reduce their electricity consumption or disconnect from the grid altogether. This potential loss of revenue is something that municipalities must guard against, and it is here that rules should be a turn to rules are made and actions taken to facilitate this shift toward energy conservation in a manner that doesn't bankrupt the municipality (Morris et al., 2020).

In fostering an environment where consumer-generated electricity finds a place in the grid, local governance plays a pivotal role. Municipalities' stamp of approval is essential for those who want to take the off-grid route, and over the last three years, several municipalities have come up with regulations that do precisely this. These include the Electricity By-law of 2010 and the Draft Electricity By-law Amendment of 2022 by the City of Johannesburg, which are making their way into the law books.

The safety and quality standards that these regulations uphold ensure that off-grid systems not only work effectively but are also not a danger to anyone nearby (Monyai et al., 2023). Recognising that their residents and businesses are suffering, local government entities are taking various measures to address the country's energy crisis. The measures range from energy consumption to the development of new sustainable energy production plants (Hlongwane & Daw, 2023).

The city of Cape Town recently launched its own “Power Heroes” initiative. Through the campaign, Cape Town becomes the first metro in the country to implement an electricity demand reduction programme. This will target 60MW in demand reduction, sufficient to protect against a complete stage of load shedding (City of Cape Town, 2023). The Hessequa Municipality, in collaboration with the Western Cape Government, is set to implement a R210 million solar photovoltaic project in Riversdale within the next three years. This initiative aims to effectively eliminate the necessity for load shedding (Western Cape Government, 2023).

Local governments in South Africa should also consider other sustainable energy solutions like biomass energy, small-scale hydropower, and energy efficiency improvements (Oelofse & Muswema, 2020). Biomass power, which uses organic materials such as agricultural residues and wood, can serve as a potent source of energy for producing both heat and electricity. The use of sustainable energy solutions can help local government entities, and through them, the nation as a whole, achieve an energy transition that is not only ecologically sound but also socially just (Oelofse & Muswema, 2020).

2.6 South African Metros and Waste-to-Energy

2.6.1 City of Johannesburg

WtE technologies offer alternative ways of managing solid waste while fostering cleaner and healthier urban environments through the recovery of waste materials and the generation of energy. Several studies have shown that with appropriate technological funding and necessary systemic reforms, waste can be transformed into a resource that aids in the socio-economic development of cities. This paper provides a critical review of the existing literature on WTE technologies and their significance for sustainable waste management in urban settings.

The Marie Louise and Robinson Deep landfills, which are waste-to-gas projects by the City of Joburg combined, are expected to produce a total of 19 megawatts of electricity from five landfill sites, which could potentially supply power to around 12,500 middle-income households (Monyai et al., 2023). Johannesburg produces nearly 1.6 million tonnes of solid waste across four operational landfill sites, resulting in substantial costs for waste transportation. This waste management approach contributes to the contamination of the air and greenhouse gas emissions from the transport trucks used for this purpose (Monyai et al., 2023).

Since 2016, Johannesburg has implemented a landfill gas-to-power initiative that has successfully extracted methane from four landfill sites, including the Robinson landfill, contributing electricity to the national grid (City of Joburg, 2020). The COJ aims to enhance this project by diverting at least one-third of its total waste, to increase electricity generation from the current 17 MW to between 30 MW and 40 MW (City of Joburg, 2023). To facilitate this expansion, transaction advisory services have been engaged to review a feasibility study conducted in 2015, guiding the project toward financial closure (City of Joburg, 2023).

Additionally, another waste-to-energy initiative has begun construction, aimed at converting biomass from the Joburg Fresh Produce Market and food waste from local restaurants into energy. Some of the generated gas will be utilised by the Metro bus system for its gas-powered fleet, while the remainder will be used to produce electricity (City of Joburg, 2023). Mathebula (2023) reported that the COJ is actively developing strategies that can assist in integrating waste pickers into the municipal waste management system. This can be achieved through the establishment of sporting facilities in various regions. This initiative aims to reduce the prevalence of illegal sorting sites that currently exist throughout the COJ.

According to Pikitup (2019), the COJ produces over 1.4 million tons of waste per year, and this excludes illegal dumping. Rapid urbanisation has contributed to the COJ's growing waste problem (Rashama et al., 2023). As the COJ expands, so does waste, while landfill space shrinks. Pikitup, the COJ's waste collection and disposal service, collects about 6,000 tonnes daily from formal and informal areas and businesses (Adeleke et al., 2022).

2.6.2 City of Cape Town

Cape Town is making notable progress in waste-to-energy projects to support its sustainability goals. The city has recently not only acknowledged the significance of this alternative energy source but has also actively sought to integrate it into its waste management plan. One major step taken by the city was the establishment of several waste-to-energy facilities. These plants convert non-recyclable waste into electricity. The City of Cape Town has even set up an incinerator that efficiently burns the waste to make electricity and power homes, businesses, and other buildings (City of Cape

Town, 2023). In the power plant, waste is shredded, dried, and then burned to heat a boiler that makes steam and the steam powers a turbine that generates electricity (City of Cape Town, 2021).

Currently, the City of Cape Town is executing its Waste-to-Energy Project, which it says will generate electricity from landfill gas that could amount to around 15 million kWh a year (City of Cape Town, 2021). This output will mainly support the operations and equipment at the landfill, including a new recycling plant that is on the drawing board. It is not enough to displace the loadshedding burden on its own, but it is something and, as the city's Energy Directorate points out, adds to the broader efforts at improving energy reliability (
et al., 2022).

An important aspect of Cape Town's waste-to-energy approach is the city's strong emphasis on recycling and waste separation (Mbazima et al., 2022). By encouraging residents and businesses to sort their waste into as many different recyclable categories as possible, the city can reduce the amount of waste that ends up in landfills. This, in turn, reduces the amount of environmental damage associated with using these landfills and also increases the operational efficiency of the waste-to-energy facilities by improving their supply of feedstock (Mbazima et al., 2022).

The City of Cape Town is also striving to increase the number of citizens who understand and engage with the waste-to-energy process. Through public education and awareness campaigns, the city is informing its residents of the immense benefits of waste-to-energy (City of Cape Town, 2022). By educating the public and promoting environmentally friendly practices such as waste separation and recycling, the city hopes to boost participation in these activities, which would lead to a greater supply of waste being available for energy production.

2.6.3 City of eThekwini

The Durban Landfill Gas-to-Electricity Project, led by the City of eThekwini, was initiated in 2004 with backing from the World Bank. This groundbreaking venture was all about tapping into the methane gas produced by landfills in the eThekwini

Municipality, because methane is a potent greenhouse gas, and harnessing it to generate electricity is much better for the environment (Zulu, 2020). The dedicated generators at the site convert the gas into electrical power, which is then fed into the local grid. The project yields about three megawatts, enough to power several thousand homes and small businesses (Zulu
, 2020).

Beyond producing energy from a renewable source, the initiative has greatly improved local air quality by cutting the amount of landfill gas that escapes into the atmosphere (Zulu, 2020). Methane is a particularly harmful gas in terms of global warming, and the efforts of the Durban landfill project have amounted to the avoidance of approximately 2.5 million metric tons of carbon dioxide equivalent emissions. With the help of the Project, it is estimated that the amount of various harmful substances in the air that would have been emitted and that are now avoided would have made local air quality even worse than it is now (Zulu, 2020).

The Durban Landfill Gas-to-Electricity Project is an initiative spearheaded by the City of eThekwini, launched in 2004 with funding from the World Bank. This innovative project focuses on harnessing methane gas from landfills within the eThekwini Municipality to generate electricity through dedicated generators. The electricity produced is supplied to the local grid and sold to the eThekwini Municipality's Electricity Department, providing around three megawatts of power (Zulu, 2020).

In addition to generating renewable energy, the project has enhanced local air quality by curtailing methane emissions that would otherwise escape into the atmosphere. It has also mitigated the detrimental impacts associated with coal transport and mining, such as dust pollution and acid mine drainage. So far, the efforts of the Durban landfill initiative have contributed to the avoidance of approximately 2.5 million metric tons of CO_2 equivalent emissions. Moreover, it has led to a reduction in pollutants such as siloxanes, nitrogen oxides, and sulphur oxides, further benefiting the air quality in the region (Zulu, 2020).

2.6.4 City of Ekurhuleni

In 2015, the City of Ekurhuleni embraced the waste-to-energy initiative by establishing the Simmer and Jack landfill biomass plant, which supplies 1MW of electricity to the Wychwood Substation in Germiston. This facility features an operational biomass power plant that utilises decomposing waste to produce electrical energy. This innovative approach not only addresses the pressing issue of waste disposal space but also captures methane emissions before they are released into the atmosphere, thereby mitigating climate change and reducing the health impacts associated with air pollution from landfills. As part of its commitment to generating clean energy from alternative sources, the Ekurhuleni Metropolitan Municipality (EMM) plans to replicate this biomass power plant model across several landfill sites in the area, aiming to create projects capable of generating an additional 2MW of power (Seshweni, 2021).

Currently, the City of Ekurhuleni is engaged in a new project in partnership with Volco Power. The proposed project had a feasibility study conducted to assess the viability of a complete waste management process using internationally proven technologies, and was deemed feasible. The project would consist of a 44MW Waste to Energy plant that will process 950 tons of waste per day. 900 tons per day of Municipal Waste would be delivered by the Municipality to the waste-to-energy plant, instead of being dumped at the landfill site (Seshweni, 2021). The landfill site is currently taking in an average of 918 tons per day of general mixed waste. According to weighbridge figures, the landfill site saw an increase of waste dumped by 15.2% over 2023 (City of Ekurhuleni, 2023).

2.6.5 Buffalo City

Buffalo City is currently situated in the Eastern Cape province of the country and has already taken progressive steps towards waste-to-energy solutions to address the increasing environmental and energy challenges facing the city. It has become imperative to implement waste-to-energy technologies due to the rapid urbanisation and industrial development in Buffalo City, leading to an exponential increase in waste generation and energy demand (Mbazima, Masekameni & Mmereki, 2022).

One of the key initiatives undertaken by Buffalo City is the establishment of waste-to-energy plants. The city has invested in state-of-the-art facilities that utilise advanced thermal and biological processes to convert municipal solid waste into energy. According to a report by the South African Waste Information Centre, these facilities can process hundreds of tons of waste per day, generating sizeable amounts of electricity and heat.

Additionally, Buffalo City has also implemented a comprehensive waste management plan that incorporates waste-to-energy as a key component. The plan includes strategies for efficient waste collection, segregation, and recycling, with a focus on diverting non-recyclable waste towards energy recovery. This approach aligns with the principles of the circular economy, where waste is seen as a valuable resource that can be utilised for energy production (Nyika et al., 2020).

Furthermore, the city has partnered with private sector companies and international organisations to leverage expertise and funding for waste-to-energy initiatives. For instance, Buffalo City has collaborated with the Global Green Growth Institute (GGGI) to access technical assistance and financial support for the implementation of waste-to-energy projects. This partnership has helped to accelerate the deployment of innovative technologies and capacity-building programs in the city.

2.6.6 Nelson Mandela Bay

Nelson Mandela Bay Metro is the largest metro in the Eastern Cape province and has been actively exploring and implementing waste-to-energy initiatives as part of its broader efforts to manage waste sustainably and reduce environmental impact. Waste-to-energy production involves converting waste materials into usable forms of energy, such as electricity or heat, through various technological processes.

One notable project in Nelson Mandela Bay is the Coega Biomass Centre, situated within the Coega Special Economic Zone (SEZ). The Coega Biomass Centre focuses on the conversion of biomass waste, such as agricultural residues and invasive alien plants, into renewable energy sources like biogas and biofuels. By utilising locally available biomass resources, the project aims to promote sustainable energy generation while simultaneously addressing waste management challenges in the region (Nguyen et al., 2021).

The Nelson Mandela Bay Municipality has expressed interest in exploring additional waste-to-energy opportunities to diversify its energy mix and reduce reliance on traditional fossil fuels. This includes considering options such as landfill gas capture and utilisation, where methane gas emitted from decomposing organic waste in landfills is captured and converted into energy. The municipality has been collaborating with various stakeholders, including private companies, research institutions, and government agencies, to identify and implement innovative waste-to-energy solutions tailored to the local context. These partnerships will facilitate knowledge sharing, technology transfer, and capacity building while enabling Nelson Mandela Bay to leverage expertise and resources for sustainable waste management and energy production (Mazhandu et al., 2021).

It's worth noting that waste-to-energy projects require careful planning, environmental assessment, and regulatory compliance to ensure their viability and minimise potential negative impacts on public health and the environment. Therefore, Nelson Mandela Bay's initiatives in this field are likely accompanied by comprehensive feasibility studies, environmental impact assessments, and stakeholder consultations to ensure responsible and sustainable implementation (Nyika et al., 2020).

As waste-to-energy technology continues to evolve and gain momentum globally, Nelson Mandela Bay's efforts in this area reflect its commitment to harnessing renewable energy sources, reducing greenhouse gas emissions, and advancing toward a more sustainable and resilient future.

2.6.7 City of Tshwane

The City of Tshwane has been proactive in harnessing the potential of landfill gas as a renewable energy source. For instance, the Onderstepoort landfill site in Tshwane has been equipped with gas extraction systems to capture methane emissions. These captured gases are then utilised for electricity generation, contributing to both waste management and renewable energy objectives (Mazhandu et al., 2021). Tshwane has also invested in waste-to-energy facilities to convert municipal solid waste into energy. One notable example is the Baviaanspoort Waste Management Facility, where a biogas plant has been established to process organic waste. Through anaerobic digestion, organic waste is broken down to produce biogas, which is then utilised for electricity generation or heating purposes (City of Tshwane, 2020).

Tshwane has also leveraged partnerships with private companies to advance waste-to-energy initiatives. For instance, the municipality has collaborated with renewable energy developers to establish solar photovoltaic (PV) installations at landfill sites. These solar PV projects not only generate clean energy but also provide additional revenue streams for the municipality (Jha et al., 2022).

2.6.8 Mangaung

One of the key initiatives undertaken by the Mangaung Metro is the construction of a waste-to-energy plant. The plant, which is currently in the planning and development phase, aims to convert the city's municipal solid waste into electricity through various thermal and biological processes. This will not only help in reducing the amount of waste sent to landfills but also contribute to the generation of clean and renewable energy.

In a case study conducted by Mofokeng, du Plessis and du Plessis (2022), it was highlighted that the Mangaung Metro is collaborating with international partners and experts to implement advanced waste-to-energy technologies. This includes the adoption of incineration, gasification, and anaerobic digestion processes to efficiently convert waste into energy. Furthermore, the study emphasised the importance of stakeholder engagement and public awareness campaigns to promote the acceptance and support of waste-to-energy initiatives within the community.

A separate case study conducted by Jha et al. (2022) emphasised the economic advantages of waste-to-energy initiatives for the Mangaung Metro. Their research revealed that the municipality could not only earn revenue from selling electricity generated from waste but also save on waste disposal costs. Furthermore, the program was found to facilitate the creation of new job opportunities and offer the potential for carbon credits, which serve as further financial incentives for adopting waste-to-energy technologies.

In addition to the waste-to-energy plant, the Mangaung Metro has also made efforts to promote recycling and waste separation at the source. By encouraging residents and businesses to segregate their waste, the municipality aims to maximise the potential for energy recovery from non-recyclable waste while minimising the environmental impact of waste disposal.

Research conducted by Mofokeng, du Plessis and du Plessis (2022), has highlighted the environmental benefits of waste-to-energy technologies. The reduction of greenhouse gas emissions, the mitigation of odour and pollution from landfills, and the conservation of natural resources are among the positive impacts of converting waste into energy.

Table 2.1: Summary of Waste-to-Energy (WtE) Technologies in South African Metros

City/Metro	WtE Technology/Project	Key Features / Outputs
City of Johannesburg	Landfill gas-to-power; biomass-to-energy (Joburg Fresh Produce Market); food waste projects	17–40 MW electricity from landfill gas; gas for Metro bus system; integration of waste pickers; 1.6M tonnes waste/year
City of Cape Town	Landfill gas-to-electricity; incineration	15 million kWh/year; boiler-steam-turbine setup; recycling and waste separation programs

City of eThekwini	Durban Landfill Gas-to-Electricity Project	3 MW power; methane capture; 2.5M tons CO_2 equivalent avoided; improved local air quality
City of Ekurhuleni	Simmer and Jack biomass plant; 44MW WtE plant (Volco Power partnership)	1 MW currently; future 44 MW plant for 950 tons/day waste; methane capture; reducing landfill use
Buffalo City	Thermal and biological WtE plants; circular economy waste management plan	Converts hundreds of tons/day; electricity and heat generation; partnership with GGGI
Nelson Mandela Bay	Coega Biomass Centre; landfill gas capture	Biogas and biofuels from biomass; exploring methane-to-energy conversion; strong stakeholder collaboration
City of Tshwane	Methane capture (Onderstepoort); biogas (Baviaanspoort); solar PV at landfills	Electricity from biogas; solar energy generation; public-private partnerships
Mangaung Metro	Planned WtE plant; incineration, gasification, anaerobic digestion, recycling at source	Energy recovery, landfill reduction, job creation, potential for carbon credits

2.7 Chapter Summary

The chapter provided a brief literature review to help readers understand the subject matter under review in the study.

Table 2.1 Consistency table: research questions and propositions

RQ #	State Research Question or Objective	Prop/hyp #	State Proposition or Hypothesis
1	To evaluate the relevance of waste-to-energy technology in the energy mix required for metros.	1	The integration of waste-to-energy technology into the energy mix of South African metropolitan municipalities will reduce reliance on conventional energy sources, leading to a more sustainable energy portfolio.
1.1		1.1	The adoption of waste-to-energy technology will positively impact the overall energy security of South African metropolitan municipalities, leading to decreased energy costs for residents and businesses.
2	To assess the lack of adoption of waste-to-energy technology by South African metros		Key barriers to the adoption of waste-to-energy technology in South African metropolitan municipalities include insufficient funding and a lack of government support, which contribute to low implementation rates.
3	To propose the relevant technologies that are appropriate for waste-to-energy projects used by metros in South Africa.	3	The proposed waste-to-energy technologies will demonstrate a higher effectiveness and economic viability compared to traditional waste management practices, leading to enhanced waste-to-energy project proposals for South African metros.

CHAPTER 3
RESEARCH METHODOLOGY

3.1 Introduction

This chapter of the research study elaborates on the proposed methodology that the researcher employed to fulfil the study's objectives and goals. The primary focus of the research was to evaluate the implementation of waste-to-electricity energy projects in metropolitan municipalities. This inquiry sought to understand the factors contributing to the slow adoption of waste-to-electricity energy initiatives, explore their significance within the broader energy mix, and suggest technological solutions for municipalities.

The chapter outlines the research methodology, including the design, sample size, data collection, and analysis methods. It also addresses ethical considerations and explains why these specific approaches were chosen, aligning with common practices in renewable energy research.

3.2 Research Approach

Goundar (2012) defines the research approach as a structured process that researchers employ to gather data, ultimately leading to well-founded conclusions or decisions. Qualitative methods such as interviews or observations are the best bets to capture the nuanced experiences, attitudes, and challenges faced by municipalities. The viewpoints of this study are also shared by various studies which were done with a qualitative aspect, which included Caferra, D'Adamo and Morone (2023), Vlachokosta et al. (2021) and Malinauskaite and Jouhara (2019).

To investigate the factors hindering the widespread adoption of WtE technology in urban environments, a multifaceted research methodology was essential. By conducting qualitative research, the study could potentially gain a better understanding of the complex factors influencing the adoption of this technology and identify potential areas for further investigation.

3.3 Research Design

Johnson (2010) describes research design as a strategy on which a study is based and the architectural plan on which the strategy is to be carried out. This study employed a qualitative approach. The study, however, had a limited quantitative analysis, with the focus only on descriptive statistics to support the qualitative data gathered. Qualitative research consisted of in-depth interviews with employees in the metros to understand their perceptions of how the WtE projects are implemented in their metros. This methodology approach was used by Adeleke et al. (2022) when studying the sustainable utilisation of energy from waste in South Africa. By integrating these methods, the study aimed to provide a comprehensive understanding of the complex factors influencing the adoption of WtE technology in cities.

Under this research design, the study adopted phenomenology, which focuses more on the information of experiences by the participants rather than the interpretations of the researcher (Shaw, Brady & Davey, 2011). This allowed the researcher to get an in-depth understanding of the views of participants on the utilisation of waste-to-energy projects in the metros.

3.4 Data Collection Methods

A comprehensive evaluation of the South African WtE landscape requires a multi-faceted approach that incorporates both primary and secondary data collection methods. In-depth interviews were conducted with key stakeholders to gather qualitative insights and perspectives. These interviews focused on understanding:

- Policy frameworks: The role of government policies and regulations in promoting or hindering WtE adoption.
- Financial hurdles: The challenges associated with securing funding for WtE projects include capital expenditure, operating costs, and return on investment.
- Technological preparedness: The availability, suitability, and scalability of WtE technologies in the South African context.

Data from municipal officials was collected from municipal employees, including officials and technicians, WtE. This information was used to identify potential barriers, recommend suitable technologies, and develop strategies for accelerating the transition to a more sustainable waste management system.

3.5 Population and Sample

This section outlines the research population and the sampling methods that were used to employ for data collection. In general terms, a population encompasses the entire group of individuals or elements that share specific characteristics (Fetters, Curry & Creswell, 2013). The context of this study population entailed the employees of the metro municipalities in charge of waste management and waste-to-energy projects. Sampling is the process whereby a small proportion or subgroup of a population is selected for analysis (Rossman & Rallis, 2012).

3.5.1 Population

Population encompasses any group of individuals or subjects that a researcher aims to investigate (Ivankova et al., 2016). In the context of this study, population referred to employees of the metro municipalities in charge of waste management, including waste-to-energy project employees, energy policymakers, technical experts, private entites with interest in WtE projects, financial officials and Department of Energy officials in charge of renewable energy.

In this study, a ‘subject matter expert’ refered to individuals with extensive knowledge, expertise, and practical experience in waste-to-energy (WtE) systems, including policy formulation, implementation, or operational management within the selected metropolitan municipalities. These included municipal waste engineers, sustainability managers, environmental planners, and energy project coordinators who were directly involved in decision-making or technical oversight related to WtE initiatives.

3.5.2 Sample and Sampling Method

The study focused on three metros in Gauteng, which are as follows:

- City of Ekurhuleni Metropolitan (Gauteng)
- City of Johannesburg Metropolitan (Gauteng)
- City of Tshwane (Gauteng)

The study made use of a sampling frame, a research term utilised to refer to the set of numbers from which a sample has been taken (Biostatistics, 2022). Each of the 3 metros had at least one waste-to-energy facility, and it was, therefore, possible to have at least a single person from each metro who was in charge of waste-to-energy operations.

The combined workforce of the three metropolitan municipalities exceeds 15,000 employees. However, not all staff members were involved in waste-to-energy initiatives, and therefore, it would be neither practical nor methodologically appropriate to survey every employee. A targeted approach focusing on individuals directly engaged in or knowledgeable about WtE was more suitable for yielding meaningful insights.

The appropriate sampling method for this study was purposive sampling. This method involved selecting participants based on their specific knowledge, expertise, or relevance to the research topic. In this case, random sampling was used due to the few numbers of officials in specific roles in the department. The selection of academics to be interviewed was based on purposive sampling; here, researchers in different renewable energy fields were interviewed. These fields included solar, anaerobic digestion, and aerobic digestion technologies. Purposive sampling allowed the research to target specific groups of participants who could provide valuable information and insights that could not be obtained through other sampling methods.

Table 3.1: Breakdown of the study participants

Group name (stratum)	**Number of participants**
Municipal Waste Management Department	03 (1 from each metro)
Waste-to-energy Project managers/officers	03 (1 from each metro)
Waste-to-energy project business development focal point person	03 (1 from each metro)

Department of Energy (Renewable energy/ waste-to-energy officers)	1
Waste-to-energy/Renewable energy technical experts (consultants, strategists and project managers)	2
Renewable energy financing experts	2
Local government expert	1
Total	**15**

The selected sample size is considered adequate based on the principle of data saturation, which suggests that meaningful patterns and insights can emerge with a focused group of knowledgeable participants. Furthermore, the sample comprised of participants specifically selected for their direct involvement or expertise in WtE projects, thereby enhancing the depth and relevance of the data collected. This purposive sampling technique ensures rich, context-specific information rather than generalised views, making the sample both manageable and analytically robust.

3.6 Procedure for Data Collection

3.6.1 Qualitative Data

The first aspect of the data collection procedure is the process of getting permission, ethical clearance and recruitment of participants in the study. Fifteen (15) participants recruited directly from the metros were exposed to the interviews, which were done on an online communication platform or face-to-face.

3.7 Data Analysis and Interpretation

It is imperative to note that the study used the JASP and NVivo tools to undertake both quantitative (descriptive statistics) and qualitative data analysis and presentation. In qualitative research, thematic analysis stands out as one of the most prevalent methods for identifying, analysing, and presenting patterns (or themes) within the data (Vaismoradi & Snelgrove, 2019). In the context of a study evaluating the use of WtE among South African metropolitan municipalities, the thematic analysis was instrumental in interpreting the insights gathered from interviews. Given the complexity surrounding issues of energy policy, technology adoption, and municipal decision-making, this method enabled the researcher to systematically scrutinise the data and pinpoint themes that aligned with the study's aims.

The initial phase of thematic analysis involved familiarising oneself with the data, and then transcribing the interviews, thoroughly reading and re-reading the transcripts, and noting early observations (Christou, 2022). This stage of familiarisation was crucial as it equipped the researcher with a comprehensive understanding of the interview content and helped identify initial patterns or recurring themes (Christou, 2022). For instance, during this phase, the researcher could recognise frequent references to financial constraints or inadequate technical skills as obstacles to WtE adoption. Immersing in the data in this way facilitated the early identification of potential themes relevant to the study objectives, such as analysing the reasons behind the slow adoption of WtE technology and assessing its role within the energy landscape.

Once the researcher had a solid grasp of the data, the next step was to generate initial codes. Coding entailed methodically labelling segments of the data that pertain to the research questions (Terry & Hayfield, 2020). Each code captured a notable feature of the data. In this study, potential codes included "policy challenges," "financial hurdles," "technical constraints, and "technology preferences."

Following the coding of the entire dataset, the researcher transitioned to the next stage: identifying themes. A theme reflected a coherent and critical pattern in the data that addresses the research questions. At this juncture, the researcher began to group related codes into broader, more abstract themes (Terry & Hayfield, 2020). In this phase, the researcher concentrated on recognising patterns that specifically connect to the study’s objectives. For example, the potential theme "obstacles to WtE adoption" could be critical for understanding the sluggish pace of WtE implementation, while the theme “technology preferences” could potentially shed light on the most relevant technologies for WtE projects in South African metropolitan contexts.

After preliminary themes were identified, the researcher reviewed them to ensure they accurately reflected the underlying data. This involved revisiting the dataset to verify that the themes truly capture the essence of the coded information and effectively address the research questions (Terry & Hayfield, 2020). During this process, the researcher needed to refine the themes by consolidating similar ones, eliminating irrelevant themes, or breaking complex themes into more manageable components.

After refining the themes, the next step was to precisely define and label each one. This required articulating exactly what each theme encompasses and determining its relevance to the study's research questions. At this stage, the researcher would craft detailed descriptions for each theme, elucidating the narrative was to convey about the data conveys. Naming the themes was equally essential, as it encapsulated the core meaning of each theme succinctly. These names could be clear, descriptive, and reflective of their content, ensuring transparency in the final report.

3.8 Limitations of the Study

- The study anticipated that the recruitment of participants to participate in the survey would be challenging. The researcher understood that there was a lot of bureaucracy in entities related to government ownership or political oversight.
- Another limitation had to do with the cost of reaching out to the participants drawn from the whole country’s 8 metros. The accessibility of some officials was a challenge. The researcher would, however, look for networks and relationships that could be used to ensure that the right people are convinced to take part in the study.

3.9 Validity and Reliability

To enhance the validity of the study, the researcher employed triangulation, gathering data from a variety of sources that is, including descriptive statistics to support the data that is qualitative data. This multifaceted approach ensured that the findings accurately represented the adoption of WtE technology within South African metropolitan municipalities. Furthermore, the researcher maintained a robust chain of evidence, ensuring that conclusions are firmly rooted in the collected data, thereby strengthening internal validity.

Regarding reliability, the study adopted a consistent data collection strategy by utilising a structured interview guide for all participants, promoting uniformity in responses. The researcher also comprehensively documented the research processes, detailing coding and analysis methods to facilitate replication by other scholars. Additionally, regular reviews and adjustments to the interview guide during preliminary testing further bolstered the reliability by clarifying questions and reducing inconsistencies in data collection.

3.10 Ethical Considerations

This research had to uphold strict confidentiality standards, honouring the privacy and anonymity of all participants. Data collected was managed with the highest level of integrity and transparency, particularly in how the questionnaire was administered. The study prioritised objectivity, avoiding any bias or undue influence, while aiming for a substantial response rate (Bless, Higson-Smith & Kagee, 2000). Participants were informed that the research was conducted exclusively for academic purposes and that their involvement was entirely voluntary.

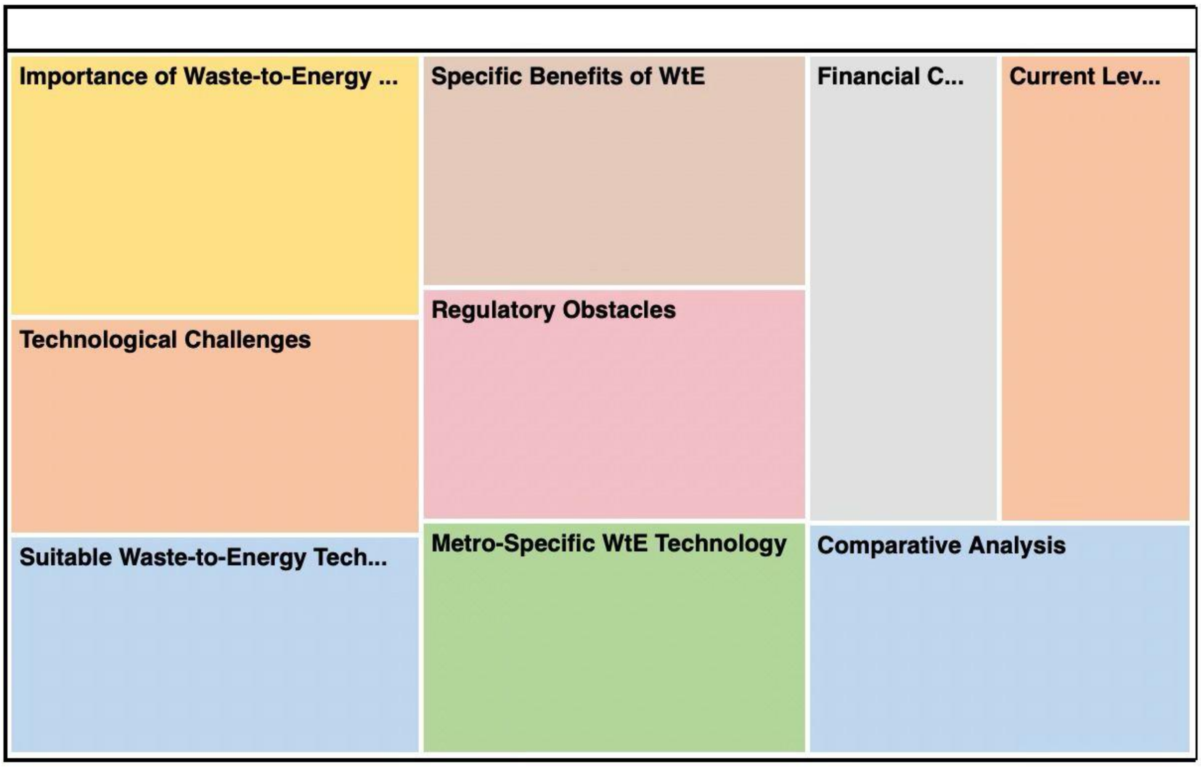
The study was conducted with a focus on minimising all potential biases, manipulative influences, and oversimplifications that could emerge throughout the research process. The researcher would go to the field as an extension of the university’s department. Permission was obtained from all 8 metros, and Department of Energy and the entities with which the external energy experts were associated.

CHAPTER 4
PRESENTATION OF RESULTS

4.1 Introduction

The thrust of this chapter is premised on the need to provide a critical discussion of the findings and results derived from the interviews and questionnaires conducted with the participants. The key to the chapter is providing data from both quantitative (descriptive statistics) and qualitative aspects to ensure that the study findings and conclusive positions are as holistic as possible. Thematic analysis is based on the assumption that the study adopted a mixed research methodology. Figure 4.1 below provides proof of the themes as identified by the study's use of the NVivo tool in undertaking thematic analysis.

Figure 4.1 NVivo Tool Themes shows some of the themes under this subsection.



4.2 Objective 1

To evaluate the inclusion of waste-to-energy technology in the current energy mix within the Gauteng metropolitan municipalities.

The integration of waste-to-energy technology into the energy mix of South African metropolitan municipalities will reduce reliance on conventional energy sources, leading to a more sustainable energy portfolio. Key findings under this objective include the importance and contribution of WtE in the energy mix, the benefits derived from WtE, the current levels of the adoption of waste-to-energy among the metros, and the comparative assessment of the Gauteng metros' WtE background against other metros in South Africa.

4.2.1 Theme 1: Importance of Waste-to-Energy technology in the current energy mix

The importance of WtE as an integral component of the current energy mix in the Gauteng metro to reduce reliance on conventional energy sources was examined using insights from officials from cities, as well as outside specialists. The questionnaire sought to understand how the participants viewed the importance of waste-to-energy within their municipalities or how those outside the municipalities viewed it.

Table 4.1 Percentage and Frequency of Importance of WtE

Importance of WtE	Frequency	Percentage
Very important	4	26.667
Important	4	26.667
Neutral	2	13.333
Important	2	13.333
Very important	2	13.333
Neutral	1	6.667
Missing	0	0.000
Total	15	100.000

The majority of municipal officials and experts in renewable energy identified WtE as a valuable tool for sustainable waste management. One municipal official emphasised:

> *"Our landfill sites are already overburdened, and we cannot continue to rely on traditional waste disposal methods. WtE provides an innovative method to manage waste while simultaneously generating energy."*

This statement is aligned with the results obtained in the survey, where 66% of participants indicated that WtE is a crucial component of a sustainable city. The engineer from the City of Johannesburg emphasised the long-term benefits by stating Thus:

> *"WtE is not just about waste management; it is about optimising resource recovery. If we implement this correctly, we can drastically reduce our dependence on fossil fuels while ensuring a cleaner environment."*

The municipal stakeholders in Gauteng who are considering or have already opted for WtE projects are responding to international best practices in urban energy management.

> *"Other countries have already integrated WtE successfully. We should learn from their experiences and adapt their best practices to our local context."*

However, municipalities in Gauteng confront particular issues, which were acknowledged. As one waste management officer noted:

> *"Financing remains a major hurdle. We need investment from both the*

public and private sectors to ensure that WtE projects are not just pilot initiatives but long-term solutions."

During an interview, a renewable energy policy consultant stated the following:

"The government should establish clear incentives for municipalities to adopt WtE. Whether through subsidies, tax breaks, or regulatory support, proactive policies will determine the success of these projects."

About 80% of respondents rated WtE as either "Important" or "Very Important". This notion was confirmed by the government official who mentioned that:

"Government should establish clear incentives for municipalities to adopt WtE. Whether through subsidies, tax breaks, or regulatory support, proactive policies will determine the success of these projects."

The results show that WtE is seen as an essential part of municipal energy plans. Even though municipalities face financial, regulatory, and environmental hurdles, many of the participants in those municipalities support the use of WtE.

When the study participants were asked about the energy outputs emanated from the waste-to-energy, they indicated various energy outputs generated from each municipality, and from different technologies, as presented below.

The City of Johannesburg WtE Project Manager provided this response:

"Our Johannesburg Landfill Gas-to-Energy Project currently generates approximately 19 MW across multiple landfill sites. We extract methane gas from five locations, ensuring a stable supply of

renewable energy that powers around 12,500 households. Our goal is to maintain and expand this capacity while reducing landfill emissions and environmental impact."

A participant from Kibo Gauteng Thermal Power Station under the City of Johannesburg stated the following:

"As part of the planned Kibo Gauteng Thermal Power Station, we anticipate a 2.7 MW capacity once operational. This project is still under development, but we are committed to using plastic waste to produce syngas, which will contribute to Johannesburg's renewable energy goals."

The City of Tshwane WtE project officer stated the following:

"The Bronkhorstspruit Biogas Plant has been operational since 2015, and we consistently produce approximately 4.6 MW of renewable energy. Over the years, we have contributed around 100 GWh to the national grid, proving that organic waste can be a sustainable energy source. The plant continues to serve as a benchmark for biogas projects in South Africa."

4.2.2 Theme 2: Specific Benefits of including WtE in the energy supply

In understanding the benefits that could be derived from the use of WtE technologies, questions related to the specific areas were asked of the participants who took part in the survey. These benefits include greenhouse gas emission reduction and in landfill sites, among others. The responses from participants indicate that WtE technology holds substantial benefits for municipalities, including energy diversification, economic gains, and job creation.

From the pool of respondents in the survey, 47% identified energy generation, GHG reduction, and landfill abatement as the main reasons why they see WtE as beneficial as a source of energy. Another 47% of the respondents pointed out the economic and job-creating potential they see in WtE. A smaller number (7%) of respondents focused mainly on landfill reduction and energy generation.

> A municipal official stated, *"We are running short of dumping site spaces. The existing ones are already at 90% capacity. If we do not implement waste-to-energy solutions, we will soon face a crisis."*

Another engineer echoed this concern, highlighting the environmental impact of landfills:

> *"When garbage is put into a landfill, it produces methane, which is a more potent greenhouse gas than CO_2. It can help reduce these emissions while also generating energy."*

Participants also considered the diversification of energy sources as an essential benefit. This was especially true for municipalities experiencing energy supply issues. They noted that having a variety of energy sources enhances the resilience of the energy supply and helps ensure a more sustainable and secure energy future. Nearly half, 47% of those queried, considered WtE a method to broaden the energy supply and bolster energy security.

A municipal energy planner highlighted the importance of integrating WtE into the broader energy mix:

> *"Our city is looking at different renewable energy sources to reduce reliance on Eskom. WtE is one of the key alternatives we are exploring."*

Another benefit is the reduction in landfill usage. When garbage is put into a landfill, it produces a great deal of methane, which is a much more potent GHG than CO_2.

Waste-to-energy Project managers stated the following:

“WtE was among the first projects we conceptualised because landfill sites will soon reach their lifespan. It makes sense to use the waste we already produce to generate energy."

Furthermore, landfills are still garbage dumps, and they take up a great deal of space, which could be used for more productive purposes. According to the local government expert:

“Methane emissions from landfills are a serious concern. WtE not only reduces these emissions but also helps in creating a cleaner and more sustainable city."

In addition to its environmental upsides, WtE offers notable financial benefits, especially when it comes to generating employment. Results indicate that nearly half (47%) of those asked consider WtE to be an economic boon and a source of new jobs. According to a waste management project manager:

“WtE projects require skilled labour for construction, operation, and maintenance. This means job opportunities for local communities."

A technical expert elaborated on the broader economic impact:

“Beyond direct employment, WtE creates value chains. It encourages businesses to invest in waste collection and sorting, leading to further economic activity."

The responses suggest that WtE serves as a driver for economic development, providing jobs and invigorating local economies. Despite the consensus about its advantages, the implementation of WtE projects faces several obstacles, as recognised by the participants. The most substantial of these appear to be securing enough financial support and obtaining the necessary technical knowledge.

According to a Department of Energy official:

> *"We lack the technical skills needed to operate and maintain WtE plants. Training programs are essential for long-term success."*

A renewable energy financing expert emphasised the need for policy support:

> *"Government incentives and funding mechanisms will determine whether WtE becomes a viable long-term solution or remains a pilot initiative."*

These issues underscore the need to develop skills and provide monetary assistance for the effective uptake of WtE systems. The myriad potential benefits of cutting down on landfill usage, diversifying energy sources, slashing greenhouse gas emissions, and spurring local economic growth have been acknowledged by participants. The realisation of these benefits, however, faces some key obstacles related to project financing and the availability of technical expertise. With preferred strategic investments and more supportive policies, municipal sustainability efforts can enhance the use of WtE systems.

4.2.3 Theme 3: Current Level of Adoption of WtE Technology

The adoption of waste-to-energy technology is anticipated to positively contribute to the overall energy security of South African municipalities, leading to decreased energy costs for residents and businesses. The results provided by the respondents in the survey are presented below:

Table 4.2 Frequencies for Current Adoption

Current Adoption	Frequency	Per cent
Moderate adoption	6	40.000
Low adoption	4	26.667
No Adoption	4	26.667
Low adoption	1	6.667
Missing	0	0.000
Total	15	100.000

The current adoption of WtE technology in municipalities paints a varied picture, marked by both progress and caution. Among 15 survey participants, a significant portion 40% reported that their municipality is experiencing a "Moderate adoption" of WtE technology, while another 33.33% (the combination of two separate "Low adoption" entries: 26.667% and 6.667%) perceive the adoption level as "Low." Meanwhile, 26.67% of the respondents stated that there is "No adoption" of WtE technology in their municipality.

With 40% of respondents indicating "Moderate adoption," it seems clear that many municipalities have started to integrate WtE technology into their plans. Among the participants, some talked about current projects, like the ones that use gasification plants or harness landfill gas to generate power. This means that several municipalities have not only sketched out their ideas on paper but have actually set up and are now running some functional WtE systems.

During an interview, according to a waste-to-energy project manager, the following sentiments were shared:

> *"We have a gasification plant which has been running for the past five years. It is linked with pick-it-up, and the energy generated is fed back to the city power via a substation."*

This response above lines up with the more general worry about whether municipalities have the human capital needed to make waste-to-energy projects work, both now and in the future.

According to an energy consultant participant, this view was shared:

> *"The technical skills to install and operate these plants are a major challenge. Many of the skilled personnel either retire or leave for other companies, creating a knowledge gap."*

According to a renewable energy financing expert, a participant shared the following:

> *"Licensing and regulatory approvals are a major hurdle. The policy frameworks are not always clear, which delays implementation."*

According to a renewable energy financing expert:

> *"Funding is a key issue. To implement incineration or improve landfill gas collection, substantial investment is required."*

Moreover, the fact that 26.67% of the respondents sense a "No adoption" level of WtE technology is noteworthy. These are the municipalities that have not made even a tentative step into the world of WtE. Absent any conversion of their refuse into energy, these municipalities could well be seen as falling behind; they have no pilot projects, no operational plants, and no semblance of a structure in terms of a public-private partnership (P3) that might one day lead to a WtE facility.

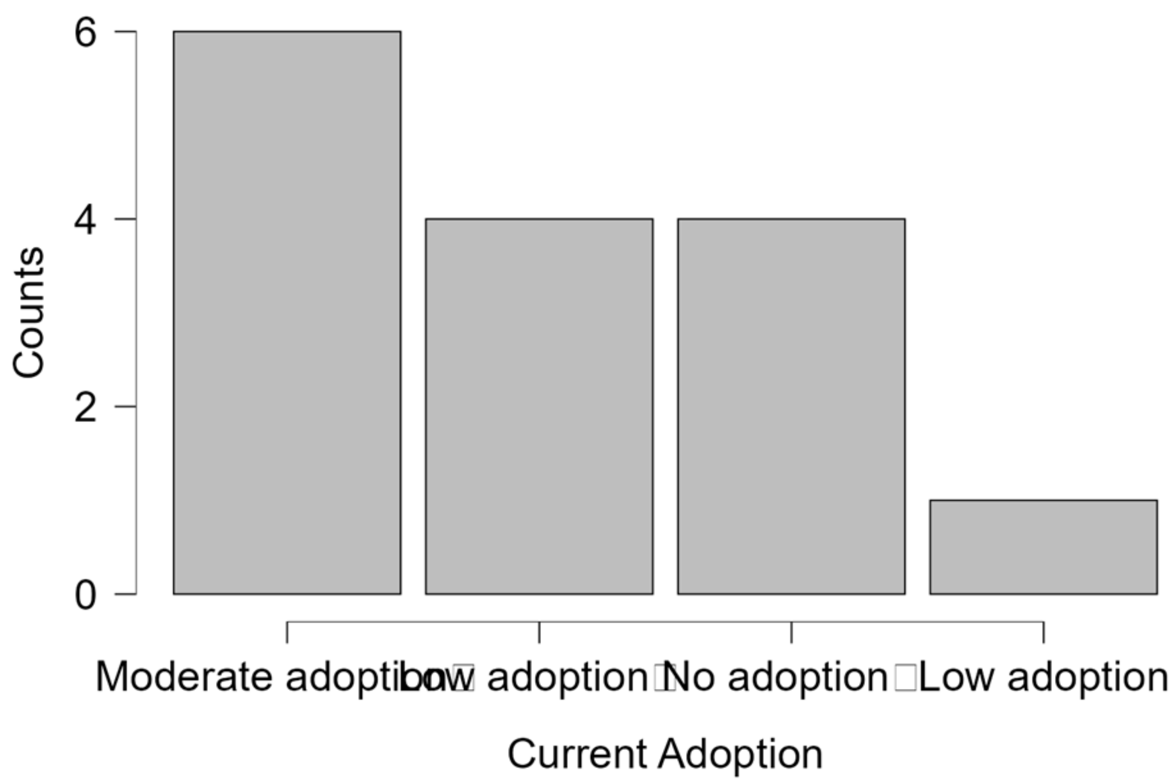
Engaging stakeholders is an essential element in expanding WtE adoption. This highlights the need for awareness efforts and supportive policies to push WtE forward with pivotal stakeholders.

> *"The people who live in the city need to understand the benefits of separating their waste and how it impacts the environment. Without*

public support, WtE projects face resistance."

These results, taken together, depict a sector that is transforming. While a considerable number of municipalities are moderately adopting WtE, a non-negligible share is either in the very early stages of adopting WtE or has not entered the realm of WtE projects at all. This range of responses possibly indicates a wide array of local factors influencing the integration, or lack thereof, of waste-to-energy technology. Those factors might be many and varied, but could include budgetary allocations, local regulatory conditions, and the availability of technical expertise.

Figure 4.2 Graph showing the breakdown of the responses of the participants on the level of adoption of WtE.



The varied responses suggest the need for focused actions to assist the municipalities that are falling behind. Facilitating the exchange of knowledge among municipalities, providing technical and financial support, and clarifying regulatory guidelines could help speed up the adoption process. Policymakers and stakeholders must understand these levels of adoption, not only to move WtE technology forward but also to ensure that its benefits, such as those related to energy diversity and waste management efficiency, are being realised across the board.

4.2.4 Theme 4: Comparative Analysis

Examining the adoption of WtE in Gauteng's municipalities against other major South African cities, such as Cape Town and Durban, offers a window into current good practices, impediments, and prospects, as well as some expert opinions on the subject. The study's participants emphasised the changing nature of WtE in Gauteng metros in comparison to other metros, mainly Cape Town and Durban.

A participant from the Department of Energy stated the following:

> *"Cape Town has made progress in WtE through its landfill gas-to-energy project, while Durban has leveraged its access to industrial waste streams more effectively than Gauteng metros."*

According to the local government participant, Johannesburg has ambitious objectives but confronts bureaucratic delays:

> *"Johannesburg has outlined WtE strategies in its integrated waste management plan, but execution is slow due to environmental regulations and community pushback."*

This implies that, while Gauteng metros realise the benefits of WtE, implementation issues remain due to legislative, technical, and budgetary constraints. When questioned about best practices, respondents identified technology selection, policy frameworks, and community engagement as critical components. A renewable energy technical expert explained thus:

> *"The use of anaerobic digestion and gasification has been effective in cities like Cape Town, where organic waste management is a priority. Gauteng metros should prioritise scalable and cost-effective*

technologies."

Regarding the aspect of policy, the renewable energy consultant stated the following:

"Durban has successfully integrated WtE by aligning municipal waste policies with national renewable energy targets, ensuring streamlined project approvals."

Community engagement came out as an important aspect, as alluded to by the Department of Energy official who stated:

"Without early community buy-in, projects face resistance. Durban's model of public consultations should be replicated in Gauteng metros to enhance acceptance."

These findings indicate that effective WtE adoption necessitates deliberate technological choices, strong policies, and aggressive community engagement. Undertaking a comparative assessment of Johannesburg, Tshwane, and Ekurhuleni, notable differences emerged.

According to a waste management official,

"Johannesburg has the most comprehensive WtE strategy but faces delays due to its complex governance structure. Tshwane is experimenting with pilot projects, while Ekurhuleni has been slow to adopt WtE."

Regarding Tshwane, a local government participant stated thus:

"Tshwane's leadership has been more proactive in pushing WtE projects, whereas Ekurhuleni's approach has been cautious, prioritising landfill

extensions instead."

Gauteng's metropolitan areas acknowledge the potential of WtE initiatives. Still, they lag behind other cities in South Africa, mainly because of delays and bureaucratic procedures. Cape Town and Durban have made more headway, and to understand how, we can analyse the ways they have integrated these policies, the methods they have employed to engage the community, and the models they have used to finance these endeavours.

4.3 Objective 2

To understand the constraints that contribute to the slow rate of adoption and implementation of waste-to-energy technology by the Gauteng metros.

This phase of the research sought to investigate the principal challenges that lead to the slow adoption of WtE systems within Gauteng's metropolitan municipalities. By examining policy frameworks, financial considerations, and technical capacities, the study identified critical barriers to adoption. Through NVivo-based thematic coding, the findings emphasised that financial constraints, governance complexities, and technological gaps emerged as dominant impediments, underscoring systemic challenges in transitioning to sustainable energy solutions.

4.3.1 Theme 1: Financial Constraints

While Gauteng's municipalities acknowledge the benefits of WtE technology for sustainable waste management and energy production, financial difficulties repeatedly emerged as the major obstacle to realising these projects. A primary economic obstacle to adopting WtE systems in Gauteng, based on participant feedback, is the high upfront capital investment required for infrastructure. Respondents consistently emphasised that constructing facilities such as gasification plants, incinerators, and anaerobic digesters involves exorbitant costs, positioning them among the most financially demanding infrastructure projects. This challenge is compounded by municipal budget limitations, as highlighted by a renewable energy financing expert, who noted:

> *"The financial burden of setting up a WtE plant is substantial, and municipalities lack sufficient budget allocations to support these projects."*

Respondents repeatedly pointed out that Gauteng's WtE projects rely heavily on foreign and private investment for viability. Even with available funds and technical expertise, these projects struggle to compete with politically prioritised municipal initiatives, as they are often deemed less urgent by municipalities seeking to improve their power supply. As one academic participant stated:

> *"The CapEx required to build a WtE plant is astronomical. Even before a project takes off, municipalities must secure millions in investment, and that's where most projects are delayed."*

The high operational costs associated with WtE technologies, including waste transportation, were highlighted by respondents as a major economic challenge. This issue makes WtE less economically viable compared to other renewable energy sources like solar and wind. A municipal waste-to-energy manager confirmed that "operational costs, including maintenance and labour, often exceed those of conventional landfills.

Other operational costs that were highlighted by the respondents include staff salaries and maintenance. One of the academics who was interviewed stated that investors generally lean toward conventional energy initiatives, like solar and wind, due to their proven market success. This inclination causes them to ignore WtE projects, even though these have considerable promise over the long haul.

Many respondents are sceptical about the incentives provided by the government to subsidise the WtE technologies. This was confirmed by a local government expert, who shared the following:

> *"The financial incentives are insufficient to offset the high capital costs, and the application process for grants is lengthy and complicated."*

In concluding this sub-section, adopting WtE solutions in Gauteng's metropolitan areas faces a range of financial hurdles, which include the high initial cost of setting up WtE plants and high operational costs associated with operating the plants.

4.3.2 Theme 2: Regulatory Obstacles

The results for this theme were obtained through surveys and interviews undertaken by all 15 participants.

When responding to the questionnaire, an energy consultant mentioned that the protracted and complex process of securing environmental permits and complying with waste management regulations poses a major barrier to WtE initiatives.

> *"Licensing and regulatory approvals drag on for years, and layered compliance obligations further delay project rollout."*

Rigorous environmental impact assessments (EIAs) compound delays and financial burdens. Additionally, poor coordination between local and national governance frameworks, confirmed by a municipal energy official, complicates efforts to align regional WtE projects with broader national strategies.

As shown in **Table 4.4**, regulatory hurdles in the energy sector are prioritised differently across stakeholder groups. Government officials rank lengthy permitting as their top concern (85%), whereas municipal leaders emphasise conflicting policy mandates (80%). WtE specialists identify EIAs as the most pressing challenge (65%).

Table 4.3: Cross-Tabulation of Regulatory Challenges (by Stakeholder Group)

Regulatory Challenge	**Govt Officials (%)**	**WtE Experts (%)**	**Municipal Leaders (%)**
Lengthy Licensing Process	85%	75%	65%
Overlapping Policies	60	50%	80%
Environmental Impact Assessments	55%	65%	45%

According to a consultant, the lengthy and bureaucratic process of obtaining environmental permits and meeting waste management requirements hinders WtE projects. They noted that:

"Licensing and regulatory approval take years, and additional compliance requirements delay implementation."

This issue is exacerbated by the need for stringent environmental impact assessments and the lack of alignment between local and national policies. A municipal energy official confirmed the difficulty in harmonising local WtE projects with national directives due to overlapping jurisdictional mandates. A similar view was shared by an official from the Department of Energy who stated that:

"We have to navigate overlapping jurisdictional mandates, making it difficult to harmonise local WtE projects with national directives."

Survey participants highlighted ambiguities within South Africa's regulatory framework, particularly regarding how WtE initiatives are classified under national energy and waste management policies. The interpretation of waste as either a resource or a pollutant critically shapes how regulations are enforced for such projects. A renewable energy consultant noted that WtE ventures often occupy an undefined regulatory space, where rules designed for conventional waste management clash with energy generation requirements, leading to redundant compliance challenges. He further stated that:

> *"WtE projects frequently navigate a regulatory grey zone, where outdated waste disposal standards overlap with energy production rules, imposing unnecessary bureaucratic hurdles."*

The survey respondents further emphasised inconsistencies in pricing structures and procurement processes for Independent Power Producers (IPPs). Although recent regulatory updates allow municipalities to purchase energy from IPPs, WtE projects still struggle to secure long-term power purchase agreements (PPAs) due to vague procurement criteria.

A renewable energy expert mentioned in the response to a survey that South Africa's fragmented and complex regulatory environment hinders WtE development. A similar sentiment was shared by the energy researcher during an interview, who stated that:

> *"The lack of clarity on whether WtE falls under waste management or energy production creates bottlenecks. Without clear categorisation, projects face prolonged regulatory delays."*

Another energy researcher in an interview mentioned that "Municipalities and private developers endure waits of up to five years for environmental approvals and PPAs. By the time permits are granted, shifting market dynamics can render projects unviable."

4.3.3 Theme 3: Technological Challenges

Participants in the survey raised concerns about the compatibility of municipal waste composition with WtE technologies, particularly in South African cities. They mentioned that mixed residential and commercial waste comprising organic, plastic, and industrial materials poses challenges for efficient energy conversion. Gasification and anaerobic digestion require specific waste types to operate effectively. A WtE project officer highlighted that the city's unsorted waste mix demands advanced pre-treatment, which current infrastructure cannot reliably provide. Another technical expert emphasised that without dedicated pre-treatment facilities, WtE systems struggle. Municipalities lack the funds and infrastructure for sorting stations, which are critical for optimal operation.

The absence of suitable infrastructure emerged as a recurring theme for most respondents. Many municipalities cannot separate biodegradable waste (constituting ~50% of municipal solid waste) for composting or anaerobic digestion. A WtE technical expert highlighted systemic gaps:

> *"Existing metro infrastructure isn't built for high-tech WtE integration. Scaling up requires major investments in sorting, transport, and logistics."*

Energy researchers echoed this, noting that inconsistent waste feedstock complicates efficiency:

> *"Heterogeneous waste streams clash with the need for uniform input in most WtE technologies."*

Current WtE facilities in Gauteng operate at minimal capacity, contributing less output to the grid. Expanding these projects demands substantial investments in technology and infrastructure, a hurdle for cash-strapped municipalities. A renewable energy expert indicated that pilot projects run far below the required capacity. Scaling is hindered by funding gaps and unpredictable waste supply. During an interview, an energy researcher involved in Tshwane's projects mentioned that operational pilots barely contribute to energy demands, and scaling up is a challenge without stable funding and sustainable waste streams.

Municipalities face a critical shortage of local technical expertise to design, operate, and maintain WtE systems. Over-reliance on external consultants and international vendors inflates costs and stifles long-term sustainability. Survey participants warned that this dependency delays the development of homegrown skills needed for project continuity.

4.4 Objective 3

To propose the relevant technologies that are appropriate for waste-to-energy projects used by the metros in Gauteng.

This section focuses on diverse, sustainable and efficient technologies for WtE that may be implemented by metros.

4.4.1 Preferred WtE Technologies in Gauteng metros

Participants favoured gasification (53%), pyrolysis/incineration (33% each), and anaerobic digestion (25%) for WtE in their municipalities, as shown in Table 4.4 below:

Table 4.4 shows the percentage of WtE Technologies preferences by the participants.

Technology Combination	Percentage of Respondents
Gasification, Anaerobic Digestion	53%
Pyrolysis, Incineration	33%
Anaerobic Digestion, Gasification	13%
Gasification, Incineration	Not Specified*
Pyrolysis, Gasification	Not Specified*
Incineration, Gasification	Not Specified*
Anaerobic Digestion, Incineration	Not Specified*

Gasification was preferred for its efficiency in converting mixed waste into cleaner synthetic gas, with Johannesburg citing its successful operational plant. Anaerobic digestion was seen as optimal for organic waste, aligning with the region's abundant food and garden waste. Pyrolysis and incineration were viewed as effective for plastic waste reduction and landfill diversion, but concerns about emissions and costs were raised. Hybrid approaches, combining technologies like gasification and pyrolysis, were suggested by the respondents to maximise energy output from diverse waste streams.

4.4.2 Metro-Specific Challenges

The feasibility of WtE projects varies across Gauteng's metropolitan municipalities due to differences in waste composition, energy demand, regulatory frameworks, and socio-political factors. The waste profile data was sourced from the waste management departments of each metro. The various types of WtE technologies applicable to each metro are outlined below.

Table 4.5 Metro-Specific challenges

Metro	**Landfill Gas Recovery**	**Incineration**	**Anaerobic Digestion**	**Gasification**
Johannesburg	High potential due to landfill saturation	Facing strong public resistance	Moderate potential from organic waste	Limited due to regulatory hurdles
Tshwane	Moderate due to inefficient waste segregation	Feasible but hindered by grid limitations	Low due to infrastructure gaps	Regulatory uncertainty challenges adoption
Ekurhuleni	Limited due to financial constraints	Moderate potential in industrial zones	High feasibility for food and organic waste	High costs hinder implementation

Johannesburg

Johannesburg faces an urgent landfill saturation crisis, making WtE projects a top priority. However, public opposition has been a major obstacle, with resistance from both residential and commercial stakeholders. Additionally, strict air quality regulations and lengthy environmental assessments delay project approvals. A renewable energy consultant highlighted and emphasised these challenges and stated the following:

> *"Each metro has to comply with national air quality standards, but Johannesburg and Tshwane have additional bylaws limiting industrial emissions. These affect WtE project approvals."*

Tshwane

Tshwane's primary challenge in implementing WtE solutions is inefficient waste segregation, which reduces the efficiency of potential projects. The city also struggles with grid limitations, making it difficult to integrate WtE-generated power. Regulatory delays further complicate the implementation of WtE projects. A survey respondent from Tshwane highlighted a challenge with the capacity of the grid:

> *"The existing grid infrastructure requires upgrades to accommodate distributed energy sources like WtE. Without grid modernisation, integration remains a challenge."*

Ekurhuleni

Ekurhuleni faces infrastructure gaps and financial shortfalls, which impede WtE development. Although decentralised WtE plants could benefit from the incentives provided in the industrial zones, the high initial costs remain a barrier. In addition to the infrastructure and financial shortfalls, there are also regulatory concerns, which were highlighted by the waste management official from Ekurhuleni:

> *"Regulations are necessary, but can slow down WtE adoption due to lengthy environmental impact assessments. Balancing compliance with project viability is key."*

The results presented in this section indicate that although WtE technologies are urgently needed across all metropolitan areas, barriers must be overcome. Among the three metros, Johannesburg should have the highest potential to adopt WtE technologies because it is the largest energy consumer, yet the city has faced stiff resistance from residential and commercial customers when it tries to use waste to produce energy. In Tshwane, the major challenge is regulation, as all potential WtE projects in the City of Tshwane have been affected by regulatory uncertainty, and even if that could be resolved, the city still has a substantive infrastructure backlog to deal with. Whereas in Ekurhuleni, the main problem is financial constraints, as the city simply does not have the funds to pay for WtE projects.

4.5 Assessing the Chapter Discussion in the Context of the Consistency Matrix

The emphasis of this section is on connecting how findings presented in Chapter 4 are in line with the consistency matrix table (attached as Annexure A). The main goal is to relate the results correspond with the pre-set research framework.

Objective 1: To evaluate the inclusion of waste-to-energy technology in the current energy mix within the Gauteng metropolitan municipalities.

The research explored how much WtE technology is part of the energy mix in Gauteng's metropolitan municipalities. The results show a strong acknowledgement of WtE as a key element in sustainable waste management and broadening the energy base. About 66% of those surveyed indicated that WtE is essential for lessening our dependence on fossil fuels and for dealing with the environmental issues tied to landfills.

In the consistency matrix, which used interview questions and quantitative secondary data, the study found a high level of integration of WtE into the metro energy mix. For the benefits part, the study established a lot of support for the use of WtE. However, the study also found that the use of WtE is being held back by several factors, including finances, regulations, and technology. The data was analysed, and the findings were reached with the combination of the use of thematic analysis and descriptive statistics as demanded by the consistency framework.

Objective 2: To understand the constraints that contribute to the slow rate of adoption and implementation of waste-to-energy technology by the Gauteng metros.

The research determined that financial limitations, absence of government incentives, and regulatory challenges are key obstacles to WtE adoption. Municipalities often do not have the funding needed to set up WtE facilities. Although private sector investment could theoretically fill the gap, uncertainties about the return on investment mean that not a great deal of WtE activity is happening there either. Additionally, the study results show that slow bureaucratic processes, national policy deficits, and poor public relations are also issues that need addressing.

Objective 3: To propose the relevant technologies that are appropriate for waste-to-energy projects used by the metros in Gauteng.

The research explored appropriate WtE technologies for South Africa's metropolitan areas. The results show that incineration with energy recovery was the best choice for Johannesburg, on account of the large volumes of mixed waste generated. Anaerobic digestion, on the other hand, was more appropriate for Tshwane, due to the abundance of organic waste. For Ekurhuleni, the survey participants recommended gasification and pyrolysis, as these methods are preferentially suited for the municipality's abundance of industrial waste.

The research emphasised that the most efficient and sustainable way forward is for each metro to adopt a mix of WtE technologies, based on their specific circumstances. The study's findings were underscored by a consistency matrix on the basis of the use of interview guides, which provided experts the platform to weigh in and provide sound technical insight.

4.6 Chapter Summary

This chapter critically analyses the integration of WtE technology in Gauteng's metropolitan municipalities through mixed-method research, combining interviews, questionnaires, and thematic analysis via NVivo. Key findings reveal strong recognition of WtE's potential to diversify the energy mix, reduce landfill reliance, and curb greenhouse gas emissions. Approximately 66% of participants viewed WtE as crucial for sustainability, with operational projects like Johannesburg's 19 MW landfill gas initiative demonstrating tangible benefits.

However, adoption remains uneven: 40% of municipalities reported moderate progress, while 33% faced low or no adoption due to financial constraints, bureaucratic delays, and public resistance. Comparative analysis highlighted Gauteng's lag behind cities like Cape Town and Durban, attributed to fragmented governance and slower policy implementation. Stakeholders emphasised the economic and environmental advantages of WtE, including job creation and energy security, but underscored systemic barriers such as high upfront costs and regulatory complexities.

The study identifies financial limitations, technological gaps, and regulatory hurdles as primary obstacles to WtE adoption. Over 85% of government officials cited prolonged licensing processes, while municipalities struggled with infrastructure gaps and inconsistent waste streams. Proposed solutions include tailored technologies like gasification for mixed waste and anaerobic digestion for organic waste, aligned with metro-specific needs. Johannesburg, Tshwane, and Ekurhuleni face distinct challenges: public opposition, regulatory uncertainty, and funding shortages, respectively. The chapter concludes by aligning findings with the research's consistency matrix, validating the mixed-methodology approach and reinforcing WtE's role in sustainable urban energy strategies.

CHAPTER 5
DISCUSSION OF RESULTS

5.1 Introduction

This chapter is premised on the need to provide critical discussions and commentary on the results presented in the previous chapter. The discussion will be based on the three major research objectives that guided this study.

5.2 Demographic Profile of Participants

Two aspects were key to the demographic section, which were the role of the participants in the municipality and the number of years they have been involved in energy or waste management.

5.2.1 Role Within the Metro Municipality

The first question of the research instrument was focused on appreciating the role of the participant within the municipality. This was an open-ended question in which the study was looking for either waste management or waste-to-energy-related positions. The percentage of participants from various professions is presented in Table 5.1

Table 5.1 The occupation of participants from Gauteng Metros

Role	**53%**	**47%**
Response		
Energy Manager	50%	50%
WIE Project Officer	0%	100%
WIE Technical Strategist	50%	50%
Other Roles		
Waste Management Officer	-	-
WIE Business Development Officer	-	-
Renewable Energy Financing Expert	-	-
Environmental Officer	-	-
Dept. of Energy Officer	-	-
Local Government Expert	-	-
WIE Project Manager	-	-
WIE Technical Consultant	-	-

Role	**53%**	**47%**
Environmental Officer (Duplicate)	-	-

The graph is split into two main parts: one part is labelled as 53%, and another as 47%. These halves seemingly represent two segments of the study. Beneath the graph, there's a key that lists the different professional roles involved, such as engineers, scientists, project managers, and others, who have taken part in this study.

- Energy Managers
- Waste Management Officers
- Environmental Officers
- Waste-to-Energy Project Managers and Officers
- Waste-to-Energy Business Development Officers
- Department of Energy Officers
- Waste-to-Energy Technical Consultants and Strategists
- Renewable Energy Financing Experts
- Local Government Experts
- Academic scholars on renewable energy

This diverse representation ensures a well-rounded assessment of the WtE landscape, incorporating perspectives from municipal, technical, financial, and strategic sectors. Energy Managers, Waste Management Officers, and Environmental Officers make up a large portion of the dataset. These positions are important in city energy and waste management strategies, as shown by the dominant colours in the visualisation. They have a high level of representation because they are directly involved in deciding, putting into practice, and overseeing operations in energy and waste management. Thus, they are closely aligned with the services under consideration in this project.

On the other hand, roles such as WtE Business Development Officers, Renewable Energy Financing Experts, and Local Government Experts seem to have a much smaller presence. This suggests that these roles are not as directly involved in making decisions at the city level. Nonetheless, they are likely to be just as crucial for ensuring the financial feasibility of WtE projects, as our next section will discuss in more detail.

With 53% of participants involved in Energy Management, Waste Management, and

Environmental roles, it highlights how waste management strategies are central to municipal operations. Their perspectives are particularly important for judging how feasible and effective the waste-to-energy approach is and what effects it might have on the environment. These are the experts who largely decide whether a municipality will approve or reject a waste-to-energy solution and how it might be integrated into the local infrastructure.

The involvement of WtE Project Managers, Technical Consultants, and experts in renewable energy financing, though their numbers may be comparatively modest, ensures that waste-to-energy projects do not fail for lack of know-how and finance. While municipal officers provide policy direction, these experts supply the technical and financial models that underpin the projects.

The inclusion of officers from the Department of Energy and experts from local governments highlights the dynamic relationship between national policy direction and local implementation strategies.

5.2.2 Years of Experience

Understanding the levels of experience of professionals involved in the survey provides valuable insights into the practical challenges of implementing waste-to-energy technologies. Table 5.2 below shows the years of experience of the participants in the survey.

Table 5.2 Frequencies for Years in the Field

Years in Field	Frequency	Per cent
4-6 years	4	26.667
7+ years	5	33.333
1-3 years	4	26.667
7+ years	1	6.667
Total	15	100.000

The dataset involves 15 participants, each sorted by how long they've been in the field. Those with more than seven years of experience make up the largest group, representing a third of the total sample (33.33%, n=5). The second largest group are the participants with four to six years in the profession, who are 26.67% (n=4) of the sample. Likewise, 26.67% (n=4) are in the 1–3-year range. A portion of the survey participants (33.33%) are individuals with more than seven years in the field. Their involvement in this study is especially important, as it ensures that the rich experience of the participants is captured.

5.3 Objective 1 Discussion

To evaluate the inclusion of waste-to-energy technology in the current energy mix within the Gauteng metropolitan municipalities.

The study highlights the gradual yet uneven adoption of WtE technologies in Gauteng, with limited operational projects such as Johannesburg's 19 MW landfill gas initiative and Tshwane's 4.6 MW Bronkhorstspruit Biogas Plant. While these align with African cities' circular economy strategies (Dlamini et al., 2019), scaling remains hindered by infrastructural gaps, inconsistent waste segregation, and fragmented systemic coordination. Globally, cities like Copenhagen integrate WtE via advanced incineration paired with district heating (Astrup et al., 2015), but Gauteng lacks analogous frameworks. While the number of WtE power plants increased by about 4.7 per cent per year during the last decade, the amount of trash burnt per year has hardly changed (Shovon et al., 2024). Nonetheless, the few municipalities that have opted for WtE have laid out an approach that, at least in part, adheres to the principles of a circular economy.

The analysis highlights that city leaders and technical experts recognise waste-to-energy (WtE) as a vital part of clean energy strategies. WtE's appeal lies in its ability to simultaneously address waste disposal in an eco-friendly way and produce energy (Liu & Rajagopal, 2019). This is especially applicable in cities facing landfill space constraints and environmental pressures. A significant majority (two-thirds) of respondents believe WtE is essential for sustainable municipalities and effective resource recovery, likely due to its practical benefits in maximising resource efficiency.

A third of respondents who were not supportive of these projects highlight obstacles such as funding limitations in early-stage projects, technical difficulties, and unclear regulations. This shows that the government, financial institutions, and the private sector must improve bottlenecks related to the implementation of WtE projects in South Africa, especially in municipalities.

Cities around the world are increasingly adopting WtE systems because they are part of a comprehensive strategy to reduce dependence on fossil fuels and lower greenhouse gas emissions (Pfadt-Trilling, Volk & Fortier, 2021). There are benefits to WtE's projects, as confirmed by most respondents in the survey performed in this study; however, the WtE implementation in Johannesburg still faces public opposition over air quality concerns, which has led to slow implementation of WtE projects in Johannesburg. Conversely, Tshwane's biogas plant demonstrates community acceptance when supported by transparency, mirroring Sweden's participatory models (Bernstad Saraiva et al., 2021).

5.4 Objective 2

To understand the constraints that contribute to the slow rate of adoption and implementation of waste-to-energy technology by the Gauteng metros.

High upfront costs for infrastructure (e.g., gasification plants) deter investment, compounded by competition for limited budgets and uncertain returns (Adeleke et al., 2022). Despite government incentives such as tax breaks, feed-in tariffs, and grants, participants in this study criticised bureaucratic hurdles in accessing these incentives. The difficulty in accessing government incentives is also experienced in other countries, such as India (Mishra & Upadhyay, 2021). While WtE offers long-term benefits such as energy generation and reduced landfill reliance, some officials in the Gauteng metros favour quicker-return alternatives like solar.

The uncertainty in the ROI of WtE projects cited by Saha and Naidoo (2024) is one of the reasons provided by the municipal officials that affect the adoption of WtE technology. The results from this study about the high upfront costs of funding WtE projects and long-term repayment periods, which deter municipalities from implementing WtE projects, confirm the findings by Li et al. (2024). This is also confirmed in a study by Hsu et al. (2024), where it is stated that the problem of high initial costs is a deterrent for municipalities unless they see a clear financial benefit for themselves or the private partners they often engage with for such projects.

The study reveals that the regulatory landscape affects WtE projects in Gauteng. Policy inconsistencies and procedural delays act as major hurdles to project approval and execution. While South Africa has national waste management policies, integrating WtE into waste management strategies at the municipal level is uneven. Some municipalities have adopted WtE initiatives in their integrated waste management plans, but the inclination of others to do the same is seen as being dependent on individual leadership, with no clear policy directive from the national government compelling any municipality to take up WtE. The regulatory requirements, particularly stringent environmental regulations, are a key factor in determining the feasibility of WtE technologies, as noted by Ram, Kumar & Rani (2021).

For example, Johannesburg's incineration project took five years to get environmental approvals, a challenge confirmed by the majority of participants who highlighted delays in issuing licenses as the main problem. Despite various incentives such as South Africa's REIPPPP, municipalities exhibit varying levels of understanding of how to benefit from these incentives. Regulatory delays, such as those that cause delays to Ekurhuleni's 2 MW biomass project (Seshweni, 2021), reflect bureaucratic hurdles noted by Lee & Im (2024) in the European Union.

Implementing effective WtE technologies faces hurdles, including the variability of waste composition and a critical shortage of skilled personnel, with only 13% of municipalities possessing sufficient technical expertise. Diverse waste streams necessitate varied technological approaches; for instance, Johannesburg utilises landfill gas, while pyrolysis is more suitable for Ekurhuleni due to its large amount of industrial waste. Furthermore, inadequate pre-treatment facilities, as identified in Tshwane and Ekurhuleni, restrict plant efficiency. Outdated methods for processing waste and insufficient infrastructure have hamstrung many municipalities' efforts to implement these projects. Poor operational performance has directly threatened the sustainability of many WtE systems, and public perception has been damaged by high-profile failures. Meanwhile, much of the rest of the world has moved on to more modern incineration and anaerobic digestion technologies, making progress in the field of WtE.

In summary, Gauteng's WtE challenges align with broader developing economy trends, where financial risks, bureaucratic hurdles, and technological gaps stall adoption of WtE technologies.

5.5 Objective 3 Discussion

To propose the relevant technologies that are appropriate for waste-to-energy projects used by the metros in Gauteng.

Findings suggest that gasification is the leading choice among local government representatives, followed by pyrolysis, incineration, and anaerobic digestion. Municipality stakeholders favour specific WtE technologies due to their alignment with global sustainability trends and the relative ease of implementing necessary infrastructure. Gasification is the preferred technology (53%), recognised for its efficient and clean conversion of solid waste into syngas, producing minimal pollutants compared to other WtE methods. Studies confirm its low emissions of dioxins, carbon monoxide, and hydrogen chloride.

Pyrolysis (33%) is gaining traction, particularly for plastic waste management, converting waste into bio-oil and synthetic gas. Its appeal stems from the need to address rising plastic pollution and reduce landfill reliance. Incineration (33%), despite controversy, remains a highly efficient energy conversion method, with advanced emission control technologies improving its environmental profile. However, public resistance, as seen in Johannesburg, remains an obstacle. Anaerobic digestion, though preferred by only 25% of respondents, is acknowledged for its effectiveness in processing organic waste, particularly in regions with high biodegradable waste volumes.

However, poor segregation infrastructure limits its adoption. Tshwane officials noted its potential if waste segregation improves, whereas Johannesburg relies on landfill gas to energy. Participants emphasised that suboptimal WtE plant operation results from a lack of pre-treatment facilities, a challenge also observed in São Paulo. Ekurhuleni's difficulty in adopting gasification due to unsorted waste underscores the necessity of pre-treatment infrastructure, a gap also observed in Mumbai.

The different Gauteng metros faced different challenges regarding using WtE technologies. Johannesburg faces landfill constraints and high energy demands, making WtE technologies an appealing alternative. Tshwane struggles with mixed waste composition and inadequate grid infrastructure, rendering its WtE plants suboptimal. Effective WtE operation requires sufficient waste volume and quality, both hindered by unsorted waste streams. Ekurhuleni's primary challenge is financing the infrastructure. These localised challenges, encompassing landfill constraints, infrastructural shortcomings, and regulatory uncertainty, confirm findings from a study by Mukwarami and van der Poll (2023), which highlight the influence of local social, political, economic, and environmental factors on WtE adoption. Gauteng's situation is particularly critical due to the pressing need for waste and energy solutions in its densely urbanised areas.

5.6 Conclusion

This study provides a comprehensive analysis of waste-to-energy WtE technology in Gauteng's metropolitan municipalities, emphasising its crucial role in addressing escalating urban waste management challenges driven by population growth. WtE offers a dual solution, alleviating waste burdens and providing a renewable energy source. However, financial, regulatory, technical, and social obstacles hinder its widespread implementation. The study identifies these barriers and proposes key strategies for enhancing WtE adoption.

Municipal energy and waste management stakeholders recognise WtE as a sustainable urban development method, particularly as landfills reach capacity and traditional waste management becomes unsustainable. WtE offers a globally recognised solution, reducing waste and generating energy. However, it's primarily viewed as an integrated component of broader urban waste management plans.

Financial constraints pose a major challenge for WtE projects. The substantial capital costs of infrastructure, such as gasification units, anaerobic digesters, and incinerators, are often prohibitive for municipalities. While financial incentives and subsidies exist, they rarely cover total project costs. Competing priorities, like schools, hospitals, and infrastructure maintenance, further complicate funding. Public-private partnerships and international funding are recommended to overcome these financial hurdles.

Regulatory challenges also impede WtE projects. Lengthy bureaucratic processes for obtaining necessary permits, environmental compliance requirements, and inconsistencies between local and national regulations create delays. Aligning national and municipal policies and establishing fast-track mechanisms are essential for encouraging WtE adoption.

Technical capacity and infrastructural inadequacies contribute to slow WtE adoption. Municipalities often lack the expertise to design, operate, and maintain WtE facilities. Additionally, unsorted waste streams hinder effective energy conversion. Investing in training programmes and collaborating with technical institutions and research centres can address these issues.

Public perception and awareness are crucial for successful WtE projects. Low public understanding and acceptance, driven by concerns about emissions, environmental impacts, and health risks, create resistance. Minimal public involvement in decision-making and a lack of transparency further exacerbates these issues. Public awareness campaigns are necessary to highlight the benefits of WtE.

The study also identified suitable WtE technologies for each metro. Incineration with energy recovery is recommended for Johannesburg, given its high waste volume. Anaerobic digestion for biogas production is appropriate for Tshwane, with its organic waste. Gasification and pyrolysis are suggested for Ekurhuleni's industrial waste streams. This multi-technology approach allows for tailored solutions based on waste composition and infrastructure readiness.

WtE holds potential for sustainable waste management and energy generation in

Gauteng's metropolitan municipalities. However, realising this potential requires addressing financial, regulatory, technical, and social challenges. Strengthening support mechanisms, streamlining regulatory approvals, building technical capacity, and raising public awareness are essential for successful WtE implementation.

CHAPTER 6
CONCLUSIONS & RECOMMENDATIONS

6.1 Introduction

This chapter draws clear conclusions and offers recommendations based on the findings of this particular study. The work of presenting insights in a thematic manner, as well as using various descriptive statistics, was done in the preceding chapter. The process of concluding is essentially tied to the results obtained in the previous chapter.

6.2 Inclusion of waste-to-energy technology in the current energy mix within the Gauteng

This study examined WtE technology in Gauteng's metropolitan areas, revealing key insights into its potential and challenges. Municipal officials and experts largely agree that WtE is essential for sustainable waste management and energy production, with approximately 80% rating it as "important" or "very important." They see it as a viable alternative to landfilling, aligning with global trends for cleaner energy. However, despite this positive outlook, concerns persist regarding the financial, technical, and policy hurdles to large-scale implementation.

Participants highlighted several benefits of WtE, including its ability to address both urban waste and space constraints, with nearly half of respondents viewing it as a solution to these dual challenges. Furthermore, WtE is seen as a means of securing energy for municipal purposes and supplementing the overall energy mix, with 47% recognising its potential as a power source. It also offers a method to mitigate methane emissions from landfills and stimulate economic growth through job creation. Conversely, WtE projects face drawbacks, including flimsy economic justification and high financial, managerial, and technological costs, often leading to project delays or cancellations.

The adoption of WtE technology varies across Gauteng's municipalities, with approximately 40% of respondents reporting "moderate" adoption, indicating some level of implementation. However, a significant portion (33.33%) reported "low" adoption, and 26.67% reported "no" adoption, reflecting concerns about financial viability and implementation challenges.

Comparing Gauteng with other South African municipalities, such as Cape Town and Durban, reveals that these cities have made greater progress due to successful landfill gas projects and robust policy frameworks. Johannesburg, despite having a comprehensive WtE strategy, has faced delays due to regulatory and bureaucratic bottlenecks. The study identified best practices from these successful cases, including community engagement, policy alignment with national renewable energy targets, and investment in scalable and cost-effective technologies, which could help Gauteng municipalities refine their WtE approaches.

6.3 Constraints to WtE Adoption

The adoption of WtE in Gauteng municipalities faces several challenges.

a. Financial Hurdles

The establishment of WtE infrastructure necessitates a substantial capital investment, representing a formidable barrier to widespread adoption. While government incentives, such as tax breaks or grants, are indeed available, they are frequently insufficient to alleviate the considerable upfront costs associated with these projects. Local authorities, often operating under tight budgetary constraints, find themselves struggling to attract private investors willing to contribute the necessary capital.

This reluctance stems from a variety of factors, including the perceived long-term return on investment, the inherent risks associated with emerging technologies, and the fluctuating nature of waste markets. Consequently, the private sector, which could potentially bridge the funding gap, remains largely disengaged, leaving local councils with a financial burden. This lack of private sector involvement further compounds the challenges faced by municipalities seeking to implement sustainable waste management solutions, hindering the transition towards a circular economy and the realisation of environmental targets. The financial strain is compounded by the fact that these projects often have to compete with other essential municipal services for funding, such as education, healthcare and basic infrastructure maintenance. WtE

b. Regulatory Barriers

The journey towards realising a WtE project is complicated and challenging due to numerous regulatory barriers. The initial hurdle is often the protracted and cumbersome permitting process, where applications can languish for years, stifled by bureaucratic obstacles. This is compounded by the intricate web of compliance requirements, which, while essential for environmental protection, are frequently presented with minimal guidance and support. Moreover, there is often a lack of incentive for state regulators to expedite these processes, contributing to unnecessary delays.

A further impediment is the pervasive misalignment between local and national policies. This disconnect creates a confusing and often contradictory regulatory landscape, where municipalities struggle to navigate the conflicting demands of different levels of government. The cumulative effect of these challenges creates an environment where promising WtE projects can languish indefinitely, discouraging investment and hindering the transition towards sustainable waste management practices.

c. Technical Challenges

The dynamic and heterogeneous nature of municipal solid waste, particularly in regions characterised by diverse populations and fluctuating consumption patterns, poses an obstacle to the efficient extraction of energy through WtE technologies. This challenge stems from the inherent variability in the composition and calorific value of municipal solid waste, which is often a complex mixture of organic materials, plastics, paper, and other refuse. WtE technologies, such as incineration or gasification, are designed to operate optimally within specific parameters regarding waste composition and moisture content.

However, MSW frequently deviates from these ideal conditions, exhibiting a wide range of densities and material types. This variability directly impacts the efficiency of combustion processes, as the presence of moisture reduces the calorific value of the waste and necessitates additional energy input for evaporation. Furthermore, the inconsistent nature of the waste stream can lead to operational challenges, such as incomplete combustion or the formation of slag, which further diminishes energy output and increases maintenance requirements. Consequently, the efficient and reliable extraction of energy from MSW necessitates robust pre-treatment processes and adaptable WtE technologies capable of accommodating the inherent variability of the waste stream.

6.4 Recommendations

This study offers a range of recommendations to facilitate the uptake and execution of WtE systems in Gauteng metros. The proposals tackle several pressing issues, notably the limitations posed by financial resources, regulatory shortcomings, and technical obstacles. With these strategies in place, Gauteng's municipalities should be able to extract benefits from WtE technologies to solve the problem of the provision of cleaner energy and the use of sustainable waste management practices.

6.4.1 Strengthening Financial Support and Investment Mechanisms

WtE projects face a hurdle: the substantial initial capital required for infrastructure development. To overcome this, local authorities should explore diverse funding avenues, particularly public-private partnerships and international grants. Simultaneously, the private sector could be incentivised through government-offered tax breaks and subsidies.

6.4.2 Streamlining Regulatory Frameworks and Approval Processes

The complex and protracted regulatory processes for WtE project approvals impede implementation. To expedite approvals, national and local policymakers must collaborate to simplify regulations, resolve inconsistencies, and establish a clear pathway for WtE facility development.

6.4.3 Enhancing Technical Capacity and Infrastructure

A shortage of technical expertise and infrastructure presents a major challenge to WtE adoption. Local authorities should prioritise training programmes to equip residents with WtE technology knowledge, fostering a skilled local workforce. The national government should partner with universities and technical colleges to develop these programmes.

6.4.4 Devise Waste Methods Segregation from the Source of Waste

Optimal WtE operation requires effective waste segregation. Municipalities should ensure that households and businesses properly separate waste. Incentive programmes, such as reduced waste disposal fees for correctly sorted waste, can encourage this practice.

6.4.5 Fostering Inter-Municipal Cooperation and Knowledge Sharing

Municipalities should collaborate and share best practices to accelerate WtE adoption. Establishing an inter-municipal WtE task force will facilitate information exchange and joint project implementation. Given the developing nature of WtE, learning from others is crucial for successful initiatives.

6.5 Suggestions for Further Research

The study suggests the following research areas to expand upon its findings.

6.5.1. Financial Models for Sustainable WtE Implementation

Exploring innovative financial models presents a promising avenue for improving the economic feasibility of WtE projects in South Africa. Mechanisms such as carbon credits and strategic public-private energy project partnerships could enhance the viability of WtE initiatives.

6.5.2. Policy and Regulatory Frameworks for Efficient WtE Adoption

Given the regulatory challenges identified, further research should focus on optimising policy integration for WtE adoption. Comparative analysis of regulatory frameworks in countries with successful WtE programmes could provide valuable insights. These analyses may reveal methods to streamline approval processes, effectively harmonise local and national policies, and ensure environmental compliance while minimising bureaucratic obstacles.

6.5.3. Technological Adaptation and Waste Composition Analysis

Research must investigate the suitability of diverse WtE technologies for the specific composition of South African waste. Determining which WtE technologies are most effective for different waste types is crucial.

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Annexure A: Permission from the City of Johannesburg

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Office of the Group Head: Group Human Capital Management

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03 December 2024
Tembalethu Nomongo
Masters in Management
Wits University

Ref: Permission to conduct research study

This letter serves to acknowledge receiving the letter requesting permission to conduct research in the City of Johannesburg under the title: **"EVALUATION OF WASTE TO ENERGY TECHNOLOGY IN METROS FOCUSING ON GAUTENG METROS ."** I am aware that the study entails the collection of information from the city, city officials and participants from communities through semi-structured interviews, questionnaires, observation participation and other fora of the city.

The City of Johannesburg promote the research study because it helps both students and practitioners to gain an understanding of the sociology of the city, as it evolves and contributes towards the building of developmental local government.

I, Tersia Johanna Groenewald, as delegated authority of the City of Johannesburg Municipality (the City), hereby give permission to the primary researcher Tembalethu Nomongo , the following:

To collect and publish information about the city is publicly not available, for the research project titled: **"EVALUATION OF WASTE TO ENERGY TECHNOLOGY IN METROS FOCUSING ON GAUTENG METROS".**

- This authorisation is based on mutual understanding that the City's name can be revealed in her/his project; and
- The researcher contacts the relevant department for arrangements pertaining to the research; and
- The information provided by the employees or any other means (such as company's archived documents or reports) of the city is purely for academic purposes and cannot be used for any other purpose.

Please note that on completion of the study, a copy of the research report should be submitted to the City of Johannesburg in honour of your commitment.

I urge you to present this letter of permission whenever you come across officials and participants in the research study. I thank you for choosing the City of Johannesburg to conduct the study.

Kind Regards

Takalani Maria Wakpo (On behalf of Tersia Groenewald)
Administration Officer
Tel. 011 407 6847
Email: takalaniw@joburg.org.za

Page 1 of 1

Annexure B: Permission to Conduct Research from the City of Ekurhuleni

Energy

City of Ekurhuleni

To: Tembalethu Nomongo
Masters in Management, Energy Leadership
Wits University

From: Head of Department : Energy
Mr. Tshilidzi Thenga

Enq: Mr. Tshilidzi Thenga

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Date : 19 December 2024

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www.ekurhuleni.gov.za

Ref: Permission to conduct research study

This letter serves to acknowledge receiving the letter requesting permission to conduct research in the City of Ekurhuleni under the title: **"EVALUATION OF WASTE TO ENERGY TECHNOLOGY IN METROS FOCUSING ON GAUTENG METROS."** I am aware that the study entails the collection of information from the city, city officials and participants from communities through semi-structured interviews, questionnaires, observation participation and other fora of the city.

The City of Ekurhuleni promote the research study because it helps both students and practitioners to gain an understanding of the sociology of the city, as it evolves and contributes towards the building of developmental local government.

I, Tshilidzi Thenga, as delegated authority of the City of Ekurhuleni Municipality (the City), hereby give permission to the primary researcher **Tembalethu Nomongo**, the following:

To collect and publish information about the city is publicly not available, for the research project titled:
"EVALUATION OF WASTE TO ENERGY TECHNOLOGY IN METROS FOCUSING ON GAUTENG METROS".

- This authorization is based on mutual understanding that the City's name can be revealed in her/his project; and
- The researcher contacts the relevant department for arrangements pertaining to the research; and
- The information provided by the employees or any other means (such as company's archived documents or reports) of the city is purely for academic purposes and cannot be used for any other purpose.

Please note that on completion of the study, a copy of the research report should be submitted to the City of Ekurhuleni in honour of your commitment.

I urge you to present this letter of permission whenever you come across officials and participants in the research study. I thank you for choosing the City of Ekurhuleni to conduct the study.

Kind Regards

TSHILIDZI THENGA
HOD: Energy Department, City of Ekurhuleni Metro
Tel. 011 999 5603
Email: Tshilidzi.Thenga@ekurhuleni.gov.za

Annexure C: Permission To Conduct Research from the City of Tshwane

CITY OF
TSHWANE
IGNITING EXCELLENCE

City Strategy and Organizational Performance

Room COE011 | Ground Floor Block C West Wing | Tshwane House | 320 Madiba Street | Pretoria | 0002
PO Box 440 | Pretoria | 0001
Tel: 012 358 1673/9999
Email: anishad@tshwane.gov.za | www.tshwane.gov.za | www.facebook.com/CityOf Tshwane

My ref:	**Research Permission/ Nomongo**	Tel:	012 358 4559
Contact person:	**Pearl Maponya**	Email:	PearlMap3@tshwane.gov.za
Section/Unit:	**Knowledge Management**	Date	17 December 2024

Mr Tembalethu Nomongo
12 Ouklip Road
Hazel Park
Germiston
1401

To whom it may concern

RE: EVALUATION OF WASTE-TO-ENERGY TECHNOLOGY USE BY SOUTH AFRICAN METROPOLITAN MUNICIPALITIES

Permission is hereby granted to Mr Tembalethu Nomongo, Master of Management Degree candidate at the University of Witwatersrand (WITS), to conduct research in the City of Tshwane Metropolitan Municipality.

It is noted that one of the research objectives is to evaluate the inclusion of waste-to-energy technology in the current energy mix within the Gauteng metropolitan municipalities. The City of Tshwane further notes that all ethical aspects of the research will be covered within the provisions of WITS Research Ethics Policy. You will be required to sign a confidentiality agreement form with the City of Tshwane prior to conducting research.

Collection of data will only be permitted when the Research Ethics Approval is presented to the City of Tshwane. Failure to comply with this requirement, the signed permission letter will be treated as null and void.

Relevant information required for the purpose of the research project will be made available as per applicable laws and regulations. The City of Tshwane is not liable to cover the costs of the research. Upon completion of the research study, it would be appreciated that the findings in the form of a report and or presentation be shared with CoT.

Yours faithfully,

PEARL MAPONYA (Ms.)
DIRECTOR: KNOWLEDGE MANAGEMENT

City Strategy and Organisational Performance • Stadstrategie en Organisatoriese Prestasie • Lefapha la Thulaganyo ya Tiro le Togamaano ya Toropokgolo • UmNyango wezokuSebenza namaQhinga aHleliweko kaMasipala • Kgoro ya Leanopeakanyo la Toropokgolo le Bodiragatši bja Mmasepala • Muhasho wa Vhupulani ha Dorobo khulwane na Mashumele • Ndzawulo ya Maqhinga ya Dorobakulu na Matirhele ya Masipala • Umnyango Wezeqhinga Ledolobha Nokusebenza Kwesikhungo

Appendix D: Permission To Conduct Research From City Power

Jo'burg
a world class African city

City Power
Johannesburg

City Power Johannesburg

40 Heronmere Road
Reuven
Johannesburg

Box 38766
Booysens
2016

Tel +27(0) 11 490 7000
Fax +27(0) 11 490 7590

www.citypower.co.za

28 January 2025
Tembalethu Nomongo
Masters in Management: Energy Leadership
University of the Witwatersrand

Re: Permission to conduct research study

This letter serves to acknowledge receiving the letter requesting permission to conduct research in the City Power under the title: **"EVALUATION OF WASTE TO ENERGY TECHNOLOGY IN METROS FOCUSING ON GAUTENG METROS."** I am aware that the study entails the collection of information from the City Power City Power officials and participants from communities through semi-structured interviews, questionnaires, observation participation and other fora of the city.

The City Power promote the research study because it helps both students and practitioners to gain an understanding of the sociology of the City Power as it evolves and contributes towards the building of developmental local government.

I, Andrew Nkuna, as delegated authority of the City Power hereby give permission to the primary researcher Tembalethu Nomongo, the following
To collect and publish information about the City Power is publicly not available, for the research project titled:
"EVALUATION OF WASTE TO ENERGY TECHNOLOGY IN METROS FOCUSING ON GAUTENG METROS".

- This authorization is based on mutual understanding that the City Power name can be revealed in her/his project; and
- The researcher contacts the relevant department for arrangements pertaining to the research; and
- The information provided by the employees or any other means (such as company's archived documents or reports) of the city is purely for academic purposes and cannot be used for any other purpose.

Please note that on completion of the study, a copy of the research report should be submitted to the City Power in honour of your commitment.

I urge you to present this letter of permission whenever you come across officials and participants in the research study. I thank you for choosing the City Power to conduct the study.

Kind Regards

Andrew Reginald Nkuna
Senior Manager: Learning Academy
Tel. (011) 490 7031
Email: ankuna@citypower.co.za

CITY POWER JOHANNESBURG
(PTY) LTD.
P.O. BOX 38766
BOOYSENS 2016

Annexure E Academic Questionnaire

Waste-to-Energy Technologies for Gauteng Metros

Introduction

Dear Participant

I am conducting a study to evaluate the potential of WtE technologies to contribute to a sustainable energy mix in the Gauteng metropolitan municipalities of South Africa. Your expertise in WtE technologies is highly valuable to my research. Please complete this questionnaire, which focuses on identifying and assessing relevant WtE technologies for the Gauteng province.

1. Your Name:…………………………………………….
2. University/Institution:……………………………………..
3. What is the technology readiness level (TRL) of the waste-to-energy technologies being considered for Gauteng?
4. What are the most critical factors to consider when selecting a WtE technology for Gauteng metros?
5. What are the potential environmental impacts of implementing WtE technologies in Gauteng?
6. What are the main challenges to the wider adoption of WtE technologies in Gauteng?
7. Which WtE technologies hold the most promise for future development and implementation in Gauteng?
8. What are the most promising areas of innovation in WtE technologies that could benefit Gauteng?
9. What are the key material challenges associated with WtE technologies in Gauteng?
10. What are the potential impacts of waste-to-energy integration on Gauteng's existing electricity grid infrastructure, and how can these be addressed?
11. What are the critical skills gaps that need to be addressed to support the growth of the WtE sector in Gauteng?

Thank you for your time and valuable input!

Annexure F: Consistency Table

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

RQ #	State Research Question or Objective	Prop/hyp #	State Proposition or Hypothesis	Data collection detail	Data analysis method
1	To evaluate the inclusion of waste-to-energy technology in the current energy mix within the Gauteng metropolitan municipalities.	1	The integration of waste-to-energy technology into the energy mix of South African metropolitan municipalities will reduce reliance on conventional energy sources, leading to a more sustainable energy portfolio.	Interview guide questions	Thematic analysis Descriptive analyses (to complement thematic analysis)
1.1		1.1	The adoption of waste-to-energy technology is perceived as important for South African metropolitan municipalities due to its potential benefits, including contributions to energy security and overall sustainability, rather than directly reducing energy costs for residents and businesses.	Interview guide questions	Thematic analysis Descriptive statistical analyses

2	To assess the lack of adoption of waste-to-energy technology by South African metros		Key barriers to the adoption of waste-to-energy technology in South African metropolitan municipalities include financial and regulatory challenges.	Interview guide questions	Thematic analysis Descriptive statistical analyses
3	To propose the relevant technologies that are appropriate for waste-to-energy projects used by metros in South Africa.	3	The proposed waste-to-energy technologies will demonstrate a higher effectiveness and economic viability compared to traditional waste management practices, leading to enhanced waste-to-energy project proposals for South African metros.	Interview guide	