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Research Article

Waste-to-energy conversion methods and implementation feasibility in Jos, Nigeria: A review

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Abstract

Population growth in Jos has outpaced the capacity of existing waste management systems. This has institutionalised open dumping as the predominant disposal method. This inadequacy has intensified environmental degradation and public health risk. It underscores the urgent need for suitable waste management strategies and resource recovery option. This review aims to assess different waste-to-energy (WtE) technologies – their operation, benefits and constraints, evaluate the current MSW management practice in Jos and identify barriers to local implementation of WtE. Relevant literature and secondary data were systematically reviewed to analyse waste composition, generation rates and previous WtE studies. Findings reveal limited and inconsistent data on waste characteristics, with some studies constrained by narrow spatial coverage and poor methodological design. Nonetheless, food and organic waste dominate the waste stream (approximately 29.2% and 36.9% respectively), yielding a biodegradable fraction of 50.7 - 65.2%, followed by plastic/polythene components (approximately 6.77 – 13.6%). These characteristics demonstrate strong potential for energy recovery through thermal and biological conversion processes. The study concludes that integrating WtE technologies could enhance waste management efficiency, mitigate greenhouse gas emissions and strengthen energy security in Jos.

1.0 Introduction

Municipal solid waste (MSW) refers to discarded materials generated from human daily activities (Ibikunle et al., 2019). Globally, inadequate waste management has become a pressing environmental issue, with less than half of the world's population having access to proper collection and disposal systems (Tsai et al., 2020; Di Foggia & Beccarello, 2021). Rapid urbanisation and changing consumption patterns have intensified MSW generation worldwide, making waste management a major sustainability challenge (Islam, 2016).

This global concern is reflected in developing nations such as Nigeria, where increasing waste generation has exceeded the capacity of existing management systems (Ukwaba et al., 2018). Jos, the capital of Plateau State, exemplified this trend. The city, comprising of Jos North and Jos South local government areas, is one of Nigeria's fastest-growing urban canters. Its population has increased from about 1.3 million in 2006 to a projected value of 2.7 million by 2025, driven by urban migration and influx of internally displaced persons from conflict-affected regions (Dung-Gwom, 2008; Yakubu, 2017). This rapid population growth has intensified pressure on waste management infrastructure, underscoring the need for a sustainable and integrated waste-to-energy (WtE) solution.

Despite these demographic changes, the city's waste management system remains largely inefficient. Open dumping is the dominant disposal method, resulting in uncontrolled waste accumulation across streets, drainages and open spaces (Eche et al., 2015). These poor practices contribute to air, water and land pollution, exacerbate flooding and pose serious public health risks including cholera, malaria and typhoid outbreaks. Furthermore, the city's growing energy deficit highlights a missed opportunity to convert waste into a resource. Addressing this dual challenge of poor waste management and energy shortage requires an integrated approach that promotes WtE conversion, recycling and resource recovery for improved environmental and energy outcomes (Omari et al., 2014).

WtE technologies offer a viable pathway for recovering energy from MSW, while reducing environmental burdens. By converting waste into useful energy forms or biofuels, WtE serves as both a waste treatment and renewable energy generation strategy (Tan et al., 2015). Implementing WtE in Jos is therefore essential to bridge the existing knowledge and technological gap in sustainable MSW management and mitigate the adverse effects associated with uncontrolled waste disposal.

Thus, to promote a sustainable economic, environmental and social development in Jos, this review aims to assess different waste-to-energy (WtE) technologies – their operation, benefits and constraints, evaluate the current MSW management practice in Jos and identify barriers to local implementation of WtE. This will establish the foundation for future investment in WtE infrastructure. Ultimately, this approach is expected to reduce indiscriminate dumping of waste, minimising the environmental and health impacts, strengthening waste management. The outcomes will provide valuable insights for policymakers, private investors and local communities in advancing an efficient and sustainable MSW management system in Jos.

2.0 Methodology

This study used a systematic review and comparative assessment approach to evaluate WtE technologies suitable for sustainable MSW management in Jos, Nigeria. Data were obtained from peer reviewed journals, institutional reports and international agency publications. The main databases searched were Scopus, ScienceDirect and Google Scholar. Only studies published between 2008 and 2025 were considered. The review focused on technical, environmental and economic performance of WtE technologies. Key information such as technology description, feedstock type, energy output, residue generation, environmental impact, cost, operational complexity and technology maturity were extracted. The analysis compared five main technologies: incineration, gasification, pyrolysis anaerobic digestion and landfill gas recovery. Each technology was assessed under suitability, environmental performance, economic viability and local feasibility.

The study also relied on secondary waste composition data for Jos, drawn primarily from reports published between 2008 – 2010. While these remains the most comprehensive datasets available, they may not fully reflect the current waste generation rates and composition due to population growth and changing urban consumption patterns.

3.0 WASTE-TO-ENERGY (WTE) TECHNOLOGY OPTIONS

Energy recovery from MSW for use as biofuel is only possible by waste-to-energy (WtE) technologies (Alao et al., 2022; Islam, 2016). These technologies convert waste into bioenergy, reducing landfill disposal and minimising environmental impacts. Thus, WtE offers a promising alternative for waste management while also serving as a potential renewable resource (Alao et al., 2022). This can offset 10% of the global yearly energy demand in the form of electricity (World Energy Council (WEC), 2013). Also, in some other estimation, by 2022, not less than 261 million tonnes of MSW annually will be processed through WtE technologies (WEC, 2013). This translates to 283-terawatt hours (TWh) worth of electricity and heat (WEC, 2013).

Fossil fuels (oil, coal, and natural gas) have been expansively used as an energy source and constitute approximately 80% of energy worldwide (Perera, 2018). Energy demand has increased globally with the market share of about 17 billion tonnes of oil (Chu & Majumdar, 2012). As a substitute to fossil fuels, contemporary WtE project presents a viable option (Nubi et al., 2022). WtE projects in large-scale have existed in countries like Germany and Sweden as well as Denmark and UK, mainly incineration of heterogeneous MSW as a method for sustainable MSW management (Munster & Meibom, 2011). Others are Malaysia (Tan et al., 2014), China, Indonesia, Korea and Japan (Ionescu et al., 2013) and the USA (Psomopoulos et al., 2009). Globally, 765 WtE plants are in existence, and out of the global annual MSW generation of 2.01 billion tonnes, only 83 million tonnes are been utilised in these plants (Roy et al., 2022). It has been estimated that by 2025, about 2.3 billion tonnes will be produced and is expected to reach an annual production of about 3.4 billion tonnes by 2050 with a corresponding energy generation of 2.6×10^{20} GJ (Islam, 2016). Hence, the proper utilisation of WtE projects has the great potential to mitigate the challenges of improper MSW management in addition to providing a sustainable economic, environmental and social development.

The two primary methods for energy recovery from WtE technologies (Ogunjuyigbe et al., 2017) are shown in Figure 1. They are thermochemical and biochemical processes. Their application depends on the waste fraction and moisture content. Each technology requires a suitable waste fraction with specified characteristics to serve as appropriate feedstock for its optimum performance (Maisarah et al., 2018). The details of the processes are discussed in the subsection.

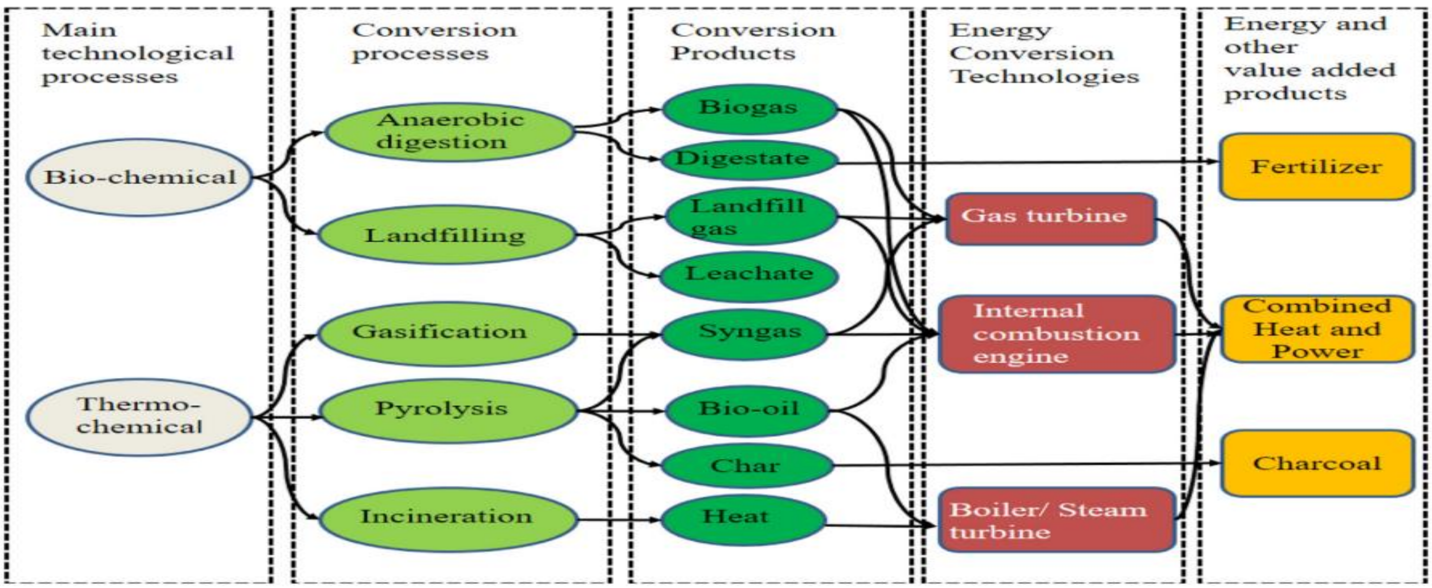

Figure 1: Waste-to-energy (WtE) conversion pathways/technologies (Ogunjuyigbe et al., 2017).

3.1 Biochemical Processes

Biochemical processes involve the breakdown of biodegradable organic fractions of waste by microorganisms. The process could be aerobic or anaerobic which produces different outcomes (compost or biogas). The process is favoured by waste with elevated portion of biodegradable substance and water content; this encourages microbial activity (Alao et al., 2022; Kumar & Samadder, 2017). Generally, MSW

contains a significant portion of biodegradable substance like food, paper and organic waste usually in excess of 60% (Angelonidi & Smith, 2015), with a great capacity to serve as a major biomass for power generation (Hamad et al., 2014). Biochemical processes are mostly applied in anaerobic digestion and landfilling (Alao et al., 2022). The summary of comparative assessment of biochemical WtE technologies are presented in Table 1.

3.2 Thermochemical Processes

Thermochemical processes encompass incineration, pyrolysis, gasification (Alao et al., 2022; Gupta et al2018; Dong et al., 2018; Gurgul et al., 2017). Other thermochemical processes are hydrothermal carbonization, plasma arc gasification and thermal de-polymerisation. Thermochemical process involves the breakdown of the waste feedstock (carbonaceous organic matter) at high temperature (Alao et al., 2022; Aleluia, & Ferrão, 2016). During this process, thermal energy, beside value-added products such as fuel oil, gas and charcoal are generated (Alao et al., 2022) and can be directed to different techniques for energy generation and resource recovery treatment (Gupta et al., 2017). The approach is suitable for waste that is less dense with low moisture content (Rajaeifar et al., 2017). The commonly applied thermochemical methods are incineration, gasification and pyrolysis. The summary of comparative assessment of thermochemical WtE technologies are presented in Table 1.

Table 1: Summary of comparative assessment of WtE technologies and suitability in Jos

Criteria	Incineration	Gasification	Pyrolysis	Anaerobic Digestion	Landfill Gas Recovery	References
Technology description	The directly burning MSW in surplus amount of oxygen in a specific facility for such purpose (a furnace)	The partial oxidation at high temperatures to produce syngas	The thermal breakdown of waste in the absence of oxygen to produce char, oil and syngas	The breakdown of organic matter in the absence of oxygen, to produces semi-solid fertilizer and biogas	Is the collection and usage of methane generated from waste buried in landfill	(DEFRA 2013; Sanlisoy & Carpinlioglu, 2017; Czajczy et al., 2017; Silpa & Perinaz, 2018)
Feedstock type	Mixed MSW with high calorific value	Pre-treated MSW, RDF	Pre-treated plastics, tire biomass etc	Organic and biodegradable waste	Biodegradable fraction of MSW	(Alao et al., 2022; Sarkar et al., 2014; Hasan et al., 2021; Silpa & Perinaz, 2018; UNEP, 2019)
Energy output	Heat and electricity	Syngas for energy	Syngas, bio-oil and char	Biogas for heat and electricity generation	Methane for energy utilisation	(LMOP, 2020; Alao et al., 2022; Silpa & Perinaz, 2018; LMOP, 2020)
Environmental impact	High emissions need air pollution control	Lower emissions than incineration	Low emissions and cleaner process due to absence of air	Least emission in relation to thermal processes	Methane leakage if poorly managed	(Ouda et al., 2016; Qazi et al., 2018; LMOP, 2020)
Capital and operational cost	High, when emissions control equipment is required to reduce emissions	High	High	Lower investment and operating costs in relation to thermal technologies	Minimum cost/economical option	(Margallo et al., 2014; Qazi et al., 2018; Ouda et al., 2016)
Technology maturity	The most developed and commonly applied technology	Are dependent on the desired application	It's an emerging method for Specific waste types like tire, wood, paper, plastic etc	is mainly suitable for agricultural and rural areas in both developed and developing countries	It is one of the commonly applied biochemical WtE methods	(Alao et al., 2022; Leckner, 2015; UNEP, 2019; Qazi et al., 2018; LMOP, 2020)
Operational complexity	Moderate: in relation to other thermochemical WtE technologies	High	High: it requires specialised expertise	Moderate	Low: no need for specialised labour	(Qazi et al., 2018; Ouda et al., 2016)
Residue generation	Bottom and fly ash	Slag, tar	Char residue	Digestate (semi-solid fertilizer)	Leachate	[DEFRA 2013; Qazi et al., 2018; Ouda et al., 2016)
Suitability for Jos	High waste reduction but costly and requires emission control	Viable, but requires skilled operation	Favourable for plastics, tire etc, but requires skilled operation	Suitable for organic waste; in agricultural and rural areas	Feasible option for existing dumpsites or a new one	-

4.0 MSW MANAGEMENT SITUATION IN JOS

Rapid population growth in Jos metropolis has intensified the challenges of MSW management, with widespread illegal dumping and collection systems. The lack of reliable and current data further limits effective planning and policy response. Available records indicate a steady rise in waste generation between 1980 to 2010 (Efe, 2013; Oluwande, 1984; NEST, 1991) (see Figure 2). Although, these estimates should be interpreted cautiously due to inconsistencies in collection methods, sampling limitations and non-representative datasets (Yakubu, 2017). Residential sources account for about 45% of the total waste generated (Eche et al., 2015), with an average generation rate of 0.55 – 0.58 kg/capita/day (PEPSA, 2013). Variations in generation rates are influenced by income, seasonal patterns and lifestyle practices (Yakubu, 2017). Using Nigeria's national average of 0.5 kg/capita/day (NEST, 1991), Peter (2016), projected that waste generation in Jos could reach approximately 1.4 million tonnes by 2025 – representing a significant increase from 2010 levels.

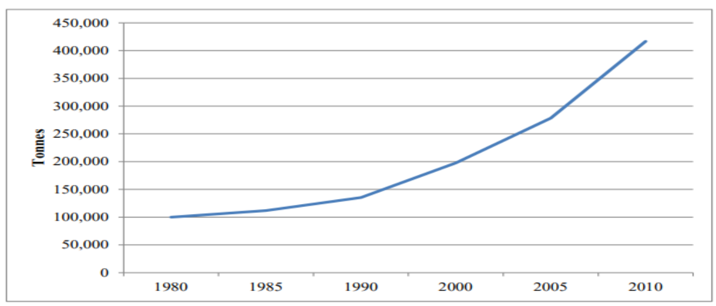

Figure 2: Estimated amount of waste produced between 1982 to 2010 in Jos (Efe, 2013; Oluwande, 1984; NEST, 1991).

Waste collection in Jos is free, and the sole responsibility of Plateau Environmental Protection and Sanitation Agency (PEPSA), but due to insufficient funds only about 50% of it is estimated to be collected (Yakubu, 2017), in most cases left in the neighbourhoods (Efe, 2013). However, from 2005 – 2007, collaborations between public and private organizations in solid waste management were implemented in Plateau State, although this approach has been applied throughout Nigeria (Osesienemo, 2008). The development led to challenges whereby private waste firms were registered by public officials just for the financial benefits but never carried out any waste removal exercise. This practice resulted in the termination of the agreements with external service providers by 2007, after which there has not been any public–private collaborations in MSW collections in Jos (Yakubu, 2017).

Waste disposal practice in Jos is indiscriminately done at open dumpsite and any available space due to lack of sanitary landfills. In Jos, two kinds of open dumping exist: the most prominent involves PEPSA disposing waste collected from public bins in open dumps (Peter, 2016). The other is where communities disposed waste indiscriminately at their backyards, street corners, open available spaces, drainages and water bodies (Daffi & Kassam, 2013; Eziashi, 1997; Gyang & Ashano, 2010). The impact of this poor waste disposal are air, water and land contamination besides flooding (Gyang & Ashano, 2010). Also, the risk of malaria is increased due to poor waste deposal, particularly polythene bags in the waste causes water stagnation that encourages the breeding of insects that cause diseases (Yakubu, 2017).

Material recovered from the waste is generally performed by unregulated sector who collect reusable material from residence, community waste containers or dumpsite and re-sell them. Also, the inhabitants in Jos are predominantly farmers and engage in large or small-scale farming. These farmers are seen to apply urban waste as manure and occasionally pay for waste to be deposited on their farmland; on the other hand, landowners pay to utilise it in reclaiming their land (Yakubu, 2017). The practice of applying urban waste on farmland in Jos is common (Pasquini, 2006; Pasquini & Harris, 2004). The problem is that the waste is burnt rather than composted and is utilised directly in ash form along with other fertilizers (Alexander, 1986; Yakubu, 2017). PEPSA workers are paid by farmers to deliver waste to their farmlands (Yakubu, 2017).

The issue of waste management in Jos has been challenging for PEPSA due to the inadequate collection trucks, public waste containers are insufficient in addition to failure to establish permanent waste disposal sites (Binbol et al., 2013; Peter et al., 2014). In another study, the challenge for PEPSA in providing sufficient containers for household was also identified by Peter (2016). This led to the application of old metal or plastic buckets for waste storage before final disposal (Yakubu, 2017). Other challenges include inadequate financial provision and staffing, conflicting roles with other organisations and enforcement of waste regulations (Yakubu, 2017). Even though the activities of PEPSA is focused on the removal of heaps of poorly disposed waste and regulating hazardous environmental practice (Mallo & Anigbogu, 2009), the performance of PEPSA is still grossly inadequate. The overall performance PEPSA has been placed at 20% by residents of low-income areas (Yakubu, 2017). Currently, PEPSA is faced with a huge challenge of rendering quality waste management services in Jos due to the projected growth in population and its resultant impact on the level of waste generation.

4.1 Potential for WtE Implementation in Jos

The increasing population in Jos has brought about significant challenges for MSW management. The current waste management approach such as open dumping and poorly controlled landfilling impacts on health and environmental (Eche et al., 2015) besides contributing to greenhouse gas emissions. However, the understanding of the organic and combustible characteristics of the waste stream in Jos could present a promising opportunity for WtE technologies. WtE implementation in Jos could not only address poor waste management challenges but could also provide a renewable source of energy, reduce dependence on fossil fuels and mitigate the impacts of climate change.

4.1.1 Waste generation, composition and characteristics in Jos

To implement WtE technology in Jos, information on the amount, composition and characteristic of the waste generated is essential for several purposes. It determines the economic feasibility WtE plant, potential for energy generation and facilitates designing WtE plant with the appropriate capacity. It also enables the valuation of environmental impact, guarantees continuous raw material supply to WtE plant and encourages WtE projects. To implement WtE technology effectively, the data on waste generation and composition most be reliable. However, reliable data on waste generation rates and characterisation are inadequate or lacking in Sub-Saharan Africa (SSA) Adedara et al., 2023).

In determining the amount of MSW generation in Jos, the population generating the waste is an important factor. The population in Jos has been projected to grow to 1,424,273 by 2025 (Peter, 2016). One of the factors connected to the increase in MSW generation is the growth in population (Omole & Alakinde, 2013). In 2007, the MSW generated in Jos was estimated from a population of 1,315,301 people to be 657,650.5kg (657.65 tonnes) (Peter, 2016), using 0.5 kg/person/day as wastes generation per capita in Nigeria (NEST, 1991). By 2025, the amount of MSW generated is expected to reach 1,369,787kg (1,369.79 tonnes) (Peter, 2016). The MSW generation in Jos will even be more if the average rate ranging from 0.55 - 0.58 kg/capita/day (PEPSA, 2013) is applied. However, in a recent study in low-income area, considering only household waste, the per capita waste generation was determined as 0.47 kg/capita/day (Yakubu et al., 2023).

The waste composition data in Jos is inadequate. The earliest waste composition evaluation was carried out in 2008 with samples collected from both densely and sparsely populated areas

(PEPSA, 2013). This was reported in a study by Peter (Peter et al., 2014). The reliability and effectiveness of the waste composition data was in question due to the lack of information on the process of the waste composition analysis (Yakubu, 2017). In addition, the percentage of the waste composition does not sum up to 100%, allowing a deficit of 5.95% as shown in Table 2. Also, in a recent study, Generation and composition of solid waste in low-income areas of Jos, Plateau State, Nigeria, only household waste in low-income areas were considered (Yakubu et al., 2023), as shown in Table 3. This is also limited in scope since it only covers household waste and does not account for high-income areas of Jos.

Table 2: Solid waste component in Jos (PEPSA, 2013).

Waste component	Percentage (%)
Fabric	3.69
Plastic	3.33
Polythene	3.44
Organic	36.86
Metals/tin	2.59
Paper	6.85
Leather	2.07
Debris	31.49
Dead dry cells	1.29
Bottles/glasses	2.44
Total	94.05

Table 3: Composition of waste sampled by mass and proportion in Jos (Yakubu et al., 2023).

Component	Total waste (kg)	Percentage (%)
Food	192.1	29.2
Ash/unburnt wood	121.2	18.4
Plastic films/bags	89.7	13.6
Fines	44.7	6.8
Misc. comb	32.0	4.9
Paper/card	30.8	4.7
Textile	29.2	4.4
WEEE	24.3	3.7
Glass	23.7	3.6
Metals	21.0	3.2
Others	20.6	3.1
Dense plastic	17.9	2.7
Garden waste	10.9	1.7
Total	658.2	100.0

The characteristics of the MSW is another important factor for the implementation of WtE technologies. It consists of the proximate and ultimate analyses. These characteristics of the MSW are vital in determining its energy content. The energy content is an important parameter in determining the implementation of WtE technologies. Hence, the data on heating value of the MSW must be reliable and true to facilitate the design of an efficient WtE facility (Shi et al., 2016). Unfortunately, although data on MSW composition in Jos are available, they are limited in both methodology and scope. Additionally, data on proximate and ultimate analyses are currently unavailable.

4.2 Benefits of WtE Technology Implementation in Jos

The implementation of WtE technologies in Jos presents a variety of benefits such as economic, environmental, social and energy-related. These benefits will not only deal with the current poor waste management challenges but also provide sustainable development and mitigate the impacts of climate change.

While the overall potential of WtE technologies in Jos is significant, a clearer understanding of the specific dimension of these benefits is necessary to appreciate their contribution to sustainable development. The impacts of WtE implementation can be categorised into four major areas, economic, environmental, social and energy related. Each contributing uniquely to addressing the city's current waste management deficiencies and advancing broader sustainability objectives. The following subsection discuss these benefits in detail, highlighting their implications for local context.

4.2.1 Economic benefits

WtE implementation can promote local development by generating employment opportunities in key areas such as facility construction, operations, maintenance, waste logistics and the overall economy (Emeka et al., 2023). Additionally, revenue can be generated for local government and private investors from the sale of electricity and potential by-products (e.g., bottom ash used in construction in the case of incineration) [39].

4.2.2 Environmental benefits

The implementation of WtE (incineration) reduces substantial the quantity of MSW that end up in landfills, thus, reducing the size of landfill and the related environmental hazards. Also, by methane capture, greenhouse gas emitted from the decomposition of MSW deposited in landfill could be mitigated. This contributes to mitigating climate change. Furthermore, important resources recovery could be obtained from MSW using WtE technologies. This helps resource management and the switch to a circular economy (Emeka et al., 2023).

4.2.3 Social and health benefits

From a social perspective, WtE implementation can promote a cleaner and healthier environment. Consequently, this can reduce the incidences of illnesses associated with waste by reducing the amount of MSW deposited in landfill or open dumpsite. In addition, WtE implementation can improved waste management and also enhances the overall aesthetics of the city, thereby attract potential investment and boost public morale. Furthermore, awareness campaign related with WtE projects can increase awareness of sustainable practices and foster community participation in waste segregation and recycling efforts.

4.2.4 Energy benefits

WtE implementation can offers a reliable and renewable source of electricity and thermal energy. For a city like Jos, the electricity supply from the national grid is often inadequate. This is because the per capita electricity supply in Nigeria is 150 kWh in 2022 (Sasu, 2023). This is extremely low when compared to about 5026 kWh in most industrialised countries (Energy Commission of Nigeria (ECN) (2022). WtE implementation presents an opportunity to enhance local energy security. The energy recovery from MSW can be used to power homes, public institutions and small industries, reducing dependence on fossil fuels.

5.0 DISCUSSION AND IMPLICATIONS OF WTE IN JOS

5.1 Waste Generation, Composition and WtE technologies

Using 0.5 kg/person/day, the amount of MSW generated is expected to reach 1,369,787kg (1,369.79 tonnes) by 2025. This is about 499,973.35 tonnes annually.

From the available data of waste composition studies carried out in Jos, food and organic waste are reported to be predominant in the waste mix. Food waste alone account for 29.2% of the entire waste, as seen in Table 3. From the same study, the total degradable waste component was 65.2%, as calculated from Table 3. This is followed by plastic waste 13.6% (Table 3). The analysis was conducted from waste collected from 74 household for a week in low-income areas of the city. Also, according to PEPSA's report (PEPSA, 2013), as reported by Peter (2016), the organic waste component is 36.86%, see Table 2. This does not include other biodegradable waste component of the waste mix as shown in Table 2. However, when the organic component was combined with other biodegradable waste components, the entire biodegradable component was about 50.74% as calculated from Table 1. The plastic and polythene component are 6.77% (Table 2). Information regarding the method for the waste composition analysis was not provided. In addition, the waste composition data analysed in the study did not sum to 100%, with a missing fraction of about 5.95%. Upon inspection, no specific category for sand was provided and it is also unclear whether sand was partially or wholly included under the broader classifications such as debris. These findings highlight the limitations in the waste composition analyses.

The study acknowledges that the waste composition data for Jos were largely obtained from secondary sources (2008-2010). This may not fully represent current waste generation patterns. Although the available studies show methodological limitations affecting data reliability, the results (Table 2 and 3) still reveal strong potential for WtE application. The high proportion of organic waste indicates that biochemical process could be an appropriate technology for energy recovery and practicable solution to waste management challenges in Jos [66]

From Table 1, the assessment of the different WtE technologies suitable for Jos, revealed the following:

i. Incineration - this has the advantage of High waste reduction but costly and emission control
ii. Gasification - Technically viable, but requires skilled operation and it is costly
iii. Pyrolysis - this favourable for plastics, tire etc, but requires skilled operation and it is costly
iv. Anaerobic digestion - this is suitable for organic waste; in agricultural and rural areas
v. Landfill gas recovery - this is feasible option for existing dumpsites or a new one

5.2 WtE Implementation and Sustainable Growth in Jos

In relation to sustainable growth, various benefits are offered by the choice of WtE implementation as earlier mentioned. However, implementation of WtE has some adverse effects such as increase in land value and emissions from plants. Even with these adverse effects, implementing WtE in Jos will be beneficial for more sustainable growth.

5.3 WtE Implementation Challenges in Jos

The implementation of WtE generation plant in developing countries comes with various challenges (Khan et al., 2022). The following challenges that could be face by implementing WtE in Jos are:

i. When the composition of waste is dominated by organic components, it poses a major challenge (Ikhlayel, 2018). The waste generated in Jos is high in organic components. The compositional characteristic may contain significant moisture content and reduced energy value. This may impact on the efficiency of WtE power generation. Although, few literatures are available and limited by methodology on the waste composition, data on proximate and ultimate analyses are currently unavailable. This makes it difficult to assess the possibility of WtE implementation in Jos.

ii. In most developing countries, waste segregation from source is a major challenge (Nixon et al., 2017). Due to poor waste management system in Jos waste segregation is not practiced. This may affect the implementation of WtE in Jos.

iii. Another challenge for WtE generation is the lack of effective waste collection system in most developing countries. The general practice for residence of most cities, is the conventional approach where waste is dumped and collected, without adequate strategy or policy (Khan et al., 2022). Inadequate collection of waste was also found to be a major challenge in Jos.

iv. The absence of appropriate WtE generation technology and trained workforce to start and manage a WtE generation plant (Yan et al., 2020). A major problem is that technology that may be helpful and successful for developed countries may not be appropriate for the developing world (UNDP, 2016). Comparatively, cleaner and effective technologies are more costly than dirty and inexpensive technologies (Khan et al., 2022), hence, making it hard to apply in developing countries and by extension Jos city.

v. Inadequate funding for implementation and management of WtE generation projects. The majority of cities in developing world have insufficient funds and human resources in dealing with waste management (Sayigh, 2015).

vi. Lack of local energy policy besides national energy policy, and guidelines and regulations regarding WtE generation (Khan et al., 2022). For example, there is lack of regulatory framework in Nigeria for tackle the possible damaging environmental effects that could arise from construction and running of WtE generation plants (Ayodele et al., 2017). The lack of determination by authorities and appropriate knowledge could hinder the acceptance of positive changes regarding efficient waste management and associated policy development (Kubanza & Simatele, 2020).

5.4 SWOT Analysis

The assessment of WtE implementation in Jos reveals notable strength such as large volume of available MSW daily generated (1,369.79 tonnes), high amount of organic waste (50.74 – 65.2%) and plastic/polythene (6.77 – 13.6%). These are suitable for WtE implementation. However, weakness persist, including inadequate reliable data, lack of waste segregation practices, and limited institutional capacity. Externally, several opportunities exist, notably growing interest in renewable energy, access to international climate funding and private sector investment in sustainable waste solution. Conversely, threats such as funding, public misconception of WtE technologies could hinder progress. While the enabling environment is promising, addressing institutional and technical weakness will be vital for successful WtE implementation in Jos.

6.0 CONCLUSION

This review examined the MSW management in Jos and assessed the potential for adopting WtE technologies. The finding revealed that information on WtE implementation in Jos is scarce, while data on waste generation, composition and characteristics remain inadequate or outdated. Open dumping is still the primary waste disposal method. Thus, the high proportion of biodegradable waste component (50.74 – 65.2%) and plastic/polythene (6.77 – 13.6%) demonstrate significant potential for energy recovery through appropriate WtE technologies. However, achieving this objective requires a structured and data-driven approach. Therefore, it is strongly recommended that:

1. That a comprehensive and up-to-date waste characterization studies be conducted across all income levels and activity groups in Jos to provide reliable baseline data for WtE planning.
2. Integrated waste management policies be developed to gradually transition from open dumping to sustainable practices that combine recycling, composting and WtE systems
3. Feasibility and pilot-scale WtE projects be initiated to evaluate the technical, environmental and economic performance of suitable technologies under local conditions.
4. Capacity building and institutional collaboration among government agencies, research institution and private investors be strengthen to support WtE implementation.
5. Environmental and emission control frameworks be established to ensure that WtE plants operate within acceptable standards, minimising potential air pollution and land value challenges.

Implementing these recommendations would not only address the prevailing waste management challenges in Jos but also contribute to Nigeria's broader sustainability goals by integrating waste valorisation into urban energy and environmental planning.

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