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# Municipal Solid Waste Characteristics and Management Practices for Waste to Energy Technology Selection in Ashanti Mampong Ghana

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## ABSTRACT

This study assessed the waste-to-energy (WtE) potential of municipal solid waste in Ashanti-Mampong Municipality, Ghana, by examining waste composition, existing management practices, and locally suitable conversion technologies. A descriptive survey design with mixed methods was employed, using questionnaires and interviews with 60 respondents selected from a study population of 71 personnel involved in municipal waste management. Data were analysed using descriptive statistics and thematic analysis. Biodegradable waste was the predominant category (mean = 4.816667, SD = 0.390205), accounting for 57% of collected waste according to the Municipal Assembly's 2020 report. Waste management constraints included insufficient compaction trucks (70.0%), inadequate separate containers for waste types (66.7%), and no segregation before disposal (100.0%). Anaerobic digestion emerged as a potential option, supported by respondents' perceptions of lower capital requirements (85.0%), affordable technical expertise (91.7%), and profitability (80.0%). Further feasibility assessment, waste segregation, and improved collection systems are needed before implementation.

**Keywords:** Anaerobic digestion; municipal solid waste; sustainable waste management; waste-to-energy; Ghana

## INTRODUCTION

The increasing generation of municipal solid waste (MSW) has become a major environmental and public health concern globally, particularly in developing countries (World Bank, 2022). Population growth, urbanisation, and technological developments have

contributed to increasing waste generation and disposal, attracting international attention because of their implications for environmental quality and public health (Dolar et al., 2016; Talalaj and Biedka, 2015; Arthur, 2007). Global MSW generation is projected to reach 480 million metric tons annually by 2030 (World Bank, 2021). Municipal solid waste originates from residential, commercial, industrial, and medical activities and comprises materials such as paper, metals, glass, cartons, plastics, and other waste products (Aymen, 2020; Shailesh et al., 2022). Its composition and quantity have important implications for waste management, environmental protection, and the potential recovery of useful resources.

Inadequate waste management remains a significant global challenge. Approximately 33% of generated solid waste is not managed using widely accepted practices but is instead dumped in open areas, creating environmental and public health problems (Jeevahan et al., 2023). Landfills also account for almost 30% of global methane emissions, although landfill gas can be recovered and utilised for electricity generation (Arthur et al., 2025; Cudjoe et al., 2020). The physical composition of MSW includes food and yard waste, cardboard, paper products, plastics, glass, metals, and miscellaneous materials (Gupta et al., 2015). These different waste fractions offer varying opportunities for recovery, recycling, and energy conversion. Consequently, appropriate waste characterisation is important for identifying suitable management and waste-to-energy (WtE) options.

In Ghana, municipal solid waste management is particularly important because of the country's growing population and urbanisation. With a population of approximately 30.8 million in 2021 and an urban population share of 56.7%, Ghana generates an estimated 19,589 metric tons of MSW daily, equivalent to more than 7.1 million metric tons annually. Organic materials account for approximately 48.6–61% of the waste stream, while plastics constitute about 14–20%; paper, textiles, metals, and inert materials make up the remainder. Only approximately 33% of the waste is collected through formal door-to-door systems, while about 30% remains uncollected and is often dumped in open areas (Boadi, 2024). The substantial proportion of organic waste and plastics indicates potential opportunities for resource recovery and energy generation, although the suitability of particular technologies depends on the composition and characteristics of the waste stream.

Effective MSW management can contribute to environmental sustainability by reducing inappropriate disposal and associated greenhouse gas emissions while supporting resource recovery and economic development (Bakkaloglu et al., 2022; Yaman, 2020). This potential is particularly relevant to Ghana, where waste management challenges coincide with the need to diversify energy sources. The Ministry of Energy's *Energy Sector Recovery Program* (2019) identifies financial unsustainability in the energy sector, partly associated with dependence on externally sourced fossil fuels for power generation (Arthur, Kporha & Arthur, 2025). Ghana's Intended Nationally Determined Contribution (INDC) also identifies a renewable energy penetration target of 10% by 2030, although achieving this target has been challenged by insufficient incentives (Arthur et al., 2025; Afful-Dadzie et al., 2020; Arthur & Asiedu-Okanta, 2021). Solar, wind, and biomass, including waste-derived resources, have therefore been identified as potential alternatives for supporting renewable energy development in the country (Arthur, Owusu & Arthur, 2023; Afonaa-Mensah et al., 2024; Odoi-Yorke et al., 2023).

Waste-to-energy technologies offer a possible means of addressing waste disposal challenges while recovering energy from materials that would otherwise be discarded. Technologies such as landfill gas-to-electricity (LFGTE), anaerobic digestion (AD), and incineration have been projected to contribute approximately 59% towards Ghana's renewable energy objective by 2030 (Darmey et al., 2023). Nevertheless, the adoption of sustainable waste management solutions remains limited. For instance, approximately 931 tons of waste are reportedly deposited in landfills daily from Accra and its surrounding towns alone (Abledu et al., 2019). These circumstances highlight the need to investigate locally appropriate approaches that can improve waste management and support energy recovery without assuming that a single technology will be suitable for every municipality.

Several technologies are available for converting waste into useful energy, including incineration, biomethanation or anaerobic digestion, and gasification (Kirkeby et al., 2006). Incineration involves the controlled combustion of solid waste and can reduce waste mass by approximately 70% and volume by 90%, while producing steam for electricity generation and combined heat and power applications. Anaerobic digestion uses microorganisms to decompose biodegradable materials under suitable conditions, producing biogas that can be used for heat and power generation. Gasification involves the partial combustion of suitable waste materials to produce a combustible gas for energy applications. Certain materials, including some agricultural residues, wood, and plastics, can be gasified without pretreatment, depending on their characteristics and the technology employed. The selection of an appropriate WtE option consequently requires an understanding of waste composition, disposal practices, and the technical suitability of available conversion processes.

Research conducted in Ghana indicates considerable potential for generating energy from the country's waste resources (Agyenim et al., 2020; Armoo et al., 2025; Boadi, 2024; Gyamfi et al., 2015; Kemausuor et al., 2014; Ulrike et al., 2014). However, the development of WtE infrastructure remains limited relative to the volume of waste generated. Safisana, a biogas facility that processes industrial and market waste, is identified as an existing example of waste-based energy production in Ghana, with reported electricity generation of 100 MWh. Although this demonstrates the practical application of waste-based energy recovery, the available capacity remains insufficient in relation to national waste generation (Armoo et al., 2025; Boadi, 2024; Energy Outlook, 2024). Further assessment of waste characteristics and locally appropriate conversion technologies is therefore necessary to inform the possible expansion of WtE initiatives.

WtE technologies can contribute to sustainable waste management by converting MSW into electricity, heat, or fuel, potentially reducing dependence on landfills while supporting renewable energy production (Kumar & Samadder, 2020). However, the feasibility of these technologies depends on local waste characteristics, existing management systems, infrastructure, and the capacity to implement and maintain the selected technology. In this regard, municipal-level assessments are important for establishing the nature and extent of available waste resources and determining which energy recovery options are appropriate to particular local contexts. Assessing the WtE potential of MSW in the Ashanti-Mampong Municipality is therefore relevant to understanding how waste management and energy recovery could be addressed together (Agyemang & Kusi, 2023).

The Ashanti-Mampong Municipality faces challenges associated with ineffective waste management, including environmental pollution, greenhouse gas emissions, and public health risks (Arthur, Amofah, Arthur & Boateng, 2025; EPA Ghana, 2022). Predominant reliance on open dumping and uncontrolled landfilling creates concerns about soil and water contamination (Fobil et al., 2020). At the same time, Ghana's energy sector continues to face challenges related to power supply and dependence on fossil fuels, strengthening the case for examining alternative energy resources (Energy Commission Ghana, 2023). Although WtE could provide an opportunity to address aspects of both challenges, its contribution would depend on the availability and characteristics of suitable waste materials and the appropriateness of the technologies selected.

Ghana has established a target of increasing renewable energy to 10% of the total energy generation mix by 2030. However, the Energy Commission reported that the country had yet to achieve 1% of this target as of 2024 (Energy Commission, 2024). This gap highlights the continuing challenge of translating renewable energy policy objectives into implementation. Despite the potential of WtE technologies to contribute to waste management and energy generation, research on their local applicability in the Ashanti-Mampong Municipality remains limited. Existing WtE studies in Ghana have focused primarily on major urban centres, including Accra and Kumasi (Agyemang et al., 2021), leaving a need for evidence from smaller municipalities. Without adequate information on local waste composition, disposal practices, and appropriate conversion technologies, it is difficult to determine the potential contribution of WtE to sustainable municipal waste management and energy recovery.

Against this background, this study evaluates the waste-to-energy potential of municipal solid waste in the Ashanti-Mampong Municipality. Specifically, it examines the composition of MSW generated in the municipality, investigates the waste disposal and management methods employed, and identifies WtE technologies that may be suitable for the local context. The study addresses three research questions: (1) What is the composition of municipal solid waste generated in the municipality? (2) What waste disposal and management methods are employed in the municipality? (3) Which waste-to-energy technologies are suitable for the local context? By addressing these questions, the study seeks to establish a basis for assessing the potential for energy recovery from locally generated MSW and identifying opportunities to improve waste management practices.

The study is significant because it addresses an information gap concerning waste composition and energy recovery in smaller Ghanaian municipalities. Its focus aligns with the United Nations Sustainable Development Goals, particularly Goal 7, which promotes affordable and clean energy, and Goal 11, which supports sustainable cities and communities. The findings may inform policy development, investment decisions, and infrastructure planning in the waste and energy sectors in Ashanti-Mampong and other municipalities with comparable circumstances. They may also support awareness of the potential uses of different waste fractions and provide information relevant to the Ministry of Environment, the Ministry of Energy, the Environmental Protection Authority (EPA), and other stakeholders involved in sustainable waste management. Potential benefits include improved waste handling, reduced pollution from inappropriate disposal, renewable energy recovery, and employment opportunities, although the extent of these benefits would depend on the practical implementation of suitable solutions.

The study focuses on household and commercial waste classified as municipal solid waste within the Ashanti-Mampong Municipality. It examines waste quantity and composition, considers energy recovery potential, and identifies WtE technologies that may be integrated into existing municipal waste management strategies. Industrial, agricultural, medical, and other hazardous waste categories are excluded because they require different management approaches and regulatory considerations. The study also does not undertake a comprehensive economic or financial feasibility analysis of the identified technologies. Its findings are intended to provide a contextual basis for understanding local waste management conditions and the potential applicability of WtE, rather than to establish the commercial viability of a particular technology.

Methodologically, the study adopts a descriptive survey design to examine the phenomenon in its natural setting, consistent with the application of descriptive designs to characterise populations and phenomena (Orodho et al., 2017). A mixed-methods approach combines quantitative and qualitative techniques, using structured questionnaires and interview guides to obtain numerical information and contextual insights. The research is guided by predetermined objectives to ensure that the data collected addresses the research problem (Kothari, 2019). Interpretation of the findings must nevertheless recognise potential limitations associated with the availability and accuracy of waste-generation records, seasonal variations in waste composition, local technical capacity, infrastructure requirements, capital investment, and public acceptance of WtE projects. These considerations reinforce the importance of context-specific planning, stakeholder engagement, and capacity development when considering the application of waste-to-energy solutions in the municipality.

## LITERATURE REVIEW

### Municipal Solid Waste Composition and Generation

Municipal solid waste (MSW) comprises diverse discarded materials generated by urban and rural populations. Its composition varies across geographical locations according to waste management policies, industrial activities, economic conditions, and lifestyle practices (Prajapati et al., 2021). In Ghana, MSW originates primarily from households, which account for approximately 55–80% of waste generation, and markets, which contribute about 20–40%, alongside commercial establishments, institutions, and street sweepings (Addae et al., 2021; Douti et al., 2017; Tihin et al., 2023). Common waste components include paper,

textiles, metals, organic matter, plastics, inert materials, leather, rubber, and glass (Safo-Adu & Owusu-Adzorah, 2023; Seshie et al., 2020).

Organic materials constitute a substantial proportion of Ghana's MSW, reflecting domestic waste generation, agricultural activities, post-harvest losses, and inadequate storage facilities in markets (Addae et al., 2021; Miezah et al., 2015). Organic waste is also a major component of waste generated by markets, hotels, restaurants, and local eateries, commonly known as *chop bars* (Singh et al., 2011; Tihin et al., 2023). Projections based on Akrami (2021) indicate that Ghana's organic waste generation could reach approximately 12,439 tonnes per day by 2030. These characteristics suggest the potential for biological waste treatment and energy recovery, particularly where biodegradable waste can be separated and managed appropriately.

Plastic waste presents another important challenge because of its non-biodegradability and potential to pollute aquatic and terrestrial ecosystems (Tyagi et al., 2018). In Ghana, plastics constitute the second most generated waste category, partly because polyethene bags are widely used in retail and commercial activities (Madara et al., 2016; Seshie et al., 2020). Darney et al. (2023) estimate that plastic waste generation increased from 1,622.55 tonnes per day in 2010 to 2,253.72 tonnes per day in 2022 and could reach 2,854.94 tonnes per day by 2030. The increasing quantities of organic and plastic waste reinforce the need for management strategies that consider both environmental protection and the potential recovery of useful resources.

Inadequate MSW management contributes to urban environmental problems, including blocked drainage systems, flooding during rainy seasons, stagnant water accumulation, and mosquito breeding (Prajapati et al., 2021). Effective waste management is therefore necessary to reduce associated public health and safety risks (Mishra et al., 2020). The management process generally comprises waste generation; collection, handling, and transfer; and disposal, processing, and treatment (Abdel-Shafy & Mansour, 2018; Nanda & Berruti, 2021). Understanding waste composition and these management stages is essential for assessing the suitability of different waste-to-energy (WtE) technologies.

**Waste-to-Energy Technologies and Their Applications**

Waste-to-energy refers to processes through which waste is converted into useful energy in the form of fuel, heat, or electricity (UNEP, 2021). Beyond removing unwanted materials, waste management can facilitate the recovery of valuable products from waste (Arancon et al., 2013; Rick et al., 2013). WtE technologies are consequently considered potential components of sustainable waste management because they can reduce reliance on landfills, support renewable energy production, and contribute to greenhouse gas emission reduction (Kumar & Samadder, 2020; Arthur & Locher, 2024). The principal technologies include thermochemical processes, such as incineration, gasification, and pyrolysis, and biological processes, including anaerobic digestion and fermentation. Mechanical-biological treatment also forms part of the broader range of available approaches (Arena, 2022).

Incineration involves controlled combustion of waste at 870–1,200°C to reduce waste volume and recover heat for steam and electricity generation (Ofori-Boateng et al., 2013). Advances in emission-control technologies have strengthened its application in waste treatment

(Brunner & Rechberger, 2015; Kumar & Samadder, 2017). Islam (2016) estimates an output of 0.5 MWh per tonne of MSW and a service life of 30 years. However, high moisture content and low calorific value can limit performance. Substantial capital, operational, and maintenance costs, skilled personnel, and effective emission controls are also required (Kalyani & Pandey, 2014).

Gasification thermally converts waste into combustible synthesis gas using a controlled supply of air, oxygen, or steam, typically at 600–1,200°C (Chen et al., 2021; Molino et al., 2020). Syngas contains mainly hydrogen, carbon monoxide, methane, and carbon dioxide, with other compounds depending on feedstock (Alnouss et al., 2020; Inayat et al., 2020). It can support electricity and fuel production. Islam (2016) estimates an output of 0.9 MWh per tonne of sorted MSW and a service life exceeding 20 years. However, sorting requirements may constrain its application where municipal waste segregation is limited.

Pyrolysis decomposes waste thermally at 300–600°C under limited oxygen, producing bio-oil, char, and combustible gases depending on feedstock and operating conditions (Mamvura et al., 2020). These products have potential energy and material applications, including bio-oil and biochar production (Pradhan et al., 2020). Islam (2016) estimates an output of 0.3 MWh per tonne of sorted MSW and a service life of 20 years. However, evidence for commercial-scale MSW energy recovery remains limited, while feedstock sorting presents an additional consideration for municipal implementation (Kumar & Samadder, 2017).

Anaerobic digestion (AD) uses microorganisms to decompose biodegradable waste without oxygen, producing biogas containing typically 60–70% methane and digestate that may be used as organic fertiliser (Li et al., 2023). It is suited to moist organic waste and can operate under dry or wet conditions (Saxena et al., 2009). Biogas supports cooking, lighting, and energy generation, while digestate can improve soil nutrient availability (Ofori-Boateng et al., 2013; Duan et al., 2021). However, mixed and unsorted municipal waste in Ghana may limit AD's use across the entire waste stream, highlighting the importance of separating biodegradable materials before treatment (Ofori-Boateng et al., 2013).

**Landfill Gas Recovery and Composting**

Landfill gas recovery captures methane produced during the anaerobic decomposition of organic waste, allowing it to be used for energy rather than released into the atmosphere (Ofori-Boateng et al., 2013; Malav et al., 2020). Duan et al. (2021) estimate that approximately 70% of global municipal solid waste (MSW) is disposed of in landfills or dumps. In Ghana, recovery potential depends on suitable sites and effective gas collection systems, particularly given the prevalence of poorly managed disposal facilities (Odom et al., 2021). Composting provides an alternative by converting biodegradable waste into a soil-improving material, supporting carbon storage, erosion control, and land reclamation (Bohacz et al., 2018; Moya et al., 2017). Although composting does not directly generate energy, it can complement waste-to-energy strategies.

**Moisture Content, Calorific Value, and Technology Selection**

Moisture content and calorific value influence the suitability and efficiency of waste-to-energy technologies. High moisture content reduces the energy available for combustion and gasification because heat is required to evaporate water (Chen et al., 2021). In Sub-Saharan African cities, the high proportion of organic waste can raise MSW moisture content above 50%, potentially reducing calorific value below the approximately 15 MJ/kg generally desirable for direct combustion (Aboyade et al., 2020; Owusu et al., 2023). MSW calorific values range from approximately 6 to 16 MJ/kg, while plastics and rubber may exceed 30 MJ/kg (Singh et al., 2020; Zakari et al., 2024). These variations highlight the need for waste characterisation, moisture measurement, and calorific-value assessment when selecting suitable technologies for Ashanti-Mampong Municipality.

**Challenges of Waste-to-Energy Implementation**

Waste characteristics influence the selection and operational efficiency of waste-to-energy (WtE) technologies. Composition and quantity vary across locations and seasons, while natural disasters may further alter waste streams (Dentel, 2013). High moisture content, low calorific value, and substantial quantities of inert materials, including construction and demolition waste, can reduce the suitability of municipal solid waste for thermal conversion. Consequently, inconsistent waste supply and poor feedstock quality may undermine facility performance and affect the sustainability of WtE projects.

Financial constraints can limit WtE implementation, particularly in developing countries. Thermal facilities require substantial investment in feasibility studies, permits, land, equipment, construction, maintenance, emissions monitoring, and residue disposal (Dentel, 2013). Limited funding may also compromise pollution-control infrastructure. Legal and institutional conditions are equally important because regulatory requirements vary across jurisdictions. Clear regulations, effective institutional coordination, and adequate enforcement are necessary to support project development and ensure compliance with waste management, energy production, and environmental protection requirements.

Environmental risks and public acceptance influence the feasibility of WtE projects. Incineration can generate air pollutants, particularly where maintenance, operational practices, and emission-control systems are inadequate (Dentel, 2013). Effective pollution-control infrastructure and emissions monitoring are therefore essential when considering thermal technologies. Public opposition may also arise from concerns about facility locations, potential health and environmental effects, and the perceived conflict between energy recovery and waste reduction, reuse, and recycling. Transparent communication and public engagement can help address these concerns during project planning.

**Theoretical Concept of WtE**

The waste hierarchy ranks management options according to their environmental implications, prioritising prevention, minimisation, reuse, recycling, energy recovery, and disposal (European Commission, 2020). Prevention reduces waste generation through eco-design and resource efficiency, while reuse extends product life and recycling recovers materials (UNEP, 2021). This framework positions waste-to-energy (WtE) as an option for suitable residual waste after higher-priority approaches.

Energy recovery includes landfill gas recovery, combustion, pyrolysis, gasification, and plasma arc gasification (Vergara & Tchobanoglous, 2022). Improved emission controls have reduced some risks associated with incineration. Disposal remains the final option, with engineered landfills designed to limit environmental and public health hazards (McDougall et al., 2021; Vergara & Tchobanoglous, 2022). For Ashanti-Mampong, the hierarchy supports integrating WtE with prevention, reuse, and recycling.

**Empirical Concept of WtE**

Internationally, WtE technologies support waste treatment and energy recovery while addressing environmental protection, resource conservation, affordability, and public acceptance (Brunner & Rechberger, 2015). Visiongain (2022) estimated that 2,498 plants processed over 487 million tonnes of waste annually worldwide. Europe had more than 589 plants in 2019 (UNEP, 2019), while Japan operated over 1,000 small- to medium-sized incineration plants, many associated with district heating systems (Inside Waste, 2023).
In Ghana and Sub-Saharan Africa, WtE implementation remains constrained by financial, technical, and policy challenges (Mensah et al., 2021). The Accra Compost and Recycling Plant has undertaken pilot-scale biogas production, while feasibility studies have explored WtE options in Accra and Kumasi (Ampofo et al., 2022). These initiatives demonstrate growing interest but do not establish suitability across municipalities. Local assessments are needed to identify appropriate technologies for Ashanti-Mampong's waste characteristics and management conditions.

**Conceptual Framework for Assessing Waste-to-Energy Potential**

The conceptual framework links municipal solid waste (MSW) characteristics, technology selection, energy recovery, sustainability outcomes, and institutional conditions. Grounded in sustainable waste management, it connects resource recovery and energy production with environmental protection (Hoornweg & Bhada-Tata, 2022; Zhang et al., 2020). Waste quantity, composition, moisture content, and calorific value influence technology suitability. Organic-rich waste may favour anaerobic digestion, whereas higher-calorific-value materials may support thermal processes (Chen et al., 2021; Kaza et al., 2022).

Technology selection depends on feedstock characteristics, costs, regulatory requirements, and environmental considerations (Khan et al., 2023; Nizami et al., 2021). Biological and thermal processes may generate biogas, heat, electricity, or fuels, alongside by-products requiring appropriate management (Zhao et al., 2024). Potential sustainability outcomes include reduced landfill dependence, pollution control, renewable energy production, employment, and improved waste management (IEA, 2023; World Bank, 2021). These outcomes depend on effective implementation, investment, infrastructure, regulation, stakeholder engagement, and institutional preparedness (Akintayo & Mensah, 2018; UNEP, 2022). For Ashanti-Mampong, the framework guides assessment of waste composition, current management practices, and potentially suitable WtE technologies.

## MATERIALS AND METHODS

**Study Area**

The study was conducted in Mampong Municipality, Ashanti Region, Ghana, with Mampong Ashanti serving as its administrative headquarters. The municipality is one of Ghana's 260 Metropolitan, Municipal and District Assemblies (MMDAs) and one of 43 MMDAs in the Ashanti Region (City Population, 2022). It was established following the division of the former Sekyere West District into Mampong Municipality and Sekyere Central District under Legislative Instrument (LI) 1908. The municipality is reported to cover approximately 23.9 km² and lies between latitudes 6°55′N and 7°30′N and longitudes 0°05′W and 1°30′W (Figure 1). It shares boundaries with Ejura Sekyeredumase to the north, Sekyere Central to the east, and Sekyere South to the south.

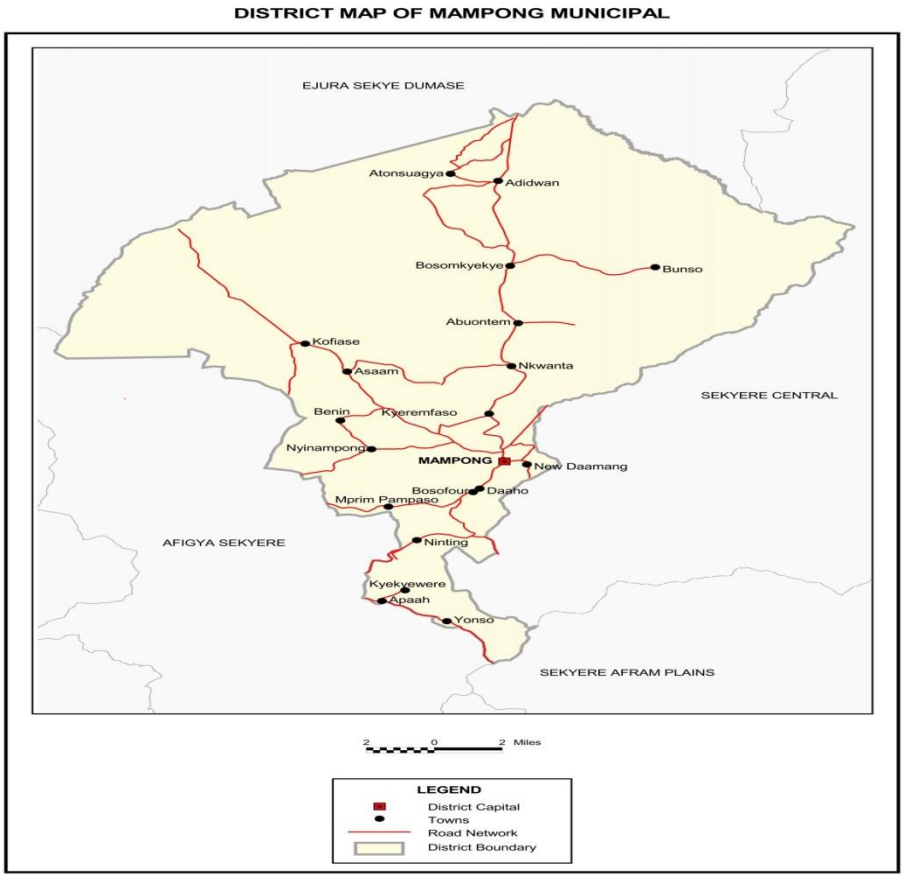



Figure 1: Map of Mampong Municipality
Source: Ghana Statistical Service, 2022

The principal settlements include Apaah, Kofiase, Adidwan, Asaam, Benim, Dadease, Krobo, and Mampong. Approximately 61% of the municipality's 79 villages are rural, with many residents conducting commercial activities at Mampong municipal market. Most rural settlements are located in the northern part of the municipality, where some villages have average populations of fewer than 300 people (GSS, 2022). According to the 2021 Population and Housing Census, the municipality had a population of 116,632, compared with 88,051 in 2010 (City Population, 2022; GSS, 2014).

Agriculture is the municipality's principal economic activity, employing approximately 67.3% of the labour force. Major crops produced for local markets include tubers, plantains,

carrots, beans, and maize. The service sector accounts for approximately 17.2% of economic activity, followed by manufacturing at 8.9%, commerce at 8.5%, and other income-generating activities at 3.2% (GSS, 2022). These economic activities provide context for understanding the sources and characteristics of municipal waste.

Waste disposal practices present an important consideration for the study. The Ghana Statistical Service (2022) reported that 50.7% of solid waste was disposed of at public dumps in open spaces, while 26.7% was deposited at public dumps in containers and only 2.8% was collected. Approximately 9.6% of households disposed of solid waste indiscriminately. Liquid waste disposal practices included discharge onto compounds (37.8%), into streets or open spaces (31%), and into gutters (16.6%) (GSS, 2022). These conditions provide a basis for examining existing waste management practices and the potential applicability of waste-to-energy technologies in the municipality.

**Design**

The study adopted a descriptive survey design to examine municipal solid waste generation, disposal and management practices, and the potential application of waste-to-energy technologies in Mampong Municipality. The research design provides the framework for collecting data in accordance with the study objectives and addressing the research problem (Kothari et al., 2019; Creswell & Creswell, 2018). Although research designs may be descriptive, exploratory, or explanatory, the descriptive survey approach was selected because it facilitates the systematic examination of a phenomenon in its existing context (Zikmund, 2017; Orodho et al., 2017). Its predefined objectives also help ensure that data collection remains relevant to the research questions (Kothari, 2019; Kombo & Tromp, 2006).

A mixed-methods approach was employed, combining quantitative and qualitative data collection through questionnaires and interviews. This approach enabled the collection of structured responses alongside contextual information from personnel directly involved in municipal waste management. The use of questionnaires and interviews is consistent with the application of descriptive surveys to investigations requiring information from respondents through both instruments (Kombo & Delno, 2006).

**Population, sample and Instruments**

The study population comprised personnel from municipal departments and waste management organisations directly involved in waste management activities. Although the Municipal Assembly had 119 staff members across its departments, the population relevant to the study consisted of 71 personnel drawn from five institutional groups: the Planning and Project Department of the Municipal Assembly (14), the Environmental Health and Sanitation Unit (25), the Environmental Department (14), Zoomlion Company (10), and the landfill site (8).

The relevant departments and waste management agencies were purposively selected because of their direct involvement in municipal waste management. The sample size was determined using the Yamane formula, as cited by Kothari et al. (2019), with a stated confidence level of 95% and an allowable error of 10%.

The standard Yamane formula is expressed as:

A representative sample size was calculated using Yamane formula (Kothari *et al*., 2019) with 95% confidence level and a 10% error level.

$$\mathrm{n} = \frac{N}{1 + N(e)^2}$$

Where n= sample size; N= Target population; e= allowable error (%). A 95% confidence level is statistically acceptable and thus z=2. Substituting these figures into the formula at 95% confidence level and 10% error level results in

$$\mathrm{n} = \frac{71}{1 + 71(0.05)^2}$$

n= 60.297espondents

The original manuscript reports a calculated sample size of 60.297 and a final sample of 60 respondents. However, this reported result does not correspond to the standard Yamane formula using the stated population and error level. The discrepancy should be resolved by checking the original formula image and calculation before submission. For the purposes of reporting the original study procedures, the manuscript records that 60 respondents were selected using simple random sampling. In addition, the Director of the Planning and Project Department was purposively selected as a key informant to provide further information and facilitate triangulation of data obtained from the participating offices.

Both primary and secondary data were used. Primary data were obtained through structured questionnaires and face-to-face, semi-structured interviews. Secondary data were obtained from relevant documentary sources, including books, journal articles, reports, and records from Zoomlion Ghana and the municipality's environmental directorates. Secondary data comprise information previously collected or documented for purposes that may differ from those of the present investigation (Zikmund, 2017).

A questionnaire comprising predominantly closed-ended questions, supplemented by open-ended questions where additional perspectives were required, was used to collect quantitative and supporting qualitative information. Questionnaires facilitate systematic data collection from a selected group of respondents (Yin, 2018; Wright, 2016). The instrument contained approximately 30 questions and was administered to personnel in the Environmental Health and Sanitation Unit, Planning and Project Department, Environmental Department, Zoomlion Company, and the landfill site.

Permission was sought from the relevant municipal authorities, and participants' consent was obtained before data collection. The questionnaire focused on the types of municipal solid waste generated, existing disposal and management practices, and the potential suitability of different waste-to-energy technologies.

Semi-structured interviews were conducted with key informants directly involved in municipal planning and waste management. Purposive sampling was used to identify informants with relevant knowledge and experience, consistent with the approach described

by Yin (2018). The interviews were intended to provide additional information on municipal waste management arrangements and the potential for energy recovery from MSW.

The interview guide contained open-ended and closed-ended questions aligned with the study objectives. Interviews with the relevant municipal personnel, including the Director of the Planning and Project Department, lasted approximately 30–45 minutes. Responses were documented using written notes and an audio recorder to support accurate record-keeping and subsequent analysis.

**Data Collection and Analysis**

Data collection involved a preliminary visit to the Municipal Assembly to establish contact with relevant personnel and familiarise key informants with the study. Questionnaires were distributed to the selected institutional groups, while semi-structured interviews were conducted with purposively selected key informants. The use of both instruments enabled the study to obtain structured information from the wider sample and more detailed accounts from personnel with direct knowledge of waste management activities.

Quantitative data were analysed descriptively using Statistical Product and Service Solutions (SPSS), version 20. Completed questionnaires were checked for accuracy and completeness, coded, and entered into the software. Frequency distributions were then used to summarise the responses. Findings were presented in frequency tables and charts to describe the types of MSW generated, the disposal and management methods employed, and respondents' views on appropriate WtE technologies.

Qualitative data obtained from the interviews were transcribed, condensed without removing essential information, and organised thematically. The analysis focused on three principal themes: municipal solid waste composition, waste disposal and management practices, and suitable waste-to-energy technologies. The qualitative findings were interpreted alongside the quantitative results and relevant literature to provide a contextual understanding of waste management and energy recovery potential in the municipality.

The methods were performed in accordance with relevant guidelines in the ethics section of revised version of the manuscript. The Ethics protocol was approved by the Graduate School Internal Review Board (IRB) of the Institute of Distance Learning, Kwame Nkrumah University of Science and Technology (KNUST), Ghana, following regulations guiding the use of human participants in research.

**Validity, Reliability and Ethical Consideration**

Validity and reliability were considered in assessing the quality of the research instruments. Validity concerns the extent to which an instrument measures the intended concepts, while reliability relates to the consistency of its results (Saunders et al., 2009; Creswell, 2014). Face and content validity were addressed through expert review of the questionnaire, including review by the research supervisor, to identify ambiguities, errors, and omissions and to ensure alignment with the study objectives. Internal consistency reliability was assessed using Cronbach's alpha (α), following the approach described by Saunders et al. (2007). Creswell (2014) provides reference values for interpreting reliability, with coefficients around 0.8 indicating satisfactory reliability and values around 0.9 indicating good reliability.

The original manuscript reports a Cronbach's alpha coefficient of 0.855 for the 30 questionnaire items, based on 70 responses described as viable for analysis. This value exceeds the stated threshold of 0.7 and indicates satisfactory internal consistency. However, the reported reliability sample of 70 differs from the stated sample of 60 respondents. The number of valid questionnaires actually used in the reliability analysis should therefore be verified and reported consistently.

Ethical considerations were addressed before data collection. Permission was sought from the relevant institutions and individuals, and participants' consent was obtained. Respondents were assured that the information they provided would be treated confidentially and used solely for academic purposes. Documents and other sources used in the study were appropriately acknowledged to maintain academic integrity and avoid plagiarism.

## RESULTS AND DISCUSSION

This section presents and discusses the study findings in relation to the research objectives and relevant literature. The results cover respondents' socio-demographic characteristics, factors hindering waste-to-energy generation, municipal solid waste characteristics and disposal methods, and the energy potential of waste collected in Mampong Municipality. The study targeted 60 Mampong Municipal Assembly workers, all of whom completed the questionnaires, yielding a 100% response rate. This provided perspectives from personnel involved in waste management and project implementation.

### Demographics

Table 1 shows that females constituted the majority of respondents (63.3%). All respondents (100%) had tertiary education, while 41.7% were aged 31–40 years and 33.3% were aged 41–50 years. Nearly half (48.3%, 29 respondents) had worked in their respective departments for 6–10 years, suggesting relevant institutional experience to inform their responses. These findings are consistent with Local Government (2018), which reported that 69.2% of local government workers had tertiary education.

**Table 1: Socio-demographics of Respondents**

| Demographic Variable | Categories / Responses | Frequency | Percent |
|---|---|---|---|
| **Position / Designation** | Supervisor | 11 | 55.0 |
| | Manager | 3 | 15.0 |
| | Lube bay Attendant | 1 | 5.0 |
| | Pump Attendant | 1 | 5.0 |
| | Programme Officer ((EPA) | 1 | 5.0 |
| | Quality Inspector (GSA) | 1 | 5.0 |
| | Municipal Environmental Health Officer | 1 | 5.0 |
| | Field Inspector (NPA) | 1 | 5.0 |
| **Years of Operation in Suame** | Less than 2 years | 3 | 15 |

| | | | |
|---|---|---|---|
| | 2-5 years | 3 | 15 |
| | 6-10 years | 8 | 40 |
| | Over 10 years | 6 | 30 |
| **Number of Fuel Pumps at Station** | 2 | 7 | 50 |
| | 3 | 6 | 42.9 |
| | 4 | 1 | 7.1 |
| | Not Applicable | 4 | 20 |

Source: Fieldwork, 2025

Composition of Municipal Solid Waste Generated In the Municipality

Table 2 shows that municipal solid waste in Mampong Municipality comprised biodegradable waste (food, kitchen, and green waste), electrical and electronic waste, recyclables (paper, cardboard, glass, bottles, and tin cans), hazardous waste, biomedical waste, toxic waste, and inert waste. Biodegradable waste was the most common (n= 4.816667, SD= 0.390205), followed by electrical and electronic waste (n= 2.966667, SD= 0.712281) and recyclable waste (n= 2.916667, SD= 0.645497). Inert waste was the least common.

**Table 2: Municipal Solid Waste Composition**

| **Ranks** | **Municipal solid waste** | **Mean (n)** | **SD** |
|---|---|---|---|
| 1 | Biodegradable waste e.g. Organic wastes including food and kitchen waste, green waste | 4.816667 | 0.390205 |
| 2 | Electrical and electronic waste e.g. Electrical appliance, TV, computers | 2.966667 | 0.712281 |
| 3 | Recyclable waste e.g. Paper, cardboard, glass, bottles, tin cans | 2.916667 | 0.645497 |
| 4 | Hazardous waste e.g. Paints, chemicals, batteries | 0.983333 | 0.747689 |
| 5 | Biomedical waste e.g. injection, pharmaceutical drugs, hospital waste | 0.816667 | 0.79173 |
| 6 | Toxic waste e.g. Pesticides, herbicides | 0.2 | 0.403376 |
| 7 | Inert waste e.g. Construction and demolition waste, dirt, rocks | 0.183333 | 0.390205 |

Source: Field Work, 2025

**Waste Disposal and Management Methods Employed in the Municipality**
**Municipal Waste Collection and Management**

Table 3 shows that 70.0% of respondents reported insufficient compaction trucks for waste transportation, while 66.7% indicated that separate central containers were not provided for different waste types. All respondents (100.0%) stated that municipal solid waste was not segregated before disposal. However, 83.3% reported adequate central waste containers for storage, 100.0% confirmed collaboration with private waste management agencies, and 71.7% indicated that residents paid for waste disposal.

Table 3: Waste Disposal and Management Methods

| Statement | Yes (%) | No (%) |
|---|---|---|
| Does the Assembly have enough compaction tracks for waste transportation? | 30 | 70 |
| Does the Assembly have enough central waste container for waste storage before disposal? | 83.3 | 16.7 |
| Does the Assembly have different central wastes containers allocated for different types of waste? | 33.3 | 66.7 |
| Does the Assembly work in collaboration with other private waste management agencies? | 100.0 | 0.0 |
| Does the Assembly/agency segregate the municipal solid waste before disposal? | 0.0 | 100.0 |
| Do the residents in the municipality pay for waste disposal? | 71.7 | 28.3 |

Source: Field Work, 2025

**Mode of Waste Collection in the Municipality**

All respondents representing 100.0% (60) claimed that the mode of waste collection in the municipality was through door-to-door waste collection, community central waste conveyor, and open refuse dump. Results observed from all respondents (100.0%) show that municipal solid waste collected is finally taken to the landfill for disposal.

**Suitable Waste-to-Energy Technologies Applicable to the Local Context**

Results presented in Figure 2 show the composition of solid waste in the Mampong municipality. The largest part of the municipal solid waste was organic waste, accounting for 57.0%. This was followed by miscellaneous waste such as hazardous waste, inert waste, and medical waste, constituting 22.0%, with glass and metal waste being the least in the municipal waste, representing 1.0% each.

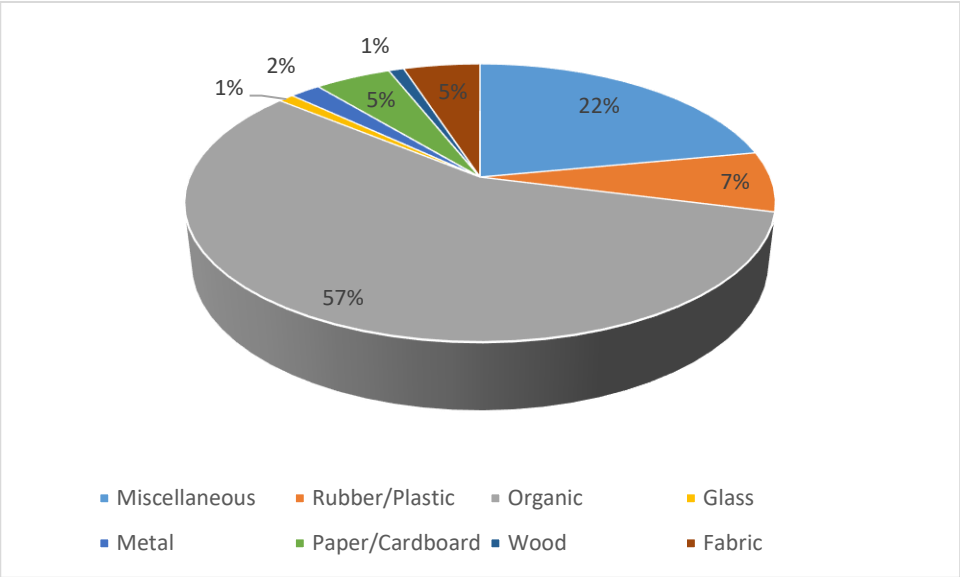



Figure 2: Most available waste in the municipality
Source: Field Work, 2025

**Suitable Waste-to-Energy Technologies**

It was observed from Table 4.4 that majority of the respondents constituting 85.0%, 91.7% and 80% agreed to the following statement that biochemical technology such as the anaerobic digestion (biogas) does not need huge capital to install and run in the municipality, can easily afford technical expertise to manage waste to energy plants, and will be profitability of waste to energy generation respectively than Thermochemical technology and Physiochemical technology.

Table 4: Suitable Waste-to-Energy Technologies

| Statement | Thermochemical technology | Biochemical technology | Physiochemical technology |
|---|---|---|---|
| Which of the following WtE technologies does not need huge capital to install and run | 0.0 | 85.0 | 15.0 |
| Which of the following WtE technologies can you easily afford technical expertise to manage waste to energy plants | 0.0 | 91.7 | 8.3 |
| Which of the following WtE technologies will it be profitability of waste to energy generation | 6.7 | 80.0 | 13.3 |

Source: Field Work, 2025

## DISCUSSION

**Composition of Municipal Solid Waste Generated in the Municipality**

Municipal solid waste composition in Mampong Municipality included biodegradable, electrical and electronic, recyclable, hazardous, biomedical, toxic, and inert waste. Biodegradable waste was the most common (n= 4.816667, SD= 0.390205), consistent with findings by Asase et al. (2009), Meiza et al. (2015), and Ofori (2016), which identified organic waste as the largest component of Ghana's municipal solid waste. Meiza et al. (2015) estimated the organic fraction at 61%–64%, indicating potential for energy generation (Ofori, 2016).

**Waste Disposal and Management Methods Employed in the Municipality**

The findings showed that the Assembly lacked sufficient compaction trucks, designated containers for different waste types, and waste segregation before disposal. These gaps reflect limited assessment of municipal waste's renewable energy potential. However, 83.3% of respondents reported adequate central waste containers, 100.0% confirmed collaboration with private waste management agencies, and 71.7% indicated residents paid for waste disposal. Collected waste is transported to landfills, which support biochemical waste-to-energy processes (Chen et al., 2021).

Applicable Suitable Waste-to-Energy Technologies

Figure 2 shows that biodegradable waste accounts for 57% of waste collected in Mampong Municipality. Additionally, 85.0%, 91.7%, and 80% of respondents agreed that biochemical technology, particularly anaerobic digestion, requires less capital, technical expertise is readily available, and waste-to-energy generation is profitable, respectively. These findings suggest that anaerobic digestion may be a suitable option for producing methane (CH4) and other biogas components in the municipality.

Anaerobic digestion offers advantages over landfill disposal through better monitoring, effluent treatment, faster decomposition, effective gas collection, and easier recovery of recyclable materials. According to Williams (2005), digestion reduces waste output. The process also recovers nutrients for agriculture, while biogas can support cooking, electricity, heating, and transport. Where sludge is free from hazardous substances, it can be used as fertiliser or soil conditioner, potentially reducing reliance on fossil fuels.

## CONCLUSION

This study assessed municipal solid waste composition, existing management practices, and suitable waste-to-energy technologies in Ashanti-Mampong Municipality. The findings indicate potential for energy recovery, particularly from biodegradable waste. However, realising this potential will require improvements in waste collection, source segregation, institutional coordination, and project planning.

Biodegradable waste was the most prevalent category, recording a mean of 4.816667 (SD = 0.390205). The Assembly's report indicated that biodegradable waste constituted 57% of collected waste. This predominance supports further investigation of anaerobic digestion as a potential approach for treating organic waste and recovering energy within the municipality.

Waste management challenges included insufficient compaction trucks (70.0%), lack of separate containers for different waste types (66.7%), and absence of waste segregation before disposal (100.0%). Although all respondents confirmed collaboration with private waste management agencies and 71.7% reported that residents paid disposal fees, collected waste was ultimately transported to landfill sites.

Anaerobic digestion emerged as a potential option, with 85.0% of respondents considering it less capital-intensive, 91.7% viewing the required technical expertise as affordable, and 80.0% perceiving waste-to-energy generation as profitable. These findings reflect respondents' perceptions rather than confirmed viability. Further technical and economic feasibility studies, waste characterisation, and environmental assessments are necessary before implementation.

**Statement on Conflict of Interests/Competing Interests**
The authors declare that there are no conflicts of interest related to this manuscript.

**Statement of Ethics Review Approval**
The methods were performed in accordance with relevant guidelines in the ethics section of revised version of the manuscript. The Ethics protocol was approved by the Graduate School Internal Review Board (IRB) of the Institute of Distance Learning, Kwame Nkrumah University of Science and Technology (KNUST), Ghana, following regulations guiding the use of human participants in research.

**Human Ethics and Consent to Participate**
'Human Ethics and Consent to Participate declarations: not applicable'.
However, Informed consent was obtained from all individual participants included in the study. Participation was voluntary, and assurance of confidentiality was given to respondents before they participated in the research. The respondents were adults working with women in a shea butter group. Personal information as well as information that could identify a particular respondent was not sought from the respondents.

**Consent to publish**
"NOT APPLICABLE"

**Data Availability**
The datasets generated during and/or analysed during the current study are available from the corresponding author upon reasonable request.

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**Clinical Trial Number**
Clinical trial number not applicable

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