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Assessment and Viability Study on Harnessing Electricity from Waste Materials in Sokoto State

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Abstract

In Nigeria, the poor management of Municipal Solid Waste (MSW) presents major environmental issues due to illegal dumping and inefficient practices. MSW, which includes household, commercial, and institutional waste, requires proper handling to minimize its harmful environmental impact. Waste-to-energy technologies provide a sustainable solution by converting MSW into energy through processes like incineration, gasification, and pyrolysis. This research aimed to assess and study the feasibility of generating electricity from waste materials in Sokoto State. Four key areas in Sokoto metropolis; Arkilla, Gawon Nama, Gidan Haki, and Gagi were selected for the study. Researchers collected data from these areas and also visited the Sokoto State Urban and Regional Planning Board (SURPB) and the Sokoto State Environmental Protection Agency (SEPA), which are tasked with maintaining a clean and refuse-free environment in Sokoto metropolis. Additional information was gathered through a review of existing data. The study revealed that Gidan Haki generates 326 tons of MSW per day, which can produce 7.61 MW of electricity. Arkilla generates 214 tons per day, capable of producing 4.99 MW. Gawon Nama generates 288 tons per day, equivalent to 6.71 MW, and Gagi generates 136 tons per day, producing 3.17 MW of electricity. Altogether, these areas generate 964 tons of MSW per day, which can produce 22.49 MW of electricity. The potential to generate 22.49 MW of electricity from 964 tons of MSW daily in Sokoto offers a significant opportunity for sustainable energy production and better waste management. However, according to Table 6 (Ibrahim et al., 2019), 30% of respondents identified malaria as a major disease related to solid waste disposal due to mosquito breeding in waste and gutters. Additionally, 20% of respondents reported respiratory issues from illegal waste burning, and another 20% cited typhoid due to the contamination of drinking water (both surface and underground) from improper waste disposal. Cholera and meningitis were also noted, accounting for 10% and 20% respectively, due to the contamination of food and water. These findings underscore the serious health risks associated with poor solid waste management.

KEYWORDS: Energy, Electricity, Municipal, Waste, Recovery, Contamination

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1.0 Introduction

Municipal solid waste (MSW) management is a critical aspect of environmental protection and socio-economic development. In Nigeria, the mismanagement of MSW poses significant environmental challenges due to illegal dumping and poor management practices. MSW, comprising household, commercial, and institutional waste, needs proper handling to mitigate its adverse effects on the environment (Tosin et al., 2017).

Waste-to-energy technologies offer a sustainable solution to manage MSW by converting it into energy through processes like incineration, gasification, and pyrolysis. These methods recover energy in the form of electricity or high-energy products such as methane. Thermal treatment processes, combined with energy recovery options, are preferred due to their ability to reduce waste volumes, recover valuable resources, and eliminate contaminants efficiently. By utilizing waste-to-energy technologies, countries like Nigeria can address the dual challenge of waste management and energy generation. Implementing these innovative solutions not only helps in proper waste disposal but also contributes to sustainable development by creating energy from resources that would otherwise end up polluting the environment. It is crucial for policymakers to prioritize the adoption of such technologies to promote environmental sustainability and economic growth (Bosmans et al., 2013).

Some research has conducted evaluations at the community level to assess the potential for Waste-to-Energy (WtE) derived from Municipal Solid Waste (MSW) in specific states of Nigeria. McIlveen-Wright et al. (2018) assessed the waste tonnage and composition of a standard landfill site in Lagos State. They determined the electricity potential by considering the caloric value, moisture content, and inert content of the fuel. Additionally, the authors examined the economic viability of constructing a 50 mw Energy from Waste coal power plant. They assumed a tipping fee of £50 per tons of waste and explored supporting measures like recycling and composting, along with other environmental and waste management strategies. Amoo et al. (2020) conducted a techno-economic evaluation for seven states in Nigeria, assessing various energy technologies and estimating the electrical power and thermal energy potential generated per kilogram of Municipal Solid Waste (MSW). Shamaki and Shehu (2017) conducted a research assessment of solid waste management in Sokoto metropolis. Their findings showed that domestic sources contribute to 55.8% of waste generated in the area, while commercial sources and agricultural waste account for 32.5% and 11.7%, respectively. The majority of respondents (81.7%) reported using waste bins for collection, with the waste often being disposed of in nearby dumpsites or drainages. Despite previous research on Waste-to-Energy (WtE) in Nigeria, there hasn't been a comprehensive assessment and viability study conducted specifically on harnessing electricity from waste materials in Sokoto State. Such a study would aim to determine the type and nature of waste products in the area, estimate the daily volume of waste generated, calculate the potential electricity generation capacity (in Megawatt-hours) from the waste volume, and identify the positive impacts of using waste for electricity generation, including cost savings, energy contributions, and health and environmental benefits, among other factors.

1.2 Statement of the Problem

Essentially, the beauty of any setting is tied to its cleanliness and hygiene standards. A clean environment safeguards the well-being of the populace by minimizing health risks

and other environmental issues. Harmful waste produced can adversely affect our land, water, and air quality. In Sokoto State, measures like establishing the Sokoto Urban Development Authority (now the State Urban and Regional Planning Board) and the State Environmental Protection Agency were taken to ensure a clean and safe environment. However, despite governmental initiatives, some individuals display carelessness by disregarding proper waste disposal methods. Consequently, there's a need to explore converting waste into electricity as a means of waste management, potentially creating job opportunities.

1.3 Aim and Objectives of the Study

Aim

The aim of this research work was to carry out an assessment and viability study on harnessing electricity from waste materials in sokoto state.

Objectives

The objectives of this research work are as follows:

a) To determine the type, nature of the waste products in the study area
b) To determine the volume of waste product generated per day in the study area
c) To determine the quantity of electricity (in Megawatt/hour) that can be generated from the volume of waste product determined in (b) above.
d) To identify the positive impact of using the waste product to generate electricity in terms of cost savings, energy contributions, health and environmental benefits among other things.

2. Background of the Study

According to a report by Gupta *et al*. (2021), in 2016, cities worldwide generated approximately 2.01 billion metric tons of solid waste, equating to a footprint of 0.74 kg per person per day. With the population growth and modernization trends, it is projected that waste generation will increase by 70 percent from the 2016 level to reach 3.40 billion metric tons annually by 2050. Municipal solid waste (MSW) represents a renewable energy source through traditional means. MSW refers to materials discarded in urban areas, collected, and disposed of by municipalities. It is considered a biomass source due to its significant composition of materials such as leather, food waste, wood, yard trimmings, and paper. Biogas emerges as an efficient energy source, offering small-scale cost-effectiveness and production feasibility using organic materials, as highlighted by Anssari *et al*. (2020).

3.0 Methods

The method of this research include; four key areas in Sokoto metropolis; Arkilla, GawonNama, GidanHaki, and Gagiwere selected for the study. Researchers collected data from these areas and also visited the Sokoto State Urban and Regional Planning Board (SURPB) and the Sokoto State Environmental Protection Agency (SEPA), which are tasked with maintaining a clean and refuse free environment in Sokoto metropolis and more information were obtained. Additional information was gathered through a review of existing data.

3.1 Solid Waste Management

The expanding volume and intricacy of waste linked to the contemporary economy present a significant threat to ecosystems and human well-being. Globally, an estimated 11.2 billion tonnes of solid waste are collected annually, and the decomposition of the organic component of this waste contributes approximately 5 percent of total global greenhouse gas emissions (Jebaranjitham, 2022).



Figure 1: Waste Dumping at Behind Marina Police station, Sokoto



Figure 2: Waste Materials Dumping at KofarKware Bypass, Sokoto

3.2 Energy Conversion Pathways from MSW

The energy present in the organic section of municipal solid waste (both biodegradable and non-biodegradable) can be harnessed to generate heat or electricity using two different methods. These methods, bio-chemical and thermo-chemical, are chosen based on the composition of the waste and its moisture content. Figure 1 illustrates these two pathways for converting municipal solid waste into energy and the associated processes.

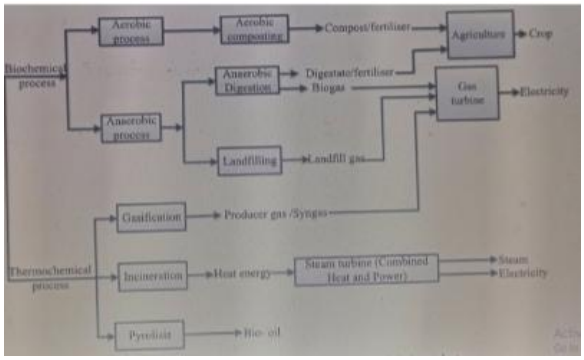

Figure 3: Energy conversion pathways from MSW and their products (Ogunjuyigbe *et al*., 2017)

3.3. Bio-chemical conversion

The bio-chemical conversion process entails the breakdown of organic waste components through biological decomposition facilitated by microbial activity. This decomposition occurs either in the presence of oxygen (aerobic digestion) or in its absence (anaerobic digestion), resulting in the production of compost or biogas (landfill gas), respectively. Key technological methods within bio-chemical conversion include anaerobic digestion and Landfill Gas to Energy (LFGTE) techniques. These processes are typically favored for waste with a significant proportion of biodegradable organic matter and a high moisture content, as these conditions support optimal microbial activity (Ogunjuyigbe *et al*., 2017)

3.3.1. Landfill Gas to Energy (LFGTE) technique

Land filling is the process of organic waste decomposition in landfills is slightly synonymous to anaerobic digestion in biogas digesters. However, the biochemical decomposition in biogas reactors is done in a more controlled manner due to its fast rate of reaction coupled with temperature stabilization (CynthaOfori, 2013).

3.3.2. Anaerobic Digestion

Biogas technology has emerged as a key environmental technology for integrated solid and liquid waste treatment concepts and climate protection in industrialized and developing countries. With the anaerobic in the wastes is retained within the biogas as methane and the rest are sludge (Cyntha Ofori, 2013).

3.4. Thermodynamic Conversion Technology

The thermo chemical process plays a crucial role in a sustainable integrated municipal solid waste (MSW) management system. This method involves the thermal decomposition of organic matter to generate heat energy, fuel oil, or gas. Key technological methods within this category include incineration, pyrolysis, and gasification (Ogunjuyigbe *et al*., 2017).

3.4.1. Incineration

Incineration stands out as a highly established technology for converting waste into energy. Through this method, waste is combusted in furnaces, producing energy through the application of heat, which can be harnessed as either electrical or thermal energy. The resulting by-products of this process include powdered ash and exhaust gases. The ash residue can undergo chemical treatment to extract metals for recycling, while the remaining material can be repurposed in the construction of various materials (Gupta *et al*., 2021)

3.4.2. Gasification and Pyrolysis

Gasification is a transformative process where organic compounds like briquettes, rice husks, and various types of wood are converted into a renewable fuel known as Syngas, along with a solid char residue. This conversion typically occurs at temperatures exceeding 650°C. Syngas, with its high calorific value, holds potential for applications in power generation and biofuel production (Gupta *et al*., 2021).

3.5 Case Study Area

The focus of the study was Sokoto metropolis, presently the capital city of Sokoto State, situated in the North-West region of Nigeria. It lies within the coordinates of latitude 13.0505° to 13.0830°N and longitude 5.015° to 5.2500°E, with an average elevation of 272 meters above sea level. The Sokoto metropolis encompasses several local administrative units, including Sokoto North and South, along with portions of Kware, Dange-Shuni, and Wamakko local government areas. However, for the purposes of this research, the study specifically concentrated in 4 areas such as, Gidan Haki, Arkilla, Gawon Nama and Gagi area all in Sokoto state.

3.6 Solid Waste Sources

Various types of solid waste are being gathered, including tree leaves, paper, furniture, wood scraps, food leftovers, bottles, clothing, and more. This waste comes in solid or semi-solid forms and can be classified into biodegradable categories such as kitchen scraps, organic matter, and paper products.

Table 1 shows that residential waste is the primary source of solid waste in the study area, accounting for 53.5 %. Commercial waste makes up 36.9%, while industrial and other wastes constitute 2.9 %. These findings indicate that residents in the various zones produce the highest volume of solid waste in the area.

Table 3.1: Waste composition category

Organic matter	**Food waste from Hostel Mess, leaves from trees in areas**
Paper / Card board	Office waste paper, old newspapers, magazines, waste card boards etc
Plastic	Plastic bags, plastic bottles, plastic strings etc. from stores, offices, workshops, labs etc.
Glass	Bottles, glassware, light bulb, ceramics etc.
Metal	Iron and Non-Iron metals including knives, metal waste from workshops, cans, wire, fence, bottle cans etc.
Wood	Wooden chips waste from workshop, furniture waste etc

Source: (Gupta *et al*., 2021).

4. Results and Discussion

Table 4.1: Sources of Solid Waste in Sokoto Metropolis

Sources	Percentages
Residential	53.5
Commercial	36.9
Industrial	2.9
Others	6.7
Total	100

Source: (Ibrahim et al, 2019)

Table 4.1 showed that residential waste is the primary source of solid waste in the study area, making up 53.5% of the total. Commercial waste constitutes 36.9%, while industrial and other types of waste account for 8.9%. These findings suggest that households in different zones generate the highest volume of solid waste, primarily due to waste disposal practices by residents.

Table 4.2: Types of Solid Waste Generated in the Study Area

Waste Generated and Type	Frequency	Percentage (%)
Leaf form	4.6	32.9
Plastic/polythene	58	41.4
Tins/cans	21	15.0
Bottles	4	2.9
Garbage	11	7.9
Total	140	100

Source: (Ibrahim *et al*, 2019)

Table 4.2 shows the different types of solid waste generated in the study area.

Table 4.3: Authorized Dumpsites in the Study Area

Response	Total	Percentage (%)
Yes	74	19
No	313	81
Total	386	100

Source: field survey 2019

According to the table 3, 81% of respondents indicated that there are no authorized dumpsites in the area, while 19% reported having dumpsites nearby.

Table 4.4: Procedure of Solid Waste Disposal in the Study Area

Procedure of Disposal	Gidan Haki (%)	Gawon Nama (%)	Arkilla (%)	Gagi (%)	Cumulative (%)
Land filling	5.2	1.7	4.3	15.2	6.60
Direct dumpin	54	50.2	47	61	53.05
Burning	19	31	27	12	22.20
Dig and bury	4.3	1.2	2.3	6.8	3.70
Store in waste bin	3.2	6.2	9.8	2.1	5.33
Other	14.3	9.7	9.6	2.9	9.12
Total	100	100	100	100	100

Source: (Ibrahim *et al*, 2019)

Open dumping, accounting for 53.05%, is the primary method of solid waste disposal and management in Sokoto metropolis. Waste burning constitutes 22.2%, storage in waste bins is 5.32%, digging and burying is 3.7%, landfilling is 6.6%, and other methods make up 9.12%. Consequently, most households dispose of their waste on roads, streets, open spaces, gutters, market areas, and other illegal dumpsites. This practice poses health hazards to the local population. Additionally, it leads to traffic congestion and road inaccessibility due to waste being dumped on major roads. Waste burning contributes to air pollution and is ineffective at processing inorganic materials like bottles, glass, and metals. According to Table 4, 81% of respondents lack authorized dumpsites in their neighborhoods. The absence of authorized waste bins has led residents to dump waste indiscriminately along major roads, behind houses, and in drainage systems, causing blockages, floods, and pollution from the stench of illegal dumpsites.

Table 4.5: Diseases associated with solid waste

Illness/diseases	Total	Percentage (%)
Maleria	116	30
Cholera	77	20
Typhoid	77	20
Meningitis	27	10
Respiratory	78	20
Total	386	100

Source: (Ibrahim *et al*, 2019)**.**

Table 4.5 showed that 30% of the respondents reported malaria fever as a major disease linked to solid waste disposal, due to mosquitoes breeding in the waste and gutters. Additionally, 20% of the respondents mentioned respiratory problems resulting from the illegal burning of waste, while another 20% cited typhoid, caused by the contamination of drinking water (both surface and underground) from improper solid waste disposal. Cholera and meningitis were also noted, accounting for 10% and 20% respectively, due to the contamination of food and water consumed by the respondents.

Table 4.6: Estimation of MSW per day in at Gidan Haki area

S/N	Type of vehicle	Vehicle capacity (tons)	Trip per day	Total (tons)
1	Pickup	2	25	50
2	Truck	12	23	276
Total				326

For the 302 tons of MSW from GidanHaki,

$$\frac{326tons}{day} x \frac{1day}{24hrs} x \frac{0.56MW}{1ton} = 7.61\text{MW}$$

Note that 0.56 is the conversion factor.

Table 4.6 presents significant data regarding the municipal solid waste (MSW) generated in GidanHaki, Sokoto. The key points from the table indicate that; total MSW generated in the area is 326 tons of MSW daily, and the potential electricity generation is 7.61 MW of electricity.

Table 4.7: Estimation of MSW per day at GawonNama Area

S/N	Type of vehicle	Vehicle capacity (tons)	Trip per day	Total (tons)
1	Pickup	2	24	48
2	Truck	12	20	240
Total				288

For the 288 tons of MSW from GawonNama

$$\frac{288tons}{day} x \frac{1day}{24hrs} x \frac{0.56MW}{1ton} = 6.72\text{MW}$$

Table 4.7 presents significant data regarding the municipal solid waste (MSW) generated in GawonNama area in Sokoto. The key points from the table indicate that; total MSW generated in the area is 288 tons of MSW daily, and the potential electricity generation is 6.72 MW of electricity.

Table 4.8: Estimation of MSW per day at Arkilla Area

S/N	**Type of vehicle**	**Vehicle capacity (tons)**	**Trip per day**	**Total (tons)**
1	Pickup	2	23	46
2	Truck	12	14	168
Total				214

For the 214 tons of MSW from Arkilla

$$\frac{214tons}{day} x \frac{1day}{24hrs} x \frac{0.56MW}{1ton} = 4.99\text{MW}$$

Therefore, Table 4.8 also presents significant data regarding the municipal solid waste (MSW) generated in GidanHaki, Sokoto. The key points from the table indicate that; total MSW generated in the area is 214 tons of MSW daily, and the potential electricity generation is 4.99 MW of electricity.

Table 4.9: Estimation of MSW per day at Gagi Area

S/N	**Type of vehicle**	**Vehicle capacity (tons)**	**Trip per day**	**Total (tons)**
1	Pickup	2	8	16
2	Truck	12	10	120
Total				136

For the 136 tons of MSW from Gagi area

$$\frac{136tons}{day} x \frac{1day}{24hrs} x \frac{0.56MW}{1ton} = 3.17\text{MW}$$

Table 4.9 presents significant data regarding the municipal solid waste (MSW) generated in GidanHaki, Sokoto. The key points from the table indicate that; total MSW generated in the area is 136 tons of MSW daily, and the potential electricity generation is 3.17 MW of electricity, this also indicated that, there is less waste generated at Gagi area compared with the arkilla, gidanhaki and gawonnama. The total energy generated

from all the study areas in sokoto = 326+288+214+136 = 964 tons, which is equivalent to 22.49MW per day.

5.0 Conclusion

The combined data from various study areas in Sokoto highlights a significant potential for energy generation from municipal solid waste (MSW). The breakdown is as follows:

a) The cumulative MSW generated from all the study areas in Sokoto is 964 tons per day.
b) This waste has the potential to generate 22.49 MW of electricity per day.

The total potential of generating 22.49 MW of electricity from 964 tons of MSW per day in Sokoto represents a significant opportunity for sustainable energy production and improved waste management. Strategic implementation, leveraging advanced technologies, and engaging the community and stakeholders are key to realizing this potential. This initiative can transform waste management practices, contribute to environmental sustainability, and enhance the socio-economic landscape of Sokoto.
However, according to Table 4.5 (Ibrahim et al., 2019), 30% of the respondents identified malaria fever as a major disease linked to solid waste disposal, due to mosquitoes breeding in the waste and gutters. Additionally, 20% of the respondents reported respiratory problems resulting from the illegal burning of waste, while another 20% cited typhoid, caused by the contamination of drinking water (both surface and underground) from improper solid waste disposal. Cholera and meningitis were also noted, accounting for 10% and 20% respectively, due to the contamination of food and water consumed by the respondents. These findings highlight the significant health risks associated with inadequate solid waste management.

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