Exploring opportunities for implementing waste-to-energy projects in the City of Johannesburg Metropolitan Municipality

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PREFACE AND ACKNOWLEDGEMENTS

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ABSTRACT

This study explores opportunities for implementing waste-to-energy technologies to alleviate the City of Johannesburg's (CoJ) current waste management challenges as well as the current energy crisis in the country. Globally, untreated, unsafe disposal, and inefficient waste collection have contributed to a waste crisis, while a rapidly increasing world population has increased waste generation, and a higher demand for energy. Waste-to-energy is therefore increasingly viewed as a viable solution to waste management and energy supply challenges. However, South Africa underutilises waste for energy generation. CoJ has initiated the adoption of waste-to-energy projects for electricity, but little progress has been made on the actual implementation. This study therefore investigates the potential for implementing waste-to-energy projects in the CoJ to recommend strategies for successfully enhancing both waste management and energy generation in the city. A qualitative approach was used to conduct the study and semi-structured interviews were utilised for collecting primary data. Using purposive sampling, 20 managers and employees in CoJ's waste management and energy departments were selected. The study found that implementing waste-to-energy projects offers numerous benefits to CoJ, including freeing up landfill space, improving energy supply, and contributing to environmental sustainability. Additionally, the study found that the successful implementation of waste-to-energy projects is complex and hinges on a number of factors, including the availability of human, financial, and technological resources, a supportive regulatory and policy environment, and the participation of all stakeholders. Recommendations include the development of employee skills and competencies and the mobilisation of financial resources through increased focus on public-private partnerships. Management is also encouraged to collaborate with policymakers to revise legislation, regulations, and policies that govern waste management and renewable energy and replace it with supportive legislation and policies. Lastly, management should promote a culture of separation at the source and increase the level of public participation.

Key words: energy crisis, environmental sustainability, renewable energy, waste management, waste-to-energy

ABBREVIATIONS AND ACRONYMS

CHG	Greenhouse Gases
COJ	City of Johannesburg
EPA	Environmental Protection Agency
EU	European Union
GW	Gigawatts
IEA	International Energy Agency
LFGE	Landfill Gas to Energy
MSW	Municipal Solid Waste
MW	Megawatts
PPP	Public-Private Partnership
UK	United Kingdom

KEY DEFINITIONS

Waste: The U.S. Environmental Protection Agency (EPA) defines waste as any garbage or refuse, sludge from a wastewater treatment plant, water supply treatment plant, or air pollution control facility and other discarded material, including solid, liquid, semi-solid, or contained gaseous material resulting from industrial, commercial, mining, and agricultural operations, and from community activities (Abbasi, 2018).

Waste-to-energy: The phrase waste-to-energy refers to a number of methods that turn non-recyclable garbage into useable energy sources such as heat, fuels, and electricity. Numerous methods, including incineration, gasification, pyrolysis, and anaerobic digestion, and landfill gas recovery, can result in waste-to-energy (Charis, Danha, & Muzenda, 2019).

Waste management: The term waste management refers to the numerous plans for handling and getting rid of trash. Wastes can be disposed of, destroyed, and processed, recycled, reused, or controlled. Reducing the amount of garbage and avoiding potential health and environmental risks are the main goals of waste management (Campitelli & Schebek, 2020).

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CHAPTER 1: INTRODUCTION

1.1 Background

This chapter provides a framework for the proposed study, which seeks to explore the opportunities for implementing waste-to-energy technologies to assist in alleviating the City of Johannesburg's (CoJ) current waste management challenges, as well as the current energy crisis in the country. Globally, there is a waste crisis which arises from untreated, unsafe disposal, and inefficient waste collection (Chepkemoi, 2015). In 2016, an estimated 2.01 billion tonnes of municipal waste were generated globally, with a projection of 3.4 billion tonnes by 2050 (Mbazima *et al*., 2022). Out of these amounts of generated waste, 33% is openly dumped and not managed in a manner that is environmentally safe (Mbazima *et al*., 2022). For low-income countries, approximately 93% of waste is dumped on roadsides, waterways, or open lands, or burned (Mbazima *et al*., 2022).

The three most important drivers of waste generation globally are economic growth, population growth, and urbanisation (Purser, 2011). Countries within the low- and middle-income categories, particularly those in South Asia and Sub-Saharan Africa, are projected to experience significant surges in waste generation (Khan & Kabir, 2020). It is anticipated that the waste levels in these countries will increase by approximately two or three times over the next three decades. On the other hand, higher-income countries such as Central Asia, North America, and Europe are expected to have a gradual increase in their levels of waste accumulation (Hoang et al., 2022).

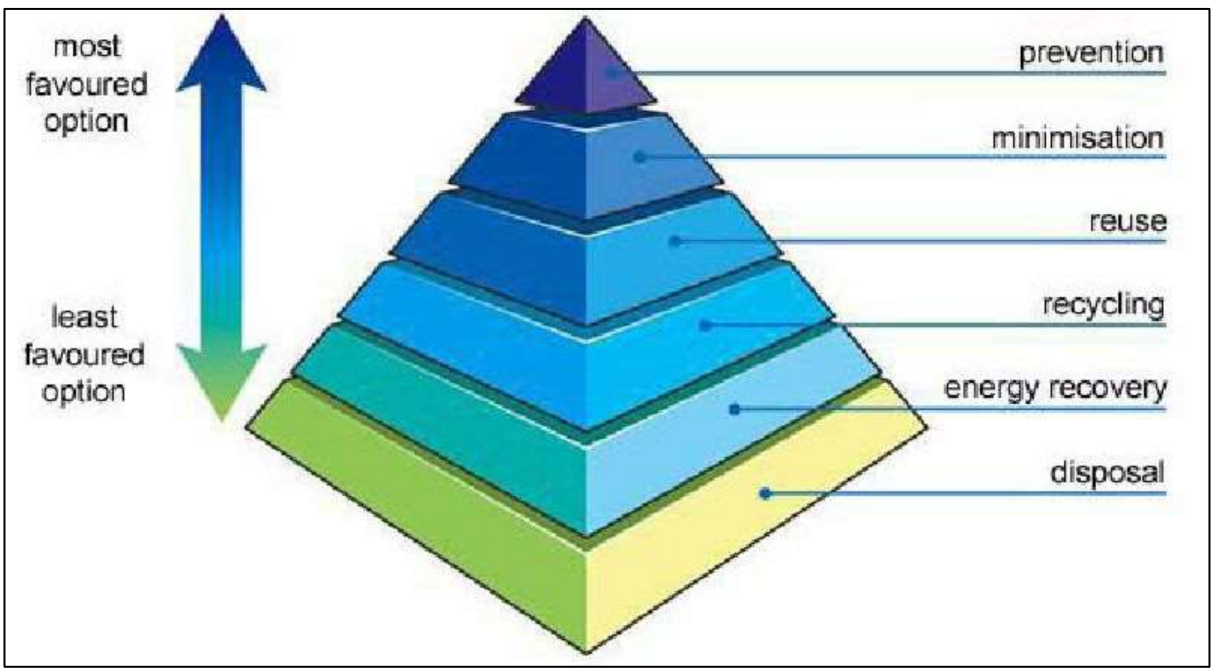
In Africa, urban growth has reflected trends across the entire developing world and is the highest in the world at 3.5%. Urban growth in Africa has resulted in poor waste management practices, which include widespread dumping of waste in uncontrolled dumpsites and watercourses (Khan & Kabir, 2020). According to Khan *et al*. (2022), 93% of waste generated in developing nations is openly dumped. These practices and trends have resulted in low sanitation levels, with the most affected areas experiencing outbreaks of diseases such as typhoid fever and cholera. In addition to increased waste generation, the rapid increase in world population stimulates a higher demand for energy. Overall, there is a significant global increase in electricity demand due to population growth, urbanisation, and industrialisation (Amsterdam & Thopil, 2017). One of the foremost challenges confronting countries around the world is ensuring the provision of sustainable energy. While the widespread use of renewable energy sources is promoted, the current global energy demand is supported by fossil sources (International Energy Agency (IEA), 2020). However, the process of converting fossil fuels to energy is characterised by the emission of greenhouse gases (GHG), which contributes to environmental degradation and climate change. There are more than 600 million people who do not have access to electricity in Africa. The continent is therefore very far from achieving Sustainable Development Goal 7 that aims at clean and affordable energy (Khan *et al*., 2022). It is therefore important to address the energy challenge with some urgency.

South Africa has recently been experiencing the two crises which are waste management and energy supply. These crises include increasing waste generation that has the potential to spiral out of control, as well as an unreliable supply of electricity (Adeleke *et al*., 2021). The current waste management practices in the country face several challenges as cities, including CoJ; struggle to provide efficient service delivery to a growing population (Mbazima *et al*., 2022). Similarly, the electricity-generating infrastructure in the country is currently struggling to keep pace with the growing population as well as growing economic activities. In South Africa, approximately 95% of electricity is generated from non-renewable sources, with coal constituting 90% of energy sources in the country (Mbazima *et al*., 2022). The electricity authority, Eskom, has on several occasions failed to meet the electricity demand in South Africa, resulting in load shedding which is aimed at keeping the grid stable and avoiding a total blackout (Amsterdam & Thopil, 2017).

Thus, these waste management and electricity supply constraints present a perfect opportunity to explore the capability of waste-to-energy technologies in enhancing the efficiency of waste management and electricity supply (Chowdhury & Techato, 2022).

Waste-to-energy is one of the potential means of disposing municipal solid waste, generate energy, recover materials, and free up scarce land that would have been used for landfilling (Purser, 2011). The opportunity to convert solid waste to energy resources can solve two problems: generation of clean energy, and management of solid waste (Kulshreshtha, 2022). Waste-to-energy plays a crucial role in the attainment of transformation to a sustainable energy eco-system. It is a renewable energy resource that can contribute immensely to the reduction of GHG emissions. Mutezo (2015) regards waste-to-energy a better option for managing Municipal Solid Waste (MSW) that is not suitable for recycling, when compared to landfilling. The waste management hierarchy, recommended by the European Union and the US Environmental Protection Agency (EPA) explicitly recognises waste-to-energy as a better alternative to landfilling. The hierarchy is in the form of a pyramid which indicates most preferred waste management strategies at the top and the least preferred at the bottom, as shown in Figure 1.1.

Figure 1.1: Waste Management Hierarchy



Source: Williams (2015)

Starting with the most preferred strategy, the order of the strategies in terms of preference are as follows: waste avoidance or prevention, waste reduction or minimisation, waste reuse, recycling, energy recovery, and disposal (Singh *et al*., 2017). Dlamini *et al*. (2019)

describe waste-to-energy as a proven technology for electric power production, industrial processes, heating, and cooling that is more sustainable than fossil fuels and also has a significantly lower carbon footprint than landfilling. An added benefit of waste-to energy is that it destroys contaminated materials that contain viruses and pathogens (Dlamini, 2019).

In several countries worldwide, waste-to-energy has proved to be an effective, economically beneficial, and environmentally sound mechanism for dealing with municipal solid waste while generating energy (Khan & Kabir, 2020). Globally, there has been substantial progress in the implementation of waste-to-energy projects, with approximately 2 240 active waste-to-energy facilities with a disposal capacity of 270 million tonnes of waste per year (Reddy, 2018). It was estimated that close to 500 new facilities with a capacity of 150 million tonnes would be installed by 2023 (Reddy, 2018). The U.S. has 76 waste-to-energy facilities that process approximately 94 000 tonnes of MSW per day and produces 2.5 gigawatts (GW) of electricity and 2.7 GW of combined power and heat (Castaldi, 2020). This is equivalent to approximately 13% of all the MSW generated in the country and has the capacity to power the equivalent of 2.3 million homes. Europe, whose waste-to-energy market is very mature, has 410 installations spread in 23 countries (Castaldi, 2020). In China and developing countries, there is a growing trend towards waste-to-energy, with countries that strive to achieve sustainability in waste management starting to adopt waste-to-energy projects (Castaldi, 2020). In Addis Abba, for example, the commissioning of a waste-to-energy unit has recently been completed, while in Minsk and Lithuania, construction work is ready to kick off (Castaldi, 2020).

Most African countries, however, have limited waste-to-energy projects despite generating significant quantities of waste that is suitable for such projects (Purmessur & Surroop, 2019). The adoption and implementation of such projects in African countries is progressing at a slow pace, mainly due to factors such as limited knowledge, high implementation and maintenance costs, poor municipal solid waste management, lack of waste data, and inadequate policies. In South Africa, a number of waste-to-energy projects have been implemented, including bio-digester plants. Other efforts include investments in waste biomass as feedstock to produce bioenergy and biofuels, mostly at a laboratory scale, with limited efforts at commercial scales (Adeleke *et al*., 2021). Research has however cited South Africa as a country with the highest energy potential from both landfill gas and incineration recovery (Dada & Mbohwa, 2018; Mohlala *et al*., 2016). Although literature has reported the high potential for energy recovery from waste-to-energy routes, the country is not fully utilising the abundant waste resources available for generating energy (Stafford, 2019).

In the City of Johannesburg, organic waste is approximately 15 to 35% of the total generated waste, and about 35 to 40% is available for anaerobic digestion to give rise to methane gas which has an inherent theoretical energy potential of 841 Tera Joules (TJ) per annum (Stafford, 2020). Efforts have already been made in the city to implement waste-to-energy projects. For example, an agreement was entered into between the CoJ and Energy Systems Joburg (Pty) Ltd for the construction and operation of landfill-to-gas electricity projects at no cost to the city for a period of 20 years (Baker & Letsoela, 2016). Electricity from the project is capable of powering about 12 500 middle-income households. Despite these developments, the CoJ has not yet implemented commercial waste-to-energy projects for electricity generation by either incineration or anaerobic digestion technology (Dlamini *et al*. 2019).

The City of Johannesburg has already started considering the adoption and implementation of waste-to-energy projects as a source of electricity, particularly in the face of increased load shedding (DeBruyn, 2021). In a press statement, the Deputy Director for Environment and infrastructure Services, Mvuselelo Mathebula, outlined the key points that have been set up for diverting waste from landfill sites and using it in the generation of electricity (DeBruyn, 2021). The plan is to divert at least one third of the total waste generated by the City of Johannesburg to generate approximately 30 to 40 megawatts (MW) of electricity. In 2015, transaction advisory services were enlisted to review a feasibility study (DeBruyn, 2021).

1.2 Problem statement

Despite its potential to contribute to sustainable development, waste-to-energy is often regarded as an expensive alternative for disposing waste and generating electricity when compared to generation from fossil sources (Mbazima *et al*., 2022). There is a disconnect as most people do not value the environmental and social advantages of waste-to-energy in comparison to renewable energy alternatives that are more established, such as solar and wind energy. Waste-to-energy usually involves complex business models, compared to established alternatives (Castaldi, 2020). Thus, the challenges posed by these complex issues must be addressed during the adoption and implementation of waste-to-energy projects in CoJ.

A number of studies have been conducted on waste-to-energy in South Africa (Adeleke *et al*., 2021; Dada & Mbohwa, 2018; Dlamini *et al*., 2019; Mbazima et al., 2022; Mohlala et al., 2016). However, there is a dearth of studies that focus on the opportunities for waste-to-energy in the City of Johannesburg. Dlamini *et al*. (2019) only conducted a literature review, and thus no empirical study has been found. The city possesses significant opportunities for generating electricity from waste, thereby reducing greenhouse gas emissions, improving access to electricity, and enhancing waste management (Dlamini *et al.,* 2019). Although CoJ has already started considering the adoption and implementation of waste-to-energy projects as a source of electricity, little progress has been made on the actual implementation. The City of Johannesburg has not yet implemented commercial waste-to-energy projects for electricity generation by either incineration or anaerobic digestion technology (Dlamini *et al*. 2019). This study seeks to explore the opportunities for implementing waste-to-energy projects in the CoJ in order to recommend strategies for successfully taking advantage of such opportunities and to enhance both waste management and energy generation in the city.

1.3 Research aim and objectives

The aim of the research is to explore opportunities for waste-to-energy projects in the City of Johannesburg.

The study seeks to achieve the following objectives:

- To establish the perceptions on the opportunities for waste-to-energy projects in the City of Johannesburg;
- To determine the factors that are critical for the success of waste-to-energy projects in the City of Johannesburg; and
- To recommend ways in which the City of Johannesburg can effectively take advantages of opportunities for implementing waste-to-energy projects.

1.4 Scope of the research

This research focuses on opportunities for waste-to-energy projects in the City of Johannesburg. The research includes management and employees in the waste management and energy departments in the City of Johannesburg. This is because the people in these departments are involved in the management of waste and the generation of energy for the city and are therefore likely to have adequate knowledge of the research problem.

1.5 Assumptions and limitations

The main assumption of this study is that the City of Johannesburg has the potential to implement waste-to-energy projects in order to address its waste management and electricity supply challenges. However, the study has its limitations. One of the limitations is the use of a single data collection method, namely interviews, due to time and cost constraints. With only one data collection method, the study is not able to address all aspects of the research problem, such as the relationships between waste-to-energy implementation and the different critical success factors. To overcome this limitation, efforts were made to ensure that the information collected would give significant coverage to the research questions. In addition, the participants of the study may not feel free to provide truthful information due to fear of reprisals from their bosses. However, assurances of confidentiality and anonymity were given to participant to lessen their fears.

1.6 Potential contributions of the research

This study will make significant practical and theoretical contributions. It has been noted that South African municipalities, including the City of Johannesburg, are faced with waste management challenges, with large volumes of waste being dumped and landfilled. Furthermore, the country is experiencing huge challenges as far as meeting the demand for electricity is concerned. Exploring the opportunities for the implementation of waste-to-energy projects in the City of Johannesburg will generate important insights into the types of waste-to-energy projects that can be implemented and the factors that need to be addressed in order to ensure successful implementation. Such knowledge will assist management and other stakeholders in ensuring the successful implementation of waste-to-energy projects in the city, thus, reducing waste management problems, as well as addressing the problem of limited access to electricity. Furthermore, the study will benefit other municipalities as they are also facing waste management challenges which can be reduced by implementing waste-to-energy projects. Policymakers will also draw some insights from this study as it highlights some of the policy issues that need to be addressed in order to ensure successful implementation of waste-to-energy projects. In addition, the findings and recommendations of the study will add to the existing body of knowledge on opportunities for waste-to-energy implementation.

1.7 Structure and outline of the dissertation

A summary of how the research report is structured is provided below.

Chapter One: Introduction

The chapter introduces the study by outlining the research context, research problem, research aim and objectives, and the significance of the study. The scope, assumptions, and limitations of the study are also outlined in this chapter.

Chapter Two: Literature Review

The chapter presents a review of literature related to waste-to-energy projects. The theoretical underpinning of the study is also discussed in chapter two.

Chapter Three: Research design and methodology

The research design that will be followed in conducting the study is discussed in chapter three. The chapter outlines the research philosophy, research approach, sampling method, data collection technique, as well as the data analysis method and procedure.

Chapter Four: Presentation and Discussion of Findings

The results from primary research are presented and discussed in chapter four. The discussion will be based on the themes that will be identified during the data analysis process.

Chapter Five: Conclusions and Recommendations

The final chapter will present the conclusions that will be drawn from the findings of the study as well as the recommendations on how to take advantage of the opportunities for waste-to-energy in the City of Johannesburg.

1.8 Chapter summary

This chapter provided a framework for the proposed study that seeks to explore the opportunities for implementing waste-to-energy technologies to assist in alleviating the City of Johannesburg's (CoJ) current waste management challenges as well as the current energy crisis in the country. The background of the study, statement of the problem, research aim and objectives, scope of the research, assumptions and limitations, and the rationale for the research was outlined in the chapter.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

This chapter examines the literature relating to opportunities for waste-to-energy. The chapter provides a global, regional, and local overview of waste management in order to understand the need for waste-to-energy initiatives. Furthermore, a global, regional, and local overview of waste-to-energy is provided in order to understand the current status as well as the trends in waste-to-energy. The chapter goes on to discuss the benefits of waste-to-energy as well as the factors that influence the success of waste-to-energy projects. The final section of the chapter highlights some studies that were conducted on opportunities for waste-to-energy and the findings of those studies. This chapter will also inform the interview questions that will be used in the collection of primary data.

2.2 Global overview of waste management

As countries progress from low-income to middle- and high-income levels, there is a shift in waste management practices (Kaza, Yao, Bhada-Tata, & Van Woerden, 2019). As countries experience economic growth, leading to increased prosperity and a growing number of people migrate to urban areas, the per capita generation of waste also increases. The situation is worsened by rapid population growth and urbanisation, leading to larger population centres and making waste collection and procurement of land for disposal and treatment more difficult (Kaza *et al*., 2019). Management of waste in urban areas is expensive (Campitelli & Schebek, 2020). For local authorities in low-income countries, waste management consumes approximately 20% of municipal budgets while almost 10% of municipal budgets in middle-income countries go towards waste management (Kaza *et al*., 2019). Such expensive and complex waste management operations compete for budget allocations with other priorities such as healthcare, education, and clean water and other utilities.

The administration of waste management in most countries is done by municipalities operating with inadequate resources as well as limited capacity for operational monitoring, contract management, and planning (Campitelli & Schebek, 2020). Due to these factors, sustainable waste management becomes a complicated task and low- and middle-income countries struggle to deal with these challenges. This results in poor waste management practices, such as dumping, which have serious negative impacts on the population. According to Bui et al. (2020), most developing countries are faced with poor waste collection and disposal systems and inappropriate location of facilities which have negative effects on human health and the environment. In these countries, integrated waste management is hampered by factors such as poor planning, lack of public participation in waste management, poor recycling facilities, and inadequate human, financial, and technological resources (Oluheyi *et al*., 2020). Landfill is the primary waste management method in developing countries (Bui *et al*., 2020). This method produces methane gas, a GHG 21 times weightier than carbon dioxide, which affects the quality of ground water, thus, threatening human health and the environment (Bui *et al*, 2020). Due to poor waste collection and disposal, developing countries have accumulations of waste in streets, public places, and other illegal dumpsites.

In South Africa, efforts towards achieving sustainable waste management practices have resulted in the development of different pieces of legislation and policies aimed at increasing efficiency in the management of solid waste health (Adeleke *et al*., 2021). However, despite making some progress in waste management systems in the country over the years, South Africa is still confronted by many challenges and shortcomings (Borello *et al*., 2018). The waste management system in the country is confronted with problems such as limited resources, exhaustion of landfill airspace, and a sharp increase in economic development and population growth, which have resulted in the acceleration of the volumes of waste generated (Dlamini *et al*., 2019). The current waste management strategies and facilities do not have sufficient capacity to deal with the challenges faced by the waste management sector. Some of the key issues faced by South Africa’s waste management sector were highlighted by Godfrey and Oelofse (2017) and include the following: weak enforcement of legislation and regulation, scarce and unreliable waste data, poor waste minimisation and recycling initiatives, limited permitted landfill airspace, unlicensed waste management activities, illegal and indiscriminate dumping, and inadequate waste collection services. Because of these challenges, South Africa has so far not been able to achieve the growth of a cleaner and greener future for the country.

2.3 Global overview of waste-to-energy

In recent years, policymakers, researchers, and decision-makers in developed countries have developed a keen interest in the topic of generating energy and other useful products from waste (Charis *et al*., 2019). Waste-to-energy technologies have evolved from simple engine turbines to advances such as microbial fuel cells (MFCs) and pyrolysis, in which waste is converted to fuels, thus filling the gaps within the circular economy (Kumar *et al*., 2022). Developed countries have therefore embraced and set up resource-efficient technologies and practices for generating energy, compost, fuel, and heat from waste. However, developing nations are considered inactive when it comes to the adoption of waste-to-energy technologies. It has been observed that the processing of waste in its different forms is highly technical and this may mean significant capital outflows (Strachan et al., 2017). Developing nations, however, are still not finding socio-economic justification for investing in some technologies. According to research, the major factors contributing to the gap in technological advancement and the level of investment in state-of-the-art technologies between developed and developing nations are well-formulated policies and well-developed infrastructure (Adekele *et al*., 2021).

In the majority of countries in Africa, energy demand is not matched by energy supply, and approximately 600 million people do not have access to electricity (Scarlat *et al*., 2015). These countries are also characterised by continuous blackouts. Gebreegziabher *et al.* (2014) estimated that the demand for electricity would increase by 2.4% in 2030. This situation requires African countries to adopt and implement initiatives and technologies that are sustainable and friendly to the environment while maximising the generation of energy from waste. Literature has highlighted that these African countries are producing increased volumes of organic waste. This provides a significant opportunity for utilizing waste-to-energy technologies such as landfill gas to energy (LFGE) to enhance energy supply and reduce the amount of waste that is dumped or landfilled (Gumbo, 2013). Despite the production of significant volumes of waste that qualifies for

LFGE, most African countries have limited projects and rely mostly on fossil fuels, which are more harmful to human health and the environment. Dlamini *et al*. (2019) and Yusuf *et al*. (2019) have attributed the slow adoption of waste-to-energy projects in Africa to the lack of research and development, limited knowledge, high implementation and maintenance costs, poor management of MSW, the absence of data on waste, and inadequate policies. As a result of the aforementioned challenges, solid waste management and limited access to electricity remain substantial areas of concern in Africa.

In South Africa, there is huge burden placed on energy as a result of increasing demand. In addition, there are large volumes of untreated waste that is disposed of in landfills (Adeleke *et al*., 2021). This situation has seen increased calls for sustainable utilisation of energy from waste resources. Literature revealed that Africa has a huge amount of theoretical energy potential recoverable from waste, with South Africa having the highest potential, based on the volumes of waste generated and collected (Dlamini *et al*., 2019; Scarlat *et al*., 2015). South Africa recovers approximately 22 710 TJ per year from landfill gas, and 104 463 TJ per year from incineration (Adeleke *et al*., 2021). However, the majority of African countries, including South Africa, are yet to take advantage of the full potential energy that can be obtained from waste to address their problems related to energy and waste management (Scarlat *et al*., 2015). Energy recovery mechanisms as anaerobic digestion and landfill gas recovery provide substantial benefits to South Africa in its efforts to deal with the looming waste management crisis, add to the power sector's energy mix, and contribute to GHG mitigation. However, the country has not conducted a comprehensive assessment of the waste-to-energy technologies adaptable, and has therefore not harnessed the full benefit and operates below its maximum potential (Dlamini *et al*., 2019).

In South Africa a Waste-to-Energy Roadmap was developed by the South African National Energy Development Institute (SANEDI), in partnership with the DSI/NRF/CSIR South African Research Chair in Waste and Climate Change at the University of KwaZulu-Natal (Kissoon & Trois, 2022). The aim of the roadmap is to contribute to the country's

Just Energy Transition, with the aim to map the potential for insertion of waste-to-energy technology in South African municipalities. The South African Waste-to-Energy Roadmap identifies relevant technologies for the effective recovery of waste into biogas and energy, while mapping barriers and drivers for potential uptake at local level (Nell & Trois, 2022). One important element of the roadmap is a waste-to-energy Policy Review document and detailed mapping of the policy and regulatory frameworks pertaining to available waste-to-energy technologies for the treatment and valorisation of MSW in South Africa (Nell & Trois, 2022).

The South African government has made investments in various projects, such as using waste biomass as a feedstock to create bioenergy and biofuels (Adeleke et al., 2021). These projects have primarily been conducted in laboratories, with little effort being made at commercial scales. High theoretical potential for energy recovery from waste-to-energy routes (for example, agricultural residues, 2.67×10^8 GJ and 3.79×10^8 GJ from residues and energy crops, and 230,000 tonnes of dry matter generating bio-methane of 91.6 million Nm^3 /year which can fuel about 2700 buses in the city of Johannesburg) have been reported in the literature (Stafford, 2019). However, the country is currently underutilizing its vast waste resources for energy generation, which prevents it from practically operating up to its full potential in meeting this objective (Dada & Mbohwa, 2020). By 2030, it is anticipated that RSA will consume 37% of energy and 46% of electricity (Stafford, 2019). This requires the government to implement and improve policies for energy efficiency and conservation.

South Africa is still struggling with the challenges of state-of-the-art technologies (Mbazima et al., 2022). The country can draw some lessons on the successful implementation of waste-to-energy projects from developed nations, particularly countries in the European Union (EU). These success factors can assist in developing or improving waste-to-energy platforms in the light of the social and economic factors affecting South Africa (Adeleke *et al*., 2021). However, it should be noted that it is not practical to simply copy and apply the EU model in South Africa without first evaluating the factors impeding waste-to-energy growth and understanding the reasons behind the failure of several waste-to-energy projects in SA. As a result, obtaining perceptions about the impediments to waste-to-energy industries in South Africa in the light of the EU success factors can assist in improving the performance of the industry and realise advancement over time (Adeleke *et al*., 2021).

2.4 Waste-to-energy technologies

Waste-to-energy technologies are capable of converting the energy content of the various types of waste into different forms of valuable energy (Campitelli & Schebek, 2020). These technologies can produce and distribute power through local and national grid systems. Furthermore, the technologies are capable of generating heat at both high and low temperatures and then distribute it for district heating purposes or specific thermodynamic processes (Campitelli & Schebek, 2020). Waste-to-energy technologies are categorised into three groups, namely, thermo-chemical, bio-chemical, and chemical (Mbazima *et al*., 2022), as shown in Table 2.1.

Table 2.1: Classification of waste-to-energy technologies (Mbazima *et al*., 2022)

Conversion Process	Technologies	Feedstock	Outputs
Themo-chemical	Incineration	Mixed waste, refuse-derived fuels (RDF)	Heat and electricity (energy)
	Gasification	Mixed waste, RFD	Hydrogen, methane, syngas electricity energy
	Pyrolysis	Sorted waste (e.g., plastics), organic waste	Char, pyrolysis oil, gases, aerosols, syngas → electricity (energy
Bio-chemical	Fermentation	Organic waste with high sugar content	Ethanol, hydrogen, biodiesel → energy
	Anaerobic Digestion	Organic waste, green waste	Methane → electricity (energy)
	Landfill with gas capture Microbial fuel cell	Organic waste, green waste Organic waste	Methane → electricity (energy) Electricity (energy)
Chemical	Electrification	Waste oil (e.g., waste coconut oil	Ethanol, biodiesel → energy

As shown in Table 2.1, waste-to-energy technologies include incineration, gasification, pyrolysis, fermentation, and others. Charis *et al*. (2019) highlight that the selection of technology is made simpler when there is a good understanding of the characteristics of the waste at hand, and consideration should be given to the determination of the capacity of a particular technology.

2.5 Perceptions on opportunities for waste-to-energy technologies

Waste-to-energy projects are viewed as having great potential to enhance waste management and energy supply globally (Amsterdam & Thopil, 2017). Most governments worldwide have instituted strict policies to reduce the emission of GHGs and this has resulted in the innovation of green technologies for generating clean energy. Globally, governments are investing in clean energy sources with the aim of reducing dependence on fossil sources, thus, encouraging the adoption of waste-to-energy as one of the clean energy sources (Baker & Letsoela, 2016). Furthermore, governments in all regions have introduced programmes and incentives for promoting effective waste collection, disposal, and processing (Campitelli & Schebek, 2020). Such programmes and incentives have created significant growth potential for the waste-to-energy industry as it can play an important role in initiating appropriate technology for generating energy.

According to Abbasi (2018), the global waste-to-energy market has shown a significant increase in the past few years and this upward trend is expected to continue. The market was valued at USD32.15 billion in 2021, with a projected growth of USD44.62 billion by 2029 (Kulshreshtha, 2022). One of the drivers of the growth in the waste-to-energy market is the increase in industrialisation and urbanisation as well as economic growth, which have resulted in increased waste generation, carbon dioxide emissions, and environmental threats. Waste-to-energy is therefore viewed as a sustainable way of effectively managing the increasing volumes of waste and averting environmental threats posed by poorly managed waste. Waste-to-energy technologies are capable of reducing the original waste volume by 90%, depending on the composition and use of outputs (Charis, Danha, & Muzenda, 2019). In some developed countries, the increasing use of waste-to-energy as a method of managing solid and liquid waste and of producing electricity has resulted in a dramatic reduction in environmental impacts of solid waste management, including the release of GHG emissions.

The opportunities for waste-to-energy projects also arise from the continuously rising global demand for energy caused by rapid industrialisation and the growing population. In South Africa, the electricity authority, Eskom, has on several occasions failed to meet the electricity demand in South Africa, resulting in load shedding, which is aimed at keeping the grid stable and avoiding a total blackout (Amsterdam & Thopil, 2017). A study by the World Council (2013) revealed that, if all countries used waste to produce energy, 10% of the demand for electricity globally could be satisfied.

In developing countries, waste-to-energy is increasingly being regarded as an alternative for dealing with the growing challenges of waste management (Menikpura et al., 2016). There are a number of benefits that municipalities and nations can derive from waste-to-energy technologies and projects. Firstly, by implementing waste-to energy projects, cities can reduce the amount of waste that is dumped illegally and disposed of in landfills. According to Mutezo (2015), waste-to-energy offers a viable alternative to the existing methods of disposing waste. It can be noted that the disposal of waste by dumping in landfills has negative impacts on human health and the environment. When waste has been disposed of in landfills, microorganisms decompose the waste under anaerobic conditions, which results in the production of leachate and landfill gas (Barros *et al*., 2018:14). According to Abbasi (2018), each kilogramme of MSW generates approximately 0.35nm^3 of landfill gas, which can cause air pollution, thus, degrading the quality of the air, as well as cause odours, and ultimately, health problems, if not controlled. Landfill sites are therefore ranked as the third producer of CHGs (Abbasi, 2018). Thus, waste-to-energy technologies and projects provide an opportunity to improve the management of waste as well as reduce CHG emissions as the demand for landfilling can be significantly reduced.

According to Menikpura et al. (2016), the implementation of waste-to-energy technologies can assist in conserving valuable natural energy resources and protecting the environment. Data collected in the US indicates that on average, the combustion of one tonne of municipal solid waste in a modern waste-to-energy plant results in the production of about 600KWh of electricity and further avoids the need to mine 0.25 tonnes of coal or import a barrel of oil (Psomopoulos et al., 2009). Furthermore, as argued by Psomopoulos et al. (2009), waste-to-energy is the only way in which non-recyclable municipal waste can be sustainably disposed.

2.6 Factors affecting the successful implementation of waste-to-energy projects

In order to realise success in the waste-to-energy sector, it is important to explore the critical factors that can drive growth in this sector (Naworio, 2022). Chepkemoi (2015) conducted a study that sought to establish the factors that affect the successful implementation of waste-to-energy facilities in Nairobi using factor analysis. The study identified the following factors: stakeholder involvement, economic incentives to attract investors, regulatory framework, and political support. Mutezo (2015) conducted an exploration of the barriers impeding the wide-scale implementation of waste-to-energy technologies in South Africa, focusing specifically on challenges that confront municipalities in the Western Cape Province. The study highlighted the following challenges: inadequate data on waste generation, unsuitable feedstock for the generation of energy, problems with the legislative framework, lack of knowledge of technologies by decision-makers, and lack of political will. Amsterdam and Thopil (2017) revisited the conceptual model for the waste-to-energy industry in South Africa based on the European model. The authors took into consideration the social and economic constraints in South Africa as they attempted to identify the barriers that impede the country's exploitation of waste in the generation of electricity and strategies for dealing with these barriers. In the process, Amsterdam and Thopil (2017) categorized the barriers impeding the full potential of the waste-to-energy industry in the country into two groups; policy-related barriers and feedstock or resource-related barriers. Some of the policy-related barriers are access to electricity grid, inexpensive and plentiful coal resources, inadequate landfill tax, lack of public and government support, and the absence of production tax credit. Resource or feedstock-related barriers include inefficient waste separation, lack of inexpensive land, lack of policies for waste diversion from landfills, and inexpensive landfilling (Amsterdam & Thopil, 2017). Some of the factors highlighted in the above studies are discussed in detail below.

2.6.1 Legislative framework

According to Kariuki (2019), the nature of renewable energy structures such as waste-to-energy demand clear policies and legal procedures that focus on increasing the interest of investors. The availability of good policies results in a stable and predictable environment and assists in dealing with hindrances. However, it has been revealed that in several countries, such as India, there are no clear renewable energy policies. In Sub-Saharan Africa, a study by Mohammed *et al*. (2013) found that the majority of countries in this region had policies relating to renewable energy. However, these policies were not yet fully developed as they lacked a proper implementation approach.

One of the factors that are critical in facilitating the introduction and up scaling of waste-to-energy technologies in South Africa is a supportive legislative framework (Mutezo, 2015). The establishment of a proper waste management system that incorporates waste-to-energy technologies requires a robust legislative and policy framework to support successful implementation (Stafford, 2019). It is important for South Africa to amend the current waste management policy to incorporate clear and strong directives for improving the waste management system (Gumbo, 2014). It is also crucial to have clear and achievable targets, guiding strategies, and implementation plans.

The country currently has a number of regulations and policies that govern waste management and promote the renewable energy industry and sustainable development (Mohlala *et al*., 2016). However, there is still a need to develop supportive policies for the adoption of renewable energy technologies such as waste-to-energy. For instance, Kariuki (2019) noted that there is very limited participation of the private sector in renewable energy projects as a result of a lack of clear and well-defined policies on private investment and delays in the approval of projects in which the private sector is involved. Large-scale waste-to-energy projects demand large amounts of capital and the failure by policy-makers to come up with measures for attracting investors has slowed down progress in the implementation of all types of renewable energy projects in several African countries, including South Africa.

2.6.2 Financial support

The implementation of waste-to-energy projects demands considerably high initial investments when compared to landfilling (Mbazima *et al*., 2022). The investment cost includes both the treatment procedure and the cost of operating and maintaining the facilities, as well as the cost allocation for operational risks, such as fires or accidents. In most developing countries, including South Africa, the costs of establishing and operating waste-to-energy facilities are even higher than those of a conventional thermal plant. A typical waste-to-energy plant with a capacity of 10 MW has been estimated to have an investment cost of R300 million, with a MW capacity plant estimated to cost R200 million in South Africa. Municipalities in the country cannot afford such high capital expenditure without financial support (Adeleke *et al*., 2021). In most developed countries, governments offer support for the implementation of capital-intensive renewable energy initiatives, including waste-to-energy projects (Chepkemoi, 2015). However, developing countries lack financial support for renewable energy projects, making it difficult for municipalities to upscale the implementation of waste-to-energy projects.

In South Africa, municipalities currently struggle to deliver efficient waste management services due to budget constraints. Consequently, the incorporation of waste-to-energy into the waste management system requires external financial support (Godfrey & Oelofse, 2017). Dlamini *et al*. (2019) suggest the public-private partnership (PPP) approach, in which municipalities work closely with the private sector, in collaboration with the government, to set up waste-to-energy facilities. Formal involvement of the private sector in waste management has been lacking in South African municipalities, which has resulted in financial challenges, as the municipalities are not able to adequately finance their service delivery activities. Khan and Kabir (2020) regard the PPP approach as a mechanism that holds significant promise in enhancing waste management in general, and in facilitating the implementation of waste-to-energy as a waste management technique.

2.6.3 Data management

In order to design effective waste management systems that incorporate waste-to-energy initiatives, it is important to have quality data on municipal waste (Silwal, 2019). However, South African municipalities lack quality waste data, as there is no effective system of collecting and analysing data. As a result, it is not easy to develop plans for designing proper waste management systems. It is important for municipalities to regularly track, update, and disseminate waste data to stakeholders in order to obtain a clear understanding of the overall waste management status (Silwal, 2019). Academics and research scientists can effectively use such data to conduct further research and develop innovations in the waste management sector.

2.6.4 Landfill tipping fee and tax

The generation of energy from waste has been proven to be an effective strategy for diverting significant amounts of waste from landfills, particularly in countries where regulations, policies, and landfill taxes discourage disposal of waste in landfills (Zhou *et al*., 2018). Countries can discourage the disposal of waste in landfills by levying a landfill tax, thereby promoting waste-to-energy initiatives (Simalane & Sa, 2016). In EU countries, high landfill taxes were introduced. In the United Kingdom (UK), for example, landfill tax was increased from £7 to £84 per tonne of waste between 1996 and 2014 (Simelane & Sa, 2016).

Adeleke *et al*. (2021) conducted an investigation into the potential for energy recovery from waste in Africa, with a focus on South Africa. The results show that there are a number of challenges impeding the ability to fully explore the energy potentials of waste and fully operational waste-to-energy processing in the country. The challenges include low landfill tax, inexpensive and affordable coal resources, and the poor waste management and energy system in the country. The very low landfill taxes charged by South African cities create a perverse incentive for continued disposal as a preferred waste management option (Adeleke *et al*., 2021). The general understanding is that an increase in the cost of landfilling to reflect the true cost of this waste management option would create incentives for diverting waste away from landfill, and towards other alternatives (Nahman, 2021). One of the reasons behind the low landfill tax in South African cities is that the majority of sites in the country are unregulated, non-compliant, or unlicensed (Mutezo, 2015). Thus, the adoption of waste-to-energy technologies, which are perceived as capital intensive, is not an attractive alternative due to the low rates of landfill tax. South Africa therefore needs to implement a well-structured waste disposal tariff that is supported by national, district, and local authorities (Mutezo, 2015). This will assist in reshaping the mind-set of the public and private sectors, as well as municipalities, on the urgent need to reduce the volume of waste that is disposed in landfills and seek alternative waste management initiatives such as waste-to-energy.

2.6.5 The need for high technical skills, standards and regulation

Establishing and operating waste-to-energy technologies demand high technical skills, standards, and specifications (Borello *et al*., 2018). Most developing countries are highly likely to encounter difficulties in meeting these strict requirements and technical skills. The EU 2010/75/EC, formulated 20 years ago, are one of the most stringent incineration standards globally, but are very difficult for South Africa and other developing countries to comply with. It is therefore the recommendation of Yan *et al*. (2020) that the initial standard of waste-to energy emissions are placed at a practical level for developing countries, with a planned careful transition through the acquisition of skills and experience over time. Furthermore, there is a need for intensive training of personnel from academics, professional, and industrial experts before implementing waste-to-energy projects in South Africa and other developing countries (Amsterdam & Thopil, 2017). In South Africa, technical capacity is a major challenge when it comes to the implementation of renewable energy projects such as waste-to-energy.

2.6.6 Separation of waste at source

The ability to separate waste at source is highlighted by Adeleke *et al*. (2021) as one of the crucial factors influencing the successful implementation of waste-to-energy initiatives. It involves the practice of separating household and post-consumer waste from the collected waste at a generating point so that such waste does not go to landfills. In South Africa, there is no culture of separating waste at source and this makes it difficult to generate value from waste (Amsterdam & Thopil, 2017). The number of dedicated recycling and separation at source activities in South Africa increased from 4% to 7.2% between 2010 and 2015 (Mutezo, 2015). However, this remains very low and does not portray an improvement in willingness and behaviour of municipalities to separate waste at the source. Separation at source facilitates the implementation of waste-to-energy activities as it assists in retaining the valuable materials suitable for recycling and biodegrading (Dlamini *et al*., 2019). Separation at source in South Africa is hampered by a number of factors, which include lack of incentives, lack of compulsory obligation to practice separation at source, high costs of waste minimisation and diversion, inconvenience, lack of knowledge, and lack of access to facilities (Adeleke *et al*., 2021). In addition, municipalities are not well prepared or educated on waste separation logistics. Therefore, without an effective system of separating waste at source, it becomes difficult to successfully implement waste-to-energy projects as they utilise only particular types of waste.

2.6.7 Public awareness and participation

According to the Rio Declaration on Environment and Development, one of the important principles of sustainable development is the involvement of all citizens in issues that relate to management of the environment (Kofi-Opata, 2013). Thus, the success of environmental programmes such as waste management is enhanced when countries promote participation and awareness amongst citizens through sharing of environmental information. This principle requires all environment-related decisions to take a bottom-up approach. Thus, all citizens in a nation must participate in decision-making in order to achieve sustainable development. This principle also applies to the success of waste management and waste-to-energy initiatives. It is important for citizens to be aware of their responsibilities in waste management. However, several African countries do not share information relating to government decisions on important issues affecting citizens (Fouche & Brent, 2019).

In South Africa, feasibility studies among residents in selected municipalities indicated that the majority of residents lack awareness of the benefits that are offered by waste-to-energy in terms of providing energy, minimising landfill disposal, as well as environmental benefits (Adeleke *et al*., 2021). This has caused apathy among residents in municipalities. According to the feasibility studies, some residents had opposed the implementation of some waste-to-energy projects as they worry about the supposed environmental effects of the facilities (Adeleke *et al*., 2021). Unless public awareness and participation initiatives are implemented to deal with the negative impressions of waste-to-energy technologies such as incineration, these initiatives will continue to face resistance from the public.

2.7 Chapter summary

In this chapter, the literature relating to opportunities for waste-to-energy was reviewed. The review included a global, regional, and local overview of waste management in order to understand the need for waste-to-energy initiatives. Furthermore, a global, regional, and local overview of waste-to-energy was provided in order to understand the current status as well as the trends in waste-to-energy. The chapter went further to discuss the benefits of waste-to-energy as well as the factors that influence the success of waste-to-energy projects in South Africa. Literature shows that there is a significant potential for waste-to-energy projects globally due to the vast amounts of waste produced and the increasing demand for electricity. Waste-to-energy projects are capable of enhancing waste management practices as well as increasing the ability of nations worldwide to fulfil the increasing demand for electricity. However, the success of waste-to-energy projects depends on the ability of countries to address critical factors, which include a supportive legislative framework, financial support, deterrent landfill taxes, availability of technical skills, the ability to separate waste at source, and public participation. The upcoming chapter discusses the methodology used in conducting the study.

CHAPTER 3: METHODOLOGY

In this chapter, the methodology that was utilised in conducting the study is outlined and discussed. The first part of the chapter explains the research design that was adopted in this study and the reasons for selecting such a design. The chapter explains the methods that were employed in collecting and analysing primary data and the steps that were followed in implementing such methods. The chapter goes on to discuss the techniques that were used in selecting sample participants, collecting data, and analysing the collected data, as well as the reasons for preferring the selected methods. Furthermore, the steps that were taken to enhance the quality of research findings and ensure the research is conducted in an ethical manner are highlighted, while the limitations of the study are also outlined.

3.1 Research design

A research design is defined by Bryman (2016) as the strategy employed in answering the research questions of the study using empirical data. Three types of research designs are cited by Burns and Grove (2003), and these are exploratory, descriptive, and explanatory research designs. This study was conducted using an exploratory research design. Babbie (2018) defines exploratory research as a preliminary phase of research that aims to gain a clearer definition of the problem at hand. Exploratory research provides useful ideas and insights as well as direction for further research (Bhattacherjee, 2012). Since the aim of this study was to explore the opportunities for waste-to-energy in the City of Johannesburg, exploratory research was seen as an appropriate research design. Through this design, the study obtained insights into the potential waste-to-energy projects that can be implemented by the city, the critical factors to consider in ensuring the success of such projects, and recommendations to effectively take advantages of opportunities for implementing waste-to-energy projects. Such insights will pave way for further research on the implementation of waste-to-energy projects in the city, and potentially elsewhere too.

3.1.1 Research philosophy

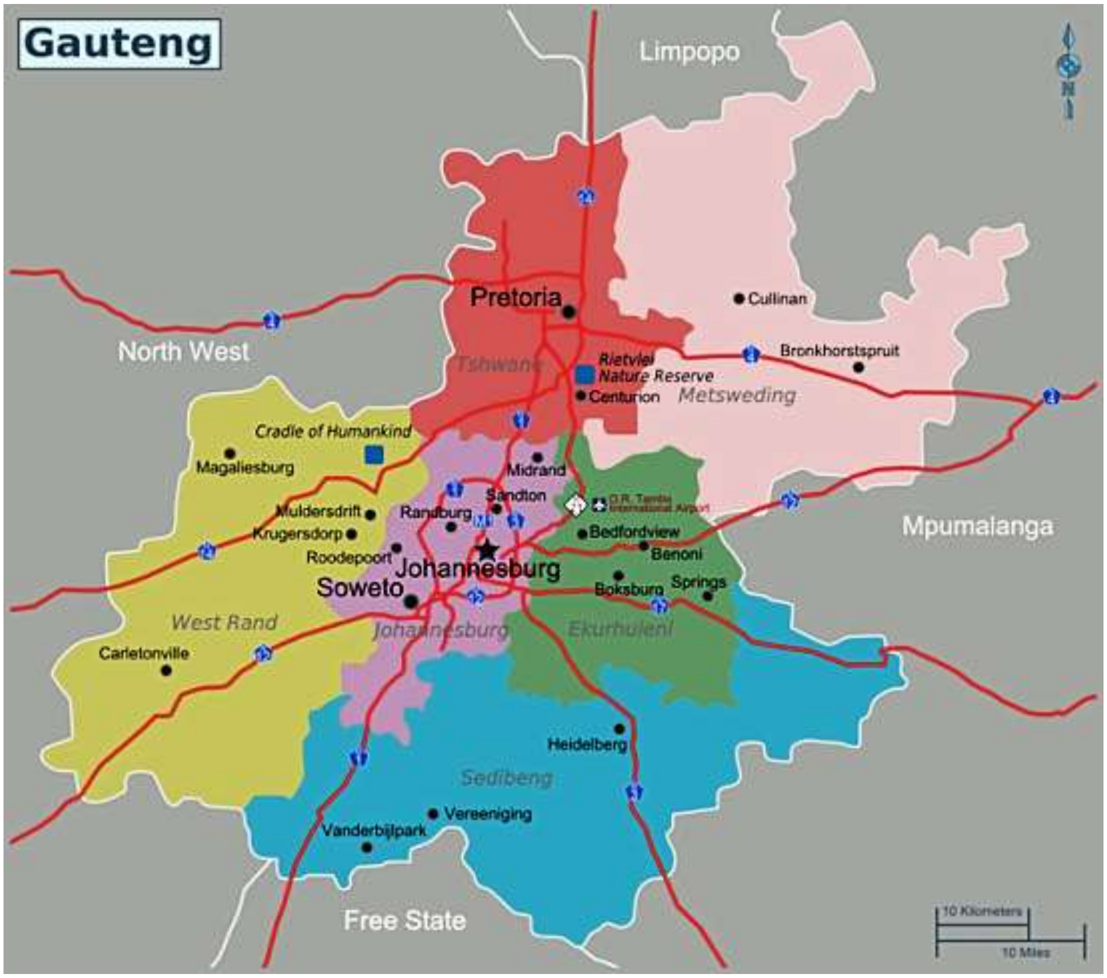
Research philosophy is concerned with the nature, source, and development of knowledge. It refers to the beliefs concerning the ways of collecting, analysing, and using data about a phenomenon. Saunders *et al*. (2019) cites the following types of research philosophy that researchers can use to underpin their studies: positivism, interpretivism realism, and pragmatism. This study was based on the assumptions of the interpretivist research philosophy, which argues that there are multiple worldviews and these can be best understood by exploring the meanings attached to such realities by the people who experience them. This philosophy was found to be appropriate for this study as it will be possible to understand the topic of waste-to-energy implementation from the views and practical experiences of employees and management in the city.

3.1.2 Research approach

Saunders *et al.* (2016) highlight three main approaches to research, which are quantitative, qualitative, and mixed methods approach. In line with the exploratory research design and the interpretivist research philosophy, this study adopted a qualitative research approach. Saunders *et al*. (2016) define qualitative research as an approach that aims to address questions concerned with developing an understanding of the meaning and experiential dimensions of the lives of humans and social worlds. This study therefore sought to understand the opportunities for waste-to-energy projects based on the perceptions of management and employees at the City of Johannesburg metropolitan municipality. The qualitative approach uses methods of data collection that are flexible and give research subjects the opportunity to express their views and experiences in detail (Babbie, 2018). In this study, participants were able to clearly explain the challenges faced by the municipality in relation to waste-to-energy projects and the factors that are critical for the success of such projects.

The study also uses a single case study, which is CoJ in South Africa. The main reason for selecting CoJ is that the researcher works in one of the municipality-owned enterprises, Pickitup, which is responsible for waste management. As a CoJ employee, it was easy for the researcher to gain access to information. In addition, CoJ is making plans to expand its waste-to-energy projects, and research in this area will assist the city with some insights. CoJ covers 1 625 km^2, and approximately 1.4 million tonnes of waste are generated every year. The City of Johannesburg indicated that the number of households with no formal refuse removal has increased annually at 4.47%, and about 7% of households experience a backlog (City of Johannesburg IDP, 2020/21). While the waste management service delivery is inadequate, the community's behaviour of poor waste disposal exacerbates the situation. Lack of awareness and community empowerment contribute such behaviour. To date, the city is only able to divert about 15% of waste from the landfill and the percentage is less compared to the tonnes of waste that end up in the landfill (City of Johannesburg IDP, 2020/21). This is due to lack of participation from the local residents in the waste management initiatives. Figure 3.1 shows an interactive map of CoJ.

Figure 3.1: Interactive Map of CoJ



3.2 Population and sampling

This section describes the population of the study and the technique that was used to select research participants, as well as the size of the sample.

3.2.1 Population

A research population is defined by Burns and Grove (2003) as the entire set of elements or objects from which the study seeks to draw inferences. The population for this study was made up of City of Johannesburg employees in the waste management and energy departments. This is an appropriate population because the people in these departments are involved in the management of waste and the generation of energy for the city and are therefore likely to have adequate knowledge of the research problem.

3.2.2 Sampling method and sample size

From the above-mentioned population, a sample of 20 managers and employees was selected using purposive sampling, which is a non-probability sampling technique. The sample of 20 was considered adequate, based on the views of researchers such as Marshall, Cardon, and Fontenot (2013), who suggested a sample of 15 to 20 participants. The authors based their view on studies that reported the number of participants in five information systems journals. According to Green and Thorogood (2004), the experience of most qualitative researchers who have collected data using interviews to answer a fairly specific research question is that there is not much information obtained after interviewing 20 people. The sample of 20 is considered adequate, as the study does not seek to generalise the findings to the entire population, as it is a qualitative study.

To ensure that the study obtained better insights into the research problem, managers and employees who had been in the two departments for a minimum of two years were selected. Managers from all the levels of the organisation's hierarchy were selected; thus, the sample included senior, middle, and junior managers. Although purposive sampling is considered to be appropriate for this study, it has its challenges. One of the challenges is that the sampling technique is highly prone to researcher bias (Bell, 2014). When the researcher's judgement is poorly considered, the final results are likely to be negatively affected. To overcome this challenge, the researcher made all efforts to select participants who meet the data requirements of the study. Purposive sampling can also be less effective when applied to a large population. This challenge was overcome by involving a relatively small population.

3.2.3 Selection criteria

It was found necessary to have a sample comprising both male and female employees to ensure that diverse views are included. According to Lewis (2013), previous studies have found behavioural and perceptual differences between men and women. Thus, excluding one gender from a study may produce unbalanced findings. In addition, the study sought to include employees from all levels in the hierarchy of the organisation on the assumption that participants' views may differ according to the positions they hold in the organisation.

Lastly, the study sought to recruit participants who had worked in the organisation for relatively long periods as it was assumed that they would provide richer information due to their experience.

3.3 Data collection

Both primary and secondary data were collected for the study. Secondary data was collected through a review of literature that relates to waste-to-energy opportunities. Primary data was collected using semi-structured interviews with the 20 managers and employees from the waste management and energy departments. One advantage of using semi-structured interviews is that they allowed for an in-depth exploration of participants' views and perceptions on waste-to-energy projects in the municipality (Bell, 2014). Semi-structured interviews use open-ended questions, which are useful for ensuring that the responses from participants are comprehensive (Babbie, 2012). In addition, it is possible for the interviewer to probe for more information during the interview if the responses are not clear, or to ask participants to elaborate. Participants in this study were therefore able to explain their responses further, thus, providing more insights on the research problem. Furthermore, the semi-structured interviews gave the researcher an opportunity to observe the non-verbal responses of participants, which are also important in assessing how the participants really felt about the issues that were being discussed.

3.3.1 Interview schedule construction

The instrument for data collection in this study was an interview schedule with a set of questions that sought to obtain the participants' views on the research problem, as shown in Appendix A. The interview schedule was prepared after a thorough examination of literature, which provided ideas on the suitable questions to ask. The questions were also derived from the objectives of the study. The questions were drafted in simple English to ensure that the participants would have a clear understanding and thus, provide responses that are relevant to the research questions. Leading questions were avoided to ensure that the participants provided their original views and perceptions on the research problem. In addition, sensitive questions and questions that sought the private information of research subjects were avoided to ensure there was no emotional or psychological harm.

3.3.2 Administration of interviews

The participants were asked to choose between face-to-face and virtual interviews. The majority of participants opted for virtual interviews, as these were more convenient for them due to their work schedules. The virtual interviews were conducted using the Zoom platform. For the few that opted for face-to-face interviews, the researcher visited them in their offices and for those who did not have individual offices; an office was arranged at the workplace. During the interviews, the participants were reassured that the information they were providing would be treated in the strictest confidence and they would remain anonymous. This assisted in gaining the participants' confidence and making them feel free to share their honest views. In addition to questions that were on the interview schedule, the interviewer asked further questions to follow up on some of the issues that were raised by participants. The participants were asked for permission to audio-record the interview. Notes were also taken by the interviewer on important issues raised by the participants as they responded. Each interview lasted for about 25 to 30 minutes.

3.4 Data analysis

Thematic analysis is one of the methods for analysing qualitative data and was used as the tool for data analysis in this study. Braun and Clarke (2006) define thematic analysis as the process of discovering themes or patterns in a data set. To start the data analysis process, audio recordings were transcribed and the researcher read through the transcripts several times in order to familiarise himself with the responses.

A process of assigning codes to similar tracts of data, known as coding, was then performed. This was followed by the identification of themes or patterns from the coded data. The themes were then revised to check if they were all appropriate. Some themes were expanded and others were collapsed. The final task was the writing of the study report based on the identified themes. The themes and sub-themes were summarised in a table and the discussion of themes was supported by verbatim quotes from the interviews.

3.5 Trustworthiness

To enhance trustworthiness in this study, some tips were taken and these were guided by Lincoln and Guba'a (1985) four criteria, which are credibility, transferability, dependability, and confirmability. These are discussed below.

3.5.1 Credibility

Credibility assesses the extent to which the findings of qualitative research are congruent with reality (Polit & Beck, 2018). One of the techniques used in assessing the credibility of the findings in this study is member checking. The complete study report was sent to the supervisor of this dissertation to solicit for feedback regarding the accuracy of the discussions and interpretations. In addition, prolonged engagement was used. The researcher took time to engage with interview participants in order to obtain a comprehensive understanding of their views and perceptions.

3.5.2 Transferability

Transferability seeks to assess the extent to which the research findings can be transferred from one context to another (Polit & Beck, 2018). This study used thick description as the technique for enabling other researchers to assess whether the findings can be transferred to other contexts. This entailed providing a comprehensive description of the context of the study as well as the methods used and the process followed in the study.

3.5.3 Dependability

Dependability in qualitative research focuses on the extent to which the results can be trusted by the readers of the research report (Polit & Beck, 2018). This study adopted peer debriefing as a strategy for ensuring dependability. A fellow masters' student was given the field notes and data collected; together with the researcher's interpretations so that he would offer his opinions on the interpretations. This was possible with the assistance of an audit trail of all the notes taken in the process of conducting primary research.

3.5.4 Confirmability

Confirmability focuses on the extent to which the findings reflect the views and perceptions of research subjects as opposed to the researcher's own assumptions or biases (Polit & Beck, 2018). To ensure confirmability in this research, the inferences were supported by direct quotes from research participants and the research confined interpretations and recommendations to the data that was presented.

3.6 Limitations of the study

One of the limitations of this study is that only one data collection method was used due to time and cost constraints. With one data collection method, the study is not able to address all aspects of the research problem, such as the relationships between waste-to-energy implementation and the different critical success factors. The use of both quantitative and qualitative methods in primary research would have enhanced the validity and reliability of the research findings. However, all efforts were made to ensure that the research questions were answered using the one method that was selected.

In addition, the participants of the study may not have felt free to provide truthful information due to fear of reprisals from their bosses. However, assurances of confidentiality and anonymity were given to participant to lessen their fears. On the other hand, some participants, particularly in senior management positions, might not have given correct information relating to the waste management and waste-to-energy challenges faced by the municipality in order to portray a good picture of their performance. To overcome this limitation, the participants were assured that the provision of the correct information would benefit the city's efforts to enhance waste management and electricity generation through the implementation of waste-to-energy projects.

3.7 Ethical considerations

In addition to ensuring the appropriate methodology and techniques are selected for a study, it is critical to adhere to ethical principles that govern the conducting of research (Bryman, 2016). This section outlines the steps that were taken to observe the ethical principles that researchers should abide by.

3.7.1 Informed consent

Denzin and Lincoln (2011) regard informed consent as the cornerstone of ethical research. To observe this principle, the participants were informed of the purpose of the study, the type of information that would be required from them, and how the information would be used. In addition, the participants were informed of any potential risks associated with participating in the study. Those who accepted the invitation to participate were asked to sign consent forms.

3.7.2 Anonymity and confidentiality

According to Saunders *et al*. (2019), the researcher has a duty to ensure that the identities of participants are kept confidential and anonymous and that the participants do not use self-identifying statements. The participants for this study were guaranteed of their anonymity, as their names were not included in the research report or any other documents relating to the research. The responses from each participant were identified by a number. To ensure confidentiality, the information provided by participants will only be shared with reviewers of the research report, and their names will remain confidential and only known to the researcher.

3.7.3 Permission to conduct the study

Saunders *et al*. (2019) also emphasise the need for researchers to negotiate for access to the sources of data. For this study, municipal management was approached to seek for permission to collect data from employees and management and to use the municipality as a case study. Permission was granted in writing before the collection of data.

3.8 Chapter summary

This chapter was dedicated to a discussion on the methodology that was used in conducting the study. The chapter outlined and discussed the methods that were employed in collecting and analysing primary data and the steps that were followed in implementing such methods. The research design that was adopted in this study and the reasons for selecting such a design were explained. The chapter went further to discuss the techniques that were used in selecting sample participants, collecting data, and analysing the collected data, as well as the reasons for preferring the selected methods. Furthermore, the steps that were taken to enhance the quality of research findings and ensure the research is conducted in an ethical manner are highlighted, while the limitations of the study were also outlined in this chapter. The upcoming chapter presents the findings of the study.

CHAPTER 4: RESULTS AND DISCUSSION

4.1 Introduction

This chapter focuses on presenting and discussing the results that were obtained from primary data collected through semi-structured interviews. The first section deals with results on the demographic profiles of participants while the second section presents the results relating to the interview questions that sought to gather information to answer the research questions.

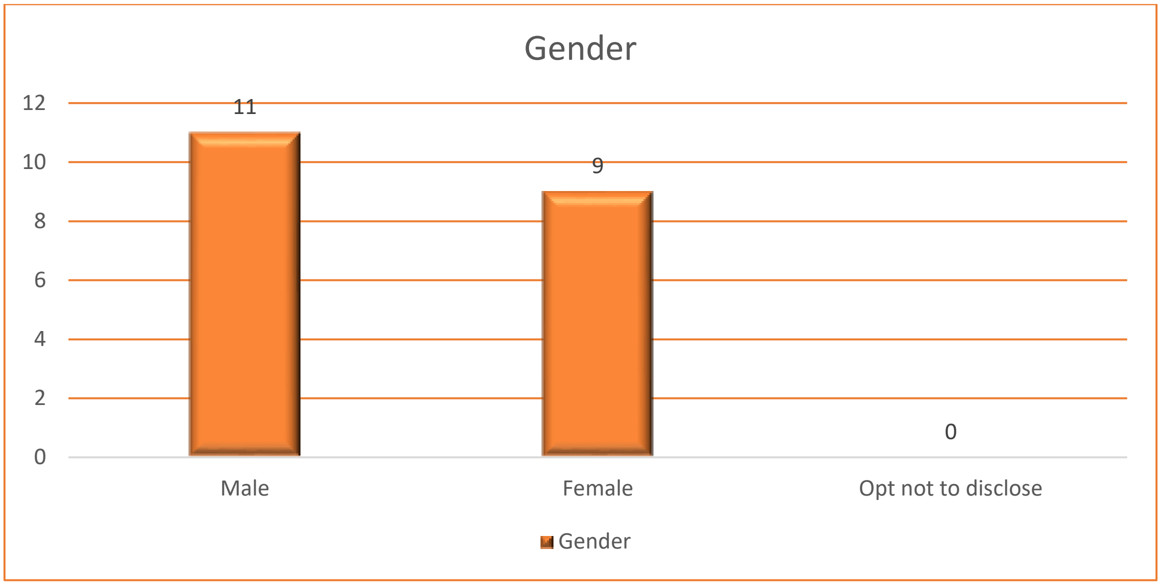
4.2 Results related to participants' demographic profiles

The information on participants' demographic profiles, focusing on three demographic variables, which are gender, position held, and length of service in the organisation, is presented below.

4.2.1 Participants' gender

Information on the gender of participants was of interest in this study, based on the assumption that their views may be influenced by gender. It was therefore deemed important to have a sample that was representative of both genders. The results are summarised in Figure 4.1.

Figure 4.1: Participants' Gender

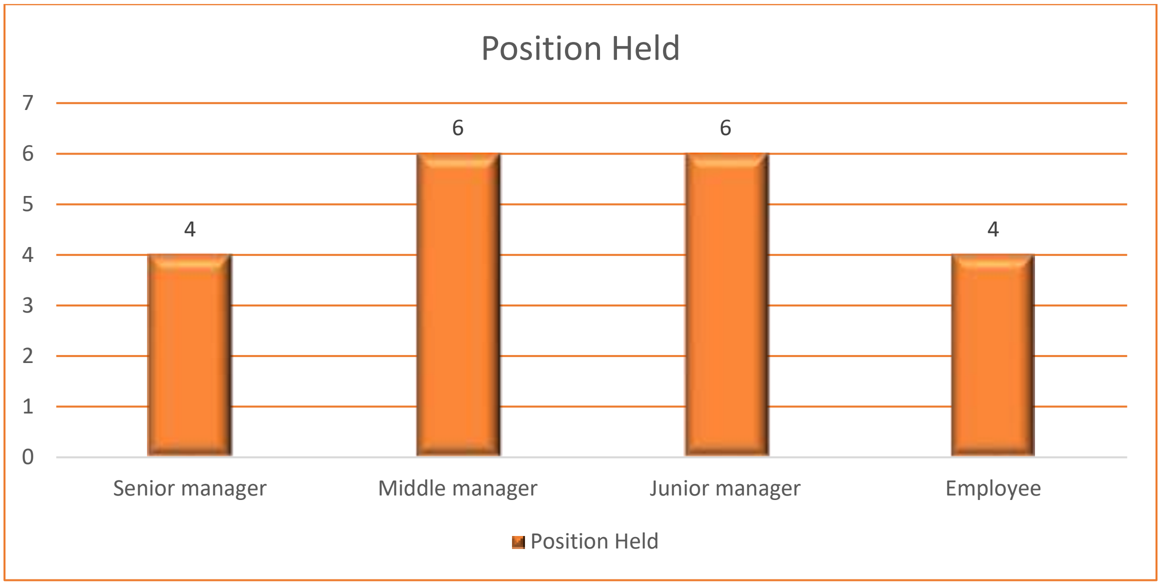


As shown in Figure 4.1, the sample was made up of eleven male and nine female participants. None of the participants opted not to disclose their gender. Although the number of male participants was slightly more than that of female participants, the results show that the study findings represent the views of both genders.

4.2.2 Participants' positions in the organisation

The results in Table 4.2 summarise the distribution of participants according to positions held in the organisation. It was assumed the views and perceptions of employees may be influenced by the positions that they hold in the organisation.

Figure 4.2: Participants' Positions in the Organisation

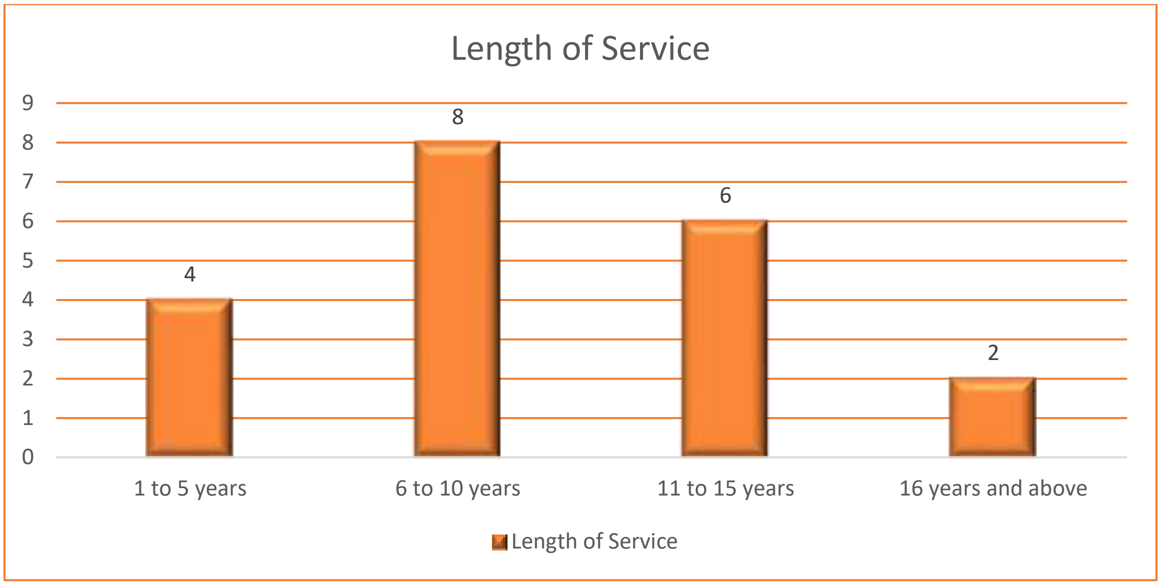


The results indicate that the sample was made up four senior managers, six middle managers, six junior managers, and four employees. The findings of the study therefore represent the views of people in different levels of the organisation's hierarchy.

4.2.3 Length of service in the organisation

The participants were also asked to indicate the number of years they had worked for the organisation, based on the assumption that the study would obtain richer information from those who had been in the organisation for relatively long periods. The results for this demographic variable are summarised in Figure 4.3.

Figure 4.3: Length of service in the Organisation



According to the results in Figure 4.3, four participants had between 1 and 5 years' experience in the organisation while eight participants had experience ranging from 6 to 10 years. Six participants had been with the organisation for between 11 and 15 years, while the remaining two participants had been in the organisation for 16 years and above. This shows that the majority of participants had been with the organisation for relatively long periods and were therefore likely to have adequate knowledge on its systems and processes, thus ensuring the provision of valuable insights into waste-to-energy implementation.

4.3 Presentation of information on research questions

This section focuses on presenting and discussing the results from the interviews conducted with a sample of CoJ management and employees. From the analysis of interview responses, a number of themes were identified under each research objective. The themes are used as the basis for discussing the interview responses. Furthermore, the discussion integrates the findings from the primary research with those from the literature review.

4.3.1 Perceptions of management and employees on opportunities for waste-to-energy projects in the City of Johannesburg

The first objective sought to establish the perceptions of management and employees on the opportunities for waste-to-energy projects in CoJ. Under this objective, three themes were identified from the interview responses, and these are: effective alternatives for managing waste, alleviating electricity challenges, and contributing to environmental management efforts. The themes are discussed below.

4.3.1.1 Effective way alternative for managing waste

All the participants viewed waste-to-energy projects as an alternative and effective way of managing waste in the city. According to the participants, the waste generation capacity of the city is increasing with the rapid increase in urban population and it is becoming difficult to effectively manage the waste being produced.

Participants 1, 4, 6, 7, 8, 14, and 15 highlighted the importance of effective waste management in the city. The participants were of the view that the city should adopt practices for effective waste management in order to enhance the quality of life in the city as well as to ensure a clean and safe environment. Waste-to-energy is therefore one of the effective methods for managing waste. Participant 4 stated:

> "*CoJ gives high priority to effective waste management. It is important to ensure that waste is not just thrown around. Poor waste management is a source of environmental degradation as well as a threat to people's health. We therefore welcome any initiative that can assist us in achieving effective waste management. Waste-to-energy is one such initiative that we embrace as a city as it will go a long way in improving our waste management system*".

Participants 2, 6, 9, 14, 18, and 20 were of the view that the implementation of waste-to-energy projects is an initiative that is set to assist in overcoming some of the waste management challenges in the city. CoJ currently struggles to deliver effective waste management practices as it is overwhelmed by the city's waste generation capacity, and some of the waste disposal practices are harmful to the environment and human health. For example, Participant 18 had the following to say:

"You find that at present, the main methods for disposing waste are landfilling and dumping, which all produce negative effects on human health and the environment. This is mainly because CoJ currently lacks the capacity to promote practices such as recycling or even waste minimisation. This is why I feel the diversion of waste to projects such as biogas will go a long way in solving the city's waste management challenges. We really need such projects and we are working tirelessly to ensure successful adoption and implementation".

Participant 18 went further to state that CoJ had already realised the importance of waste-to-energy projects in alleviating waste management challenges and providing electricity, and in 2011 a project was launched to transform methane emissions from wastewater and landfill waste into energy.

"*The project currently supplies 1.1 MW of electricity to the Northern Water Treatment plant, the largest in the city, which is equivalent to 12% of the plant's operational needs. The city plans to expand the project to four other wastewater plants. In addition, to further scale up this solution, Johannesburg will partner with an energy management services company to develop bio digesters that will process organic waste from the city's five landfills, turning it into biogas used to fuel the city's bus fleet*".

Participants 1, 5, 8, 9, 10, 12, 14, 16, and 18 welcomed the implementation of waste-to-energy projects in CoJ as a way of reducing landfill waste. According to the participants, the conversion of waste to energy can substantially minimise the quantities of waste entering landfills. The city is currently running short of landfill space and waste-to-energy projects are a way of freeing landfill space. This view was clearly stated by Participant 9 who stated:

"*Sending waste to landfill has always been an easy option. It gets dumped and buried, and in time it will decompose. The majority of waste generators do not want to pursue options such as recycling as they find it easy to dispose waste in landfills. However,* *landfill takes up a lot of space and destroys habitats and landscapes. At the moment, we are running a risk of ending up without landfill space as the amount of waste being generated continues to increase. Waste-to-energy conversion is therefore an effective alternative*".

The above responses therefore show that the participants perceive waste-to-energy conversion as a welcome development as it presents an opportunity to overcome some of the problems faced by the city in its efforts to effectively manage waste. The participants' views are aligned to findings from literature. According to Menikpura et al. (2016), waste-to-energy is increasingly being regarded as an alternative for dealing with the growing challenges of waste management in developing countries. Through waste-to-energy projects, local authorities can reduce the amount of waste that is dumped illegally and disposed of in landfills (Abbasi, 2018). Mutezo (2015) viewed waste-to-energy as proving to be a viable alternative to the existing methods of disposing waste. Mutezo (2015) further stated that when waste has been disposed in landfills, such waste is decomposed by microorganisms under anaerobic conditions, resulting in the production of leachate and landfill gas, which are harmful to human health and the environment. Thus, by diverting the greater portion of its waste-to-energy generating projects, CoJ can deal with the problems that are associated with landfilling and dumping of waste.

4.3.1.2 Alleviating energy challenges

The interview responses also cited the alleviation of electricity challenges as one of the opportunities associated with the implementation of waste-to-energy projects in CoJ. According to the participants, the whole country is currently facing electricity shortages due to Eskom's failure to meet the increasing demand for energy. Waste-to-energy projects are therefore set to provide solutions to both waste management and electricity supply challenges.

According to Participants 5, 6, 9, 11, 13, 15, and 19, residents in the city are experiencing regular power cuts due to Eskom's loadshedding schedule and this has affected the operations of several businesses. In addition, the quality of life of residents is being compromised because of the long hours of loadshedding that are experienced. The production of electricity from waste is therefore an opportunity to supplement Eskom's electricity supply efforts and improve the quality of life of residents. Participant 5 stated:

> *"Any initiative that produces extra electricity to the city should be embraced as we are currently facing electricity shortages that are affecting the whole country. So, you find that with waste-to-energy projects, you will be killing two birds with one stone; that is, managing waste effectively and increasing the supply of electricity, which is very important for industries in the city to function properly*".

Participants 3, 12, 16, and 20 highlighted that, with the huge quantities of waste that are generated in the city, it is possible to have an unending supply of energy, which is useful for driving economic activities. Participant 12 stated:

> *"If we use our waste correctly, we can create huge amounts of energy. Waste-to-energy facilities cam use waste to produce gas, electricity and heat, and other forms of fuel. Inevitably, we will always generate some waste. Turning this waste into energy means creating fuel sources that enable us to reduce the use of fossil fuels. Whether it is food waste or other organic waste, we can put it to good use. When considering the amount of waste we generate, we can enhance energy efficiency by using these new energy sources*".

The above responses therefore show that there is a significant opportunity for generating electricity and other forms of energy from waste generated in the city. This will assist the country in meeting the ever-increasing demand for electricity and enhance economic activity in the city. This view is also emphasised in literature, which regards waste-to-energy projects as one of the effective ways of dealing with electricity challenges, particularly in developing countries. According to Menikpura et al. (2016), there is a significant increase in electricity demand worldwide due to population growth, urbanisation, and industrialisation. The South African electricity authority, Eskom, has on several occasions failed to meet the electricity demand in South Africa, resulting in load shedding which is aimed at keeping the grid stable and avoiding a total blackout (Amsterdam & Thopil, 2017). A study by the World Council (2013) revealed that, if countries can use all waste to produce energy, 10% of the global demand for electricity can be satisfied.

4.3.1.3 Contributing to environmental management efforts

The participants also viewed waste-to-energy projects as one of the several ways in which the city can contribute to the country's efforts towards effective environmental management and achieving sustainability. According to the participants, improper waste disposal practices are among the major contributors to environmental degradation and threats to human health. Therefore, by converting waste to energy, the city will do away with poor waste disposal as well as develop environmentally friendly ways to generate energy.

Participants 1, 2, 8, 9, 12, 18, and 19 were of the view that the diversion of waste to energy-producing projects will assist in greatly reducing the quantities of waste that are either dumped illegally or are disposed of in landfills. Although the greater portions of waste disposed in landfills ultimately decomposes, the process of decomposition produces gases that are harmful to the environment. Participant 19 stated:

> *"… However, landfill takes up a lot of space and destroys habitats and landscapes. Along with this we have to address an even more significant problem – the release of methane. When our waste is placed in landfills, it gives off methane. This gas is extremely harmful to our environment, more so than CO2. While it does not hang around in the atmosphere as CO2, it absorbs more heat, contributing to global warming".*

Participant 6 gave the example of a landfill-to-gas project that can provide an opportunity to minimise environmental pollution while producing energy and reducing electricity costs for the local authority.

> "…. *This project results in improved quality of ground water as well as air quality and safety. It also reduces the odour that for communities that are close to landfill sites. At present, landfill site management is a huge problem and so many negative environmental impacts are being produced by landfills*".

Thus, by diverting waste to projects that generate energy, or converting landfill waste to gas, the city will reduce the amounts of greenhouse gases (GHGs) that are emitted into the atmosphere, thereby contributing to efforts to fight environmental pollution and climate change. Mutezo (2015) also notes that the disposal of waste by dumping in landfills has negative impacts on human health and the environment. When waste has been disposed in landfills, “microorganisms decompose the waste under anaerobic conditions, which results in the production of leachate and landfill gas” (Barros et al., 2018:14). According to Abbasi (2018), each kilogramme of MSW generates approximately $0.35nm^3$ of landfill gas, which can cause air pollution, thus degrading the quality of the air, as well as cause odours, and ultimately, health problems, if not controlled. Landfill sites are therefore ranked as the third producer of CHGs. Thus, waste-to-energy technologies and projects provide an opportunity to improve the management of waste as well as reduce CHG emissions as the demand for landfilling can be significantly reduced.

Participants 1, 4, 5, 7, 9, 10, 16, 18, and 19 pointed out that the adoption and implementation of waste-to-energy projects in CoJ is a welcome development, as such projects generate clean energy, which reduces pollution of the atmosphere. The participants were of the view that the current sources of energy that are dominant in South Africa are contributing to atmospheric pollution as the generation process produces a huge quantity of GHGs. Participant 4 stated:

> *“The entire process of turning waste into energy is sustainable. We don't call on fossil fuels or non-renewable sources to make it happen. Most of the processes are natural such as the anaerobic digestion process. As a result, the organic waste is turned into a source of energy that would have once been lost when placed in landfills”.*

Participant 7 stated:

> *“Resorting to waste-to-energy as a way of generating electricity and other forms of energy is commendable as the process produces clean energy. When we have a large proportion of electricity coming from waste-to-energy projects, we reduce the*

country's dependency of coal, which produces a significant amount of GHGs during the process of generating energy. By so doing, the country will be moving towards achieving environmental sustainability".

According to Kulshreshtha (2022), the opportunity to convert solid waste to energy resources can solve two problems: generation of clean energy and management of solid waste. Waste-to-energy plays a crucial role in the attainment of transformation to a sustainable energy eco-system. It is a renewable energy resource that can contribute immensely to the reduction of greenhouse gas (GHG) emission. Dlamini et al. (2019) describe waste-to-energy as a proven technology for electric power production, industrial processes, heating, and cooling that is better than fossil fuels and also has a significantly lower carbon footprint than landfilling. An added benefit of waste-to energy is that it destroys contaminated materials that contain viruses and pathogens.

4.3.1.4 Employment creation

The participants also viewed waste-to-energy projects as a channel for employment creation in the city. According to the participants, there are several processes involved in the designing and implementation of such projects, and human resources are needed in such processes. With the current high levels of unemployment in the country, the participants felt that the adoption and implementation of waste-to-energy projects on a large scale is one way of alleviating the unemployment challenge in the country.

Participant 4 stated:

"Waste-to-energy projects are great sources of job opportunities for our population, which is currently faced with high levels of unemployment. The process of designing these projects is the first source of employment. Furthermore, there is construction as well as operation of the projects, which also creates several jobs for construction personnel, administrative workers, engineers, and so many others".

Participant 13 stated:

"We are anticipating that the implementation of waste-to-energy projects will empower our community by providing jobs to several unemployed people. This will improve the quality of life of several residents, as they will now be able to earn income

for meeting their daily needs. The projects are therefore a welcome development in the city".

Global employment in renewable energy projects is increasing as more and more projects are implemented in different countries. In 2020, an estimated 12 million jobs were created in the renewable energy sector, up from 11.5 million in 2019 (International Renewable Energy Agency (IRENA), 2021). According to Burger (2021), increased adoption and implementation of waste-to-energy projects in South Africa is capable of creating 150 000 jobs by 2024. Therefore, by implementing waste-to-energy projects, CoJ will contribute towards reducing the rate of unemployment in the country.

4.3.2 Critical factors for the success of waste-to-energy projects in CoJ

The second objective sought to establish the factors that are critical for the success of energy-to-waste projects in CoJ. From the interview responses, the following themes were identified: the availability of human, financial, and technological resources; a supportive legislative framework; and stakeholder collaboration and partnerships. The themes are discussed below.

4.3.2.1 Availability of human, financial, and technological resources

There was consensus among the participants that the implementation of waste-to-energy projects requires adequate support in terms of human, financial, and technological resources. It is important for CoJ to conduct an internal analysis that focuses on assessing its strengths and weaknesses in relation to resources. Without adequate resources, the city will not be able to enjoy maximum benefits from waste-to-energy projects, as it will not be able to achieve effective implementation.

All the participants cited the availability of skilled and competent human resources as one of the key factors that enable the successful implementation of energy-to-waste projects. Participant 10 stated:

"*Waste-to-energy projects are still being implemented at a very small scale in the country and I do not think that we have enough skilled and competent personnel for* *such projects yet. These projects involve designing, implementation, operation, and maintenance, which demand particular sets of skills. Before implementing such projects, it is crucial for the city to identify the skills that are required and assess whether such skills and competencies are available within the organisation. If they are not available, the municipality should make plans to recruit staff with such skills*".

According to Participant 16, one of the first steps towards the adoption and implementation of waste-to-energy projects is ensuring the availability of personnel with the right skills and competencies.

"Waste-to-energy technologies and new and complex and require people with the right skills and competencies. We should therefore be able to identify the people to be deployed in such projects and prepare them through training and development initiatives. Even the managers for such projects need to be trained since they will be dealing with a new technological environment".

In literature, the availability of skilled and competent human resources is also cited as a critical success factor for the implementation of waste-to-energy projects. According to Borello et al. (2018), the establishment and operation of waste-to-energy technologies demand high technical skills, standards, and specifications. As a result, there is a need for intensive training of personnel from academics, professional, and industrial experts before implementing waste-to-energy projects in South Africa and other developing countries (Amsterdam & Thopil, 2017). In South Africa, technical capacity is a major challenge when it comes to the implementation of renewable energy projects such as waste-to-energy.

In addition to human resources, financial resources were cited as a major consideration for CoJ to take into account before kick-starting waste-to-energy projects. According to the participants, such projects require huge amounts of capital and it is therefore crucial for the city to conduct comprehensive financial planning before implementing waste-to-energy projects. On the topic of whether CoJ currently has adequate financial resources for implementation of the projects, the participants had mixed views.

Some participants felt the current financial position of the city is not suitable for the implementation of waste-to-energy projects. For example, Participant 11 stated:

> "*When we talk about waste-to-energy projects, we are talking about huge amounts of investment. Those technologies are very expensive to set up. Our municipality is however currently struggling financially and I do not see it having the capacity to afford such investments. If you look at waste management, we are already struggling to implement effective practices because of financial constraints. I think we need external financial support for waste-to-energy projects*".

However, other participants felt that the municipality has the financial capacity to implement waste-to-energy projects through PPPs. Participant 20 stated:

> "*COJ has a public-private partnership wherein the city provides the rights to the landfill gas to the developer, who is responsible for financing and operating the project. This arrangement enables the city to undertake the project risk-free while receiving royalties from the developer. The PPP arrangement can be made for all future projects, meaning that municipality will not face financial constraints when it comes to waste-to-energy projects*".

Despite the varying views on the financial capacity of CoJ to implement waste-to-energy projects, all the participants agreed that financial capacity is a very important factor that determines the success of waste-to-energy projects. This view is supported by a number of researchers. Mbazima *et al.* (2022) pointed out that the implementation of waste-to-energy projects demands considerably high initial investments when compared to landfilling and thus, financial capability should be assessed before embarking on such projects. However, developing countries, including South Africa, lack financial support for renewable energy projects, making it difficult for municipalities to upscale the implementation of waste-to-energy projects (Adeleke *et al.*, 2021). In South Africa, municipalities are currently struggling to provide efficient waste management services due to inadequate budgets, and thus, the incorporation of waste-to-energy in the waste management system requires external financial support (Godfrey & Oelofse, 2017).

Dlamini et al. (2019) suggest the PPP approach, in which municipalities work closely with the private sector, in collaboration with the government, to set up waste-to-energy facilities.

4.3.2.2 Supportive legislative and policy framework

The participants also cited the availability of a supportive legislative and policy framework as another factor that enables the successful implementation of waste-to-energy projects. According to the participants, clear legislation and policies governing waste management and renewable energy projects are needed so that they can guide and direct all stakeholders in the implementation of such projects. Mutezo (2015) also regards a supportive legislative framework as one of the factors that are critical in facilitating the introduction and up scaling of waste-to-energy technologies in South Africa. Similarly, Stafford (2019) highlights the importance of establishing a robust legislative and policy framework to support successful implementation of a waste management system that incorporates waste-to-energy technologies. Some participants highlighted that currently, there are pieces of legislation, such as the National Environmental Management: Waste Act (59 of 2008) (NEM: WA) and the National Waste Management Strategy (NWMS) 2020. However, there is more that needs to be done in order to discourage landfilling and encourage separation at source.

Participants 9, 12, 15, 17, 18, and 19 provided the example of landfill tax, which they said does not currently support the diversion of waste from landfills to more sustainable forms of waste disposal such recycling and waste-to-energy. This means that there is a need to revisit landfill tax so that it supports the implementation of waste-to-energy projects. Participant 15 stated:

> "*The regulation regarding landfill tax needs to be revisited. The amount of landfill tax being levied by CoJ is very small and it does not act as a disincentive for waste generators to think of innovative methods of disposing waste. I feel that the tax should be raised to deterrent levels so that waste generators find it expensive to dispose their waste in landfills. This will make them support the city's efforts to implement waste-to-energy projects*".

This view is supported by Zhou et al. (2018) who posit that the generation of energy from waste has been proven to be an effective strategy for diverting significant amounts of waste from landfills, particularly in countries where regulations, policies, and landfill taxes discourage disposal of waste in landfills. According to Simalane and SA (2016), countries can discourage the disposal of waste in landfills by levying a landfill tax, thereby promoting waste-to-energy initiatives. In EU countries, high landfill taxes were introduced. As mentioned previously, in the United Kingdom (UK), for example, landfill tax was increased from £7 to £84 per tonne of waste between 1996 and 2014 (Simelane & Sa, 2016). According to Adeleke et al. (2021), the low landfill taxes charged by South African cities create a perverse incentive for continued preference of disposal as a waste management option.

Participants 1, 2, 6, 10, and 13 proposed the development of regulations that make it mandatory to separate waste at source as this is one of the activities that facilitates the operation of waste-to-energy technologies. According to the participants, not all waste types are suitable for waste-to-energy projects and the separation of waste at source makes it easy to obtain waste that is suitable for such projects. Participant 2 stated:

> "*Efforts should be made to create a culture of waste separation at source through regulation and strict enforcement to ensure that the waste that is suitable for conversion to energy is easily obtained. In addition, incentives can also be provided to encourage residents to separate waste at source. It is therefore important for policymakers to pay attention to this area if waste-to-energy projects are to be highly successful*".

According to the participants, the current scenario is that all waste from households and other sources is mixed, which means there has to be another exercise of separating the waste. The ability to separate waste at source is highlighted by Adeleke et al. (2021) as one of the crucial factors influencing the successful implementation of waste-to-energy initiatives. It involves the practice of separating household and post-consumer waste at the point at which it is generated so that such waste does not go to landfills. In South

Africa, there is no culture of separating waste at the source, which makes it difficult to generate value from waste (Amsterdam & Thopil, 2017). Dlamini et al. (2019) highlight that the separation of waste at the source facilitates the implementation of waste-to-energy activities as it assists in retaining the valuable materials suitable for recycling and biodegrading. Therefore, without an effective system of separating waste at the source, it becomes difficult to successfully implement waste-to-energy projects as they utilise only particular types of waste.

In terms of the legislative and policy framework, Participants 4, 5, 6, 9, 12, 14, and 16 suggested the establishment of policies that provide incentives for the establishment of PPs. According to the participants, waste-to-energy projects are capital intensive and the municipality on its own will never be in a position to afford the implementation of large-scale projects. It is only with the active participation of the private sector that the city can achieve large-scale implementation of waste-to-energy technologies. Participant 6 stated:

> "*Our policy environment needs to be more friendly to private investors than it is at the moment. We really need the participation of the private sector in these projects, as it is the one that has the financial capacity to implement projects on a large scale. Incentives such as tax holidays for, say 3 years are important for attracting investors into waste-to-energy projects. Other benefits for partnering in these projects should also be attractive ...*"

It is therefore important for the municipality to collaborate with policymakers and highlight the need for more policy instruments relating to waste-to-energy projects. Mohlala et al. (2016) argues that, although South Africa has a number of policies and regulations governing waste management and promoting renewable energy, there is still a need to develop supportive policies for the adoption of renewable energy technologies such as waste-to-energy. For instance, Kariuki (2019) noted that there is very limited participation of the private sector in renewable energy projects due to a lack of clear and well-defined policies on private investment and delays in the approval of projects in which the private sector is involved.

4.3.2.3 Stakeholder collaboration and partnerships

The interview responses also highlighted the important role played by stakeholder collaboration and partnerships in enhancing the success of waste-to-energy projects in the city. According to the participants, it is important for the municipality's management, the government, the private sector, financial institutions, and the community to work together in the implementation of waste-to-energy projects. Each stakeholder has an important role to play; and when that role is not played little progress is achieved.

Participants 1, 4, 7, 10, 11, 19, and 20 highlighted the need for the community to play its part in implementing good waste management practices such as separation at source and avoiding illegal dumping of waste. This will complement the waste management efforts of the municipality and facilitate the implementation of waste-to-energy projects. Participant 19 stated:

> "*Community involvement in waste management and waste-to-energy processes is very important for achieving success in these areas. When the community is aware of what it is supposed to do in order to achieve effective waste management, it can make huge contributions towards the success of the process. For example, awareness of the need to separate waste at source will go a long way in facilitating the process of diverting waste towards energy generating projects*".

Although there is a realisation of the importance of community participation, most of the participants felt that the efforts by the municipality to involve the community are minimal. The participants were mostly concerned about the general lack of awareness of the community on environmental and waste management issues. For instance, Participant 8 stated:

> "*We have very little activities involving the separation of waste at source mostly because our people are not aware of this phenomenon. Public awareness initiatives are not being given serious attention in our municipality. In this era of advanced technology and increasing use of social media, we should be increasing our public awareness efforts to ensure that the public makes positive contributions towards waste management and waste-to-energy efforts*".

According to Participant 6, public participation and awareness are also important, particularly for waste-to-energy projects since residents in some municipalities are on record for having resisted such initiatives, citing issues such as the noise produced by the projects.

> *"Our municipality needs to improve its engagement with residents so that there is a common understanding of some of the issues that usually make residents resist some renewable energy projects such as waste-to-energy. Through the different public participation platform, residents should be provided with compelling reasons for venturing into such projects. Without effective communication, residents will always resist waste-to-energy projects on the basis of the little information they will be having*".

According to the Rio Declaration on Environment and Development, one of the important principles of sustainable development is the involvement of all citizens in issues that relate to management of the environment (Kofi-Opata, 2013). Thus, the success of environmental programmes such as waste management is enhanced when countries promote participation and awareness amongst citizens through sharing of environmental information. In South Africa, feasibility studies among residents in selected municipalities indicated that the majority of residents lack awareness of the benefits offered by waste-to-energy in terms of providing energy, minimising landfill disposal, and the environmental benefits (Adeleke et al., 2021). This has caused apathy among residents in municipalities. According to the feasibility studies, some residents had opposed the implementation of some waste-to-energy projects, as they were concerned about the supposed environmental effects of the facilities (Adeleke et al., 2021). Unless there is an initiation of public awareness and participation to deal with the negative impressions of waste-to-energy technologies such as incineration, these initiatives will continue to face resistance from the public.

4.4 Chapter summary

This chapter focused on presenting and discussing the results that were obtained from primary data collected through semi-structured interviews. The first section presented the results on the demographic profiles of participants while the second section focused on the results relating to the interview questions that sought to gather information to answer the research questions. The results show that the implementation of waste-to-energy projects in CoJ offers several opportunities, which include improving the effectiveness of waste management, alleviating the energy challenges in the municipality, contributing towards the achievement of a sustainable environment, and creating jobs for residents. According to the results, some of the factors that are critical for achieving success in the implementation of waste-to-energy projects are the availability of human, financial, and technological resources, a supportive legislative and policy environment, and the involvement of all stakeholders. These factors are in line with those that have been highlighted in literature, as discussed in Chapter 2.

CHAPTER 5: CONCLUSIONS AND RECOMMENDATIONS

5.1 Introduction

This final chapter focuses on the conclusions and recommendations of the study. The first section provides the conclusions drawn from the study's findings, and shows how the research objectives were achieved. This is followed by the recommendations to CoJ management as well as policymakers on ways in which they can effectively take advantage of opportunities for implementing waste-to-energy projects. Lastly, recommendations on areas for further research are provided.

5.2 Conclusions

The conclusions drawn from both the primary research and the literature review are presented in this section under each of the research objectives.

5.2.1 Research Objective 1: Perceptions of management and employees on opportunities for waste-to-energy projects in the City of Johannesburg

The participants of this study highlighted a number of opportunities that are available to CoJ from the implementation of waste-to-energy projects. There is a significant opportunity for CoJ to overcome the current waste management challenges through the adoption of waste-to-energy projects. Like all other municipalities in the country, CoJ is faced with increased rates of waste generation due to growing urbanisation and increasing population. Simultaneously faced with resource constraints, the city is struggling to implement effective and sustainable waste management practices and the greatest portion of waste ends up being landfilled or dumped. Such waste disposal practices produce negative impacts on the environment and human health.

Waste-to-energy projects will therefore provide CoJ with an opportunity to divert waste from landfills, and at the same time, utilise the waste for the generation of energy. In addition to freeing up landfill space, which is slowly running out, CoJ will address the energy challenges which are currently being encountered by the whole country. Due to increased demand for electricity and other forms of energy, shortages are being experienced and these have resulted in regular power cuts. Waste-to-energy projects will complement the efforts to increase the supply of electricity in the municipality, thus improving the performance of businesses and enhancing the growth of the economy.

In addition to enhancing the waste management system and improving the supply of energy, waste-to-energy projects also have the potential to contribute to the country's efforts towards effective environmental management and achieving sustainability while creating jobs for several people. By diverting waste to projects that generate energy, or converting landfill waste to gas, the city will reduce the amounts of greenhouse gases (GHGs) that are emitted into the atmosphere and therefore contributing to the efforts to fight environmental pollution and climate change. Furthermore, waste-to-energy is a renewable energy resource that can contribute immensely to the reduction of greenhouse gas (GHG) emission.

5.2.2 Research Objective 2: Critical factors for the success of waste-to-energy projects in CoJ

The study also found that the implementation of waste-to-energy projects is a complex phenomenon whose success is driven by the interaction of a number of factors. The successful implementation of such projects is therefore dependant on the ability of CoJ and other stakeholders to address these critical factors. Firstly, it is important to ensure the availability of human, financial, and technological resources. Waste-to-energy technologies demand new skills that are currently not available in the municipality and there is a need to train existing staff as well as hire new personnel with the required skills and competencies. Furthermore, the city should mobilise adequate financial resources, as the technologies are capital intensive and demand huge amounts of investments. The study found that the establishment of PPPs will assist CoJ in overcoming the financial barriers to the implementation of waste-to-energy technologies.

The availability of financial and human resources is also cited in literature as one of the critical success factors for the implementation of waste-to-energy projects. When compared to landfilling, the implementation of waste-to-energy projects requires considerably high initial investments, making financial capability a factor to assess before undertaking such projects (Mbazima et al., 2022; Stafford, 2019). Developing countries, unlike most developed nations, are however, struggling with a lack of financial support for renewable energy projects and therefore have to find innovative ways of financing such projects (Adeleke et al., 2021; Dlamini et al., 2019).

Secondly, the regulatory and policy framework was found to play a significant role in influencing the success of waste-to-energy projects. A supportive legislative and policy environment is crucial. It is important to establish a robust legislative and policy framework to support successful implementation of a waste management system that incorporates waste-to-energy technologies. Although South Africa has a number of pieces of legislation that govern waste management, more needs to be done in order to discourage landfilling and encourage practices such as separation at source. Reviewing landfill tax rates and designing and enforcing regulations supporting separation at source are therefore important considerations that need to be made.

Literature also highlights a supportive legislative framework as one of the factors that are critical in facilitating the introduction and up scaling of waste-to-energy technologies globally (Abbasi, 2018; Chepkemoi, 2015). In most African countries, for instance, there are no clear and well-defined policies on private investment, and this hampers sector participation in renewable energy projects. On the issue of landfill tax, it has been noted that countries in the EU have introduced high rates of landfill tax to discourage the disposal of waste in landfills and promote waste-to-energy projects. South Africa and other developing countries can therefore emulate the waste-to-energy policies in developed countries to ensure the success of their own projects.

Lastly, the participation of all stakeholders was found to be critical for the success of waste-to-energy projects. Of particular importance, this study found public participation and involvement as a major consideration that CoJ should take into account. Currently, the municipality has low levels of public participation and if not addressed, this can hinder the implementation of waste-to-energy projects. The study found that there is a general lack of awareness of good waste management practices, such as separation at source. Consequently, residents are not playing their part in the waste management process, mainly due to a lack of awareness. In addition, it is critical for the municipality to engage citizens and convince them of the benefits of waste-to-energy projects as these are usually resisted by residents on the basis of the little information they have about the impact of such projects. Enhancing public participation should therefore be one of the focus areas before the implementation of waste-to-energy projects.

The Rio Declaration on Environment and Development cited the involvement of all citizens in issues that relate to environmental management as one of the principles of sustainable development (Kofi-Opata, 2013). Thus, all environmental-related decisions are expected to take a bottom-up approach. It is therefore crucial for all countries to ensure the participation of citizens in decision-making in order to attain sustainable development. Since waste management and waste-to-energy have the aim of preserving the environment, the principle of public participation also applies. Just like South Africa, most African countries do not share information relating to government decisions on important issues affecting citizens (Fouche & Brent, 2019). It is therefore crucial for all countries to increase public participation in order to enhance the success of waste-to-energy projects.

5.3 Research Objective 3: Recommendations on ways to effectively take advantage of opportunities for implementing waste-to-energy projects

The following are recommendations to CoJ management and policymakers on ways in which they can effectively take advantage of opportunities for implementing waste-to-energy projects.

5.3.1 Human resource development

Skilled and competent human resources were found in this study to be one of the pillars of successful implementation of waste-to-energy project. It is therefore recommended that the city should ensure the availability of personnel with the required skills before rolling out the projects. For the existing staff, it is important for management to conduct a thorough assessment of the skills and competencies that are required for designing, implementing, operating, and maintaining waste-to-energy projects. The next step will be to analyse the existing skills and competencies that are currently available, and thus establish the skills gap. Training programmes that are suitable for closing the skills gap should then be designed. In addition to upgrading the skills of the current personnel, management should also recruit skilled and competent people who have a track record of working in successful waste-to energy projects.

5.3.2 Mobilisation of financial resources

The study also established that the implementation of waste-to-energy projects requires substantial amounts of capital, which CoJ alone is not able to raise. It is therefore critical for CoJ to establish partnerships with the private sector in order to generate the required investment capital. Although the city currently has a PPP for the implementation of some waste-to-energy projects, there is a need to create more partnerships in order to achieve large-scale implementation of the project. Through attractive contract terms, CoJ can attract sufficient investment capital for waste-to-energy projects.

5.3.3 Formulating supportive legislation and policies

It is also important for CoJ management and policymakers to revise the legislation, regulations, and policies that govern waste management and renewable energy in order to come up with supportive legislation and policies. As highlighted in the findings of this study, there are gaps in the current legislation and these gaps need to be closed in order to achieve a supportive legislative and policy environment. It is important for CoJ management to conduct a thorough analysis of legislation and policies and make proposals to policymakers on areas that need amendments or additional laws. For example, CoJ management should propose the development of policies that attract investors into waste-to-energy projects, such as economic incentives and tax holidays. In addition, it is important to ensure that existing and new laws are enforced in order to achieve high levels of compliance.

5.3.4 Promote separation at source

It is also critical for CoJ to promote a culture of separating waste at the source among all residents in order to facilitate the implementation of waste-to-energy projects. The findings of this study indicate that the separation of waste at the source assists in easily obtaining the waste types that are suitable for waste-to-energy projects. Promoting a culture of separating waste at the source can be done through regulations that are strictly enforced to achieve high levels of compliance. In addition, the city can provide separate waste collection containers for degradable and non-degradable waste materials.

5.3.5 Increase public participation

It is also crucial for CoJ to increase the level of public participation in decision-making relating to waste management and waste-to-energy projects. Increasing public participation will assist in increasing awareness among residents on the importance of good waste management practices as well the benefits of waste-to-energy projects. Equipped with adequate knowledge, residents are more likely to support waste management efforts and will be less likely to resist the implementation of waste-to-energy projects in their communities. CoJ can take advantage of the increased use of technology and social media to increase its interaction with residents.

This study has therefore revealed that there are significant opportunities for the implementation of waste-to-energy projects in CoJ and that the city is still far from fully utilising such opportunities. The implementation of waste-to-energy projects has the potential to transform the waste management and electricity situation of the city and put to an end to the waste management challenges that have characterised CoJ for a long time. In order to realise such opportunities, CoJ needs to comprehensively plan for the implementation of waste-to-energy projects by taking into account all the critical success factors.

5.4 Recommendations for further research

This study focused on exploring the opportunities for waste-to-energy in CoJ using the qualitative approach. Due to time constraints, the study used only one method of data collection and did not cover a large sample. Further research can be conducted on the same topic using a mixed-methods approach to obtain both depth and breadth for the study. Such a study could further explore the extent of the CoJ’s planning and implementation of waste-to-energy projects, as well as the challenges encountered in the process, in order to propose strategies for addressing these challenges. The results can also be compared with the achievements in other municipalities regarding the implementation of waste-to-energy projects.

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APPENDICES

Appendix A: Interview guide

Section A: Demographic Information

1. Please indicate your gender

Male	
Female	

2. Please state your position in the organisation

Senior manager	
Middle manager	
Junior manager	
Employee	

3. Please indicate the period that you have worked in the organisation

2 to 6 years	
7 to 11 years	
12 to 16 years	
17 years and above	

4. Please indicate your highest educational qualifications

Matric	
Certificate	
Diploma	
Undergraduate degree	
Postgraduate degree	

The following section provides the questions designed to gather information needed to address the research objectives.

Section B: Interview Questions

5. In what ways do you think the implementation of waste-to-energy projects can assist in improving waste management in CoJ?
6. Do you think the implementation of waste-to-energy projects in the city can help in alleviating the electricity supply problem? Please explain. What can you say is the overall attitude of CoJ with regard to waste-to-energy projects?
7. What steps are being taken to adopt and implement waste-to-energy projects in the city?
8. What are your views on the current rates of landfill tax charged by the city?

- Is it high enough to induce alternative waste disposal strategies?
- What are the implications of revising such a tax upwards?

9. To what extent is CoJ financially prepared to implement waste-to-energy projects?
10. Do you think CoJ has adequate human capacity to implement waste-to-energy projects? Please comment on the availability of skills and the size of the workforce.
11. To what extent does CoJ involve residents in waste management and environmental protection issues?
12. Please highlight and explain any other factors that are critical for successful implementation of waste-to-energy projects.
13. What strategies do you suggest the city should adopt in order to enhance its capacity to take advantage of waste-to-energy projects?
14. Are there any other issues that you would want to comment on in relation to the implementation of waste-to-energy projects?