Examining the Opportunities and Obstacles of Waste-To-Energy For Sustainable Energy Utilization In Nigeria: A Brief review.

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Abstract
The global surge in energy demand, fueled by population growth and economic expansion, underscores the increasing reliance on fossil fuels and the pressing need for renewable energy solutions. While fossil fuels dominated global energy consumption in 2020, the transition to renewables, particularly solar and biomass, is gaining momentum, with projections indicating a two-fold increase in the renewable energy market by 2040. In Nigeria, the energy sector faces multifaceted challenges, including an overreliance on fossil fuels, inadequate electricity supply, and environmental degradation from alternative energy sources like generators. Waste-to-Energy (WTE) technologies present a promising solution to address Nigeria's dual crises of energy scarcity and waste management. With an abundance of organic waste and untapped potential for energy recovery, methods such as anaerobic digestion, landfill gas recovery, and incineration offer viable pathways for clean energy production. However, barriers such as inadequate funding, technological limitations, and policy constraints hinder the development of WTE initiatives. Drawing on global WTE successes, particularly in the European Union, this study evaluates Nigeria's WTE potential, highlighting proposed and failed projects, and identifies critical factors for overcoming current challenges. The findings emphasize the necessity of tailored approaches that integrate local conditions, policy reforms, and increased investment to harness Nigeria’s vast waste-to-energy potential. Ultimately, this research contributes to the discourse on achieving sustainable development through innovative energy recovery methods.

Keywords*: Global energy demand, fossil fuels, renewable energy, Nigeria, waste-to-energy (WtE), waste management, organic waste, anaerobic digestion, sustainable development*.

1.0 Introduction

Global energy demand between 2010 and 2024 and future predictions suggests a significant increase in fossil energy use, driven by population growth and economic development (Al-Yasiri & Journal, 2021). The predicted percentage increase in global energy demands varies, with estimates ranging from 57% by 2030 (Zielinski, 2007) to a doubling of energy demand within the next 40-50 years (Burri, 2010). The global energy demand in 2020 was primarily met by fossil fuels, with renewable energy accounting for a smaller portion (Breyer, 2020; Holechek et al., 2022; Volotkovskaya et al., 2020)

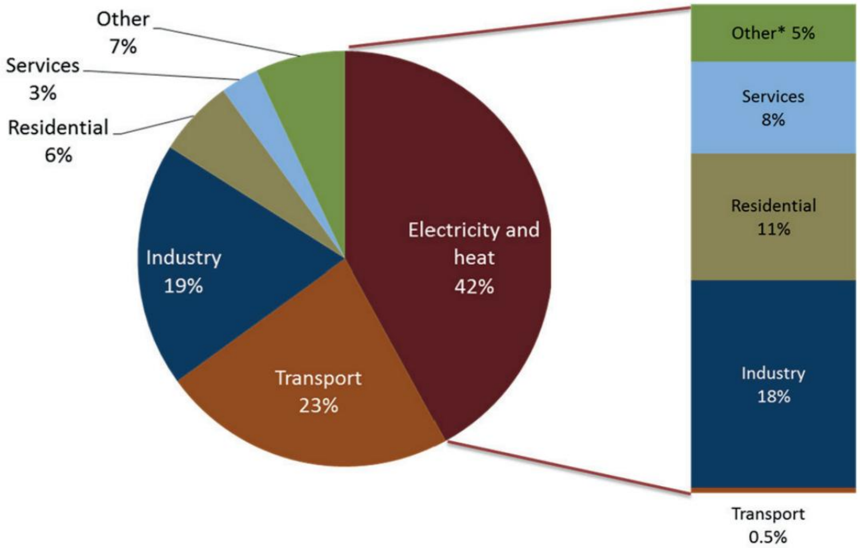

Figure 1.2: Sector-Wise Distribution of World CO2 Emission (Bajracharya, 2018)

However, there is a growing shift towards renewable energy sources, with a projected two-fold increase in the global energy production market by 2040 (Volotkovskaya et al., 2020)
Nigeria's energy demands are a significant concern, with a reliance on fossil fuels that is no longer sustainable (Eweka et al., 2022). Renewable energy sources, particularly solar and biomass, have been identified as potential solutions, with solar PV currently the most promising due to its cost competitiveness (Eweka, 2022). However, the high cost of cooking energy, particularly liquefied petroleum gas (LPG) and kerosene, has a negative impact on energy demand (Orji, 2021). The country's energy consumption is influenced by globalization and financial deepening, with a need to develop the financial sector to enhance investment in energy-saving equipment (Adagunodo, 2021).

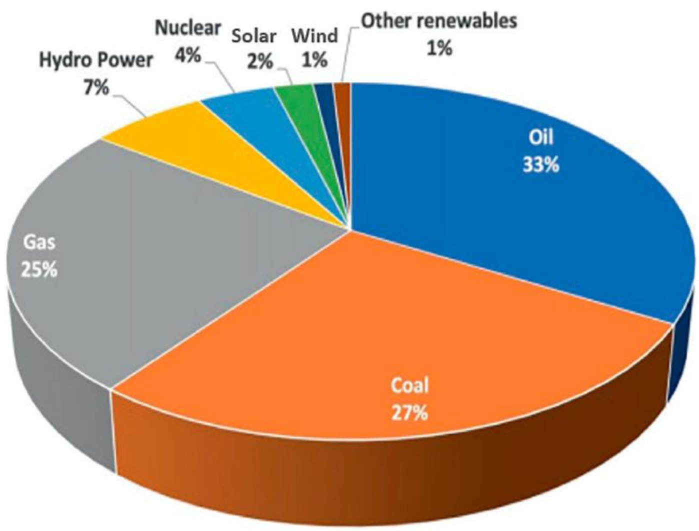

Figure 1. Sources of energy generation in Nigeria(Ilenikhena & Ezemonye, 2010)

Research on municipal solid waste generation in Nigeria has revealed significant challenges and opportunities. Simon (2022) found that organic waste, particularly food waste, is the most abundant component, while inorganic waste, including plastic and nylon bags, is also prevalent. Ibikunle (2021) projected a substantial quantity of waste, with potential for energy production. Nigeria faces significant challenges in meeting its energy demands due to inadequate supply. Despite being Africa's largest oil producer, the country still struggles with power shortages and frequent blackouts. This disparity between demand and supply has led to widespread reliance on alternative sources like generators, which are expensive and environmentally damaging. Additionally, the lack of access to reliable electricity hampers economic development and affects the quality of life for millions of Nigerians.

Nigeria's energy sector faces significant challenges, including political and regulatory issues, inadequate investment, and reliance on costly and environmentally damaging alternatives like generators (Obar, 2022). The country's energy crisis, exacerbated by a growing population and economy, underscores the need for renewable energy solutions (Olaoye, 2016). However, the transition to clean energy is hindered by factors such as high installation and maintenance costs, limited private sector involvement, and subsidies for fossil fuel energy (Popoola, 2020). This crisis not only hinders the country's socio-economic growth but also poses a threat to the attainment of sustainable development goals (Jack, 2022). The quest for clean, renewable, cheap and sustainable energy in Nigeria has become inevitable (Adediran, 2021).

The challenges of waste management in sustainable and environmental friendly viable approach are a global issue, with both developed and developing countries facing similar difficulties (Srivastava, 2014; Jalalipour, 2020). Waste to energy (WTE) technologies, such as biogas utilization and landfill gas (LFG) production, are increasingly being recognized as a solution to the dual challenges of waste management and energy generation (Muawad, 2019; Alwiyah, 2022; Rana, 2022). The disposal of waste in developing countries is a complex issue, with landfilling being the most common method (Sankoh 2020). However, this method is not always successful due to limited time frames and capacity (Griffin 1998). Successful waste management in developing countries often involves the implementation of environmental policies and the adoption of resource recovery methods (Medina-Salas 2020). Despite the challenges, landfilling remains the lowest cost disposal option in these countries (Agamuthu 2013). A range of waste-to-energy (WTE) technologies have been developed, offering potential solutions to the challenges of waste management and energy generation. These technologies, including gasification, plasma gasification, pyrolysis, and incineration, have the potential to reduce toxic emissions and landfilling, while also producing clean energy and valuable by-products (Seltenrich, 2016; Saini, 2021; Nanda, 2021; Parashar, 2019). However, their widespread adoption is hindered by concerns about their compatibility with recycling efforts, financial feasibility, and public perception (Seltenrich, 2016). Despite these challenges, the use of these technologies, particularly in the context of municipal solid waste, holds promise for sustainable energy production and waste diversion (Nanda, 2021; Parashar, 2019).

sustainable development, as defined by the Brundtland Commission, emphasizes meeting present needs without compromising the ability of future generations to meet their own needs (Basiago 1995, Wilhite 2014, Ardeleanu 2012, Prizzia 2007, Johanna 2018). This definition has been widely accepted and has influenced international environmental diplomacy (Prizzia 2007). These studies collectively highlight the interconnectedness of economic, environmental, and social aspects in the pursuit of sustainability. WTE significantly reduce waste volume for landfilling, lower total greenhouse gas emissions, and provide a source of renewable energy, thus mitigating climate change effects (Shaji, 2016). They also reduce environmental impact, public health threats, and the dependency on fossil fuels for power generation (Saha, 2020). The efficiency of these technologies ranges from 20-40%, with a typical 100,000-tonne per annum waste to energy plant producing around 7MW of electricity, enough to power approximately 10,000 homes (Saha, 2011). The cost of energy from these technologies is relatively low, ranging from $0.03 to $0.05 per kilowatt-hour (Saha, 2020).

The goals of sustainable development in waste-to-energy in Nigeria are multifaceted, encompassing energy sustainability, human welfare, and environmental protection. Akindele-Sotunbo (2023) emphasizes the need for cleaner energy sources to promote good life for the people, in line with SDG 7. Adeleke (2023) underscores the potential of biogas production from organic waste, which can contribute to energy sustainability, waste management, and climate change mitigation. Faiz (2024) presents a practical solution for waste management and electricity generation through a waste-to-energy plant, addressing both environmental and energy needs. These studies collectively highlight the importance of sustainable waste-to-energy solutions in Nigeria, aligning with the broader goals of sustainable development.

The abundance of organic waste in Nigeria presents a significant opportunity for bio-methane generation, as highlighted by Okafor (2022). This potential is further underscored by Riagbayire (2023), who emphasizes the benefits of biogas as an alternative energy source. Ajaero (2023) and Adeoye (2023) both explore the energy production potential of organic waste, with Ajaero focusing on the organic fraction of municipal solid waste and Adeoye discussing biomass waste pyrolysis. These studies collectively underscore the potential of organic waste in Nigeria for clean and affordable energy generation, aligning with the goals of sustainable development.

Biogas Upgrading for Energy Applications

Upgraded biogas can be used as an alternative to natural gas, district heating, electricity production, valuable transport fuel, or stored as a liquefied bio-methane. Biogas, a renewable energy source, can be upgraded to enhance its applications, including as a fuel for vehicles, district heating, electricity production, and as a valuable transport fuel (Bora, 2021; Jana, 2021; Kabeyi, 2022). The upgrading process involves removing impurities such as CO2 and H2S, and increasing the methane content to over 90% (Bora, 2021). This can be achieved through various physico-chemical and biological methods, with biological biogas upgrading technologies showing promise in energy storage and carbon capture (Lóránt, 2022). The use of biogas as a sustainable energy resource is further supported by its competitive cost and wide range of applications (Kabeyi, 2022). Advancing WTE Technologies for Sustainable Energy and Environmental Protection in Developed Countries. The possibility of WTE technologies to alternatively provide energy and minimize the detrimental consequence of waste on the environment especially in developed countries can be attributed to factors such as technological progression, an enhanced system for regulating pollution, motivations from the government, and uncompromising regulations.

Waste-to-Energy (WtE) technologies have the potential to provide energy and mitigate the environmental impact of waste, particularly in developed countries. This is due to factors such as technological progression, enhanced pollution regulation, government support, and stringent regulations (Labib, 2019; Rezania, 2023; Kumar, 2017; Rasheed, 2021). These technologies, including incineration, gasification, pyrolysis, and anaerobic digestion, offer a sustainable and economically viable solution for effective waste management and energy recovery (Kumar, 2017; Rasheed, 2021).

Waste-to-energy (WtE) presents significant opportunities in developing countries, including Pakistan, where it can help bridge the gap between electricity demand and generation (Khan, 2023). However, the technology's potential is contingent on effective waste management and cost considerations (Pujara, 2020). In Southeast Asia, the sector is growing, with a focus on incineration, landfill gas capture, and anaerobic digestion technologies (Tun, 2020). In Nigeria, the challenges of waste management, including open dumping and low collection rates, underscore the need for a comprehensive waste management framework to support the introduction of WtE technologies (Ojiji, 2021).

Nigeria, akin to many other African nations, produces organic-rich waste possessing significant inherent energy potential that can be harnessed through anaerobic digestion, landfill gas recovery, and incineration methods. The amount of theoretical energy potential that can be recovered from waste energised in African countries has been assessed in a number of studies. Records, however, indicate that many African nations are still not fully utilizing their ability to address their energy and waste management crises. The success of WTE in developed nations, particularly in EU nations, offers certain insights. These success criteria can aid in creating a plan for enhancing WTE Industries in Nigeria. However, without assessing the unique local circumstances that hinder the establishment of WTE and have resulted in numerous unsuccessful WTE projects, it is not practical to simply transfer the EU model or technologies into Nigeria and other developing nations.

The evaluation of WTE processes through current, proposed, and unsuccessful energy recovery projects at different parts of Nigeria is what motivates this study. This study assesses the potential for energy production from waste in Africa, focusing on Nigeria. It also discusses current and proposed WTE initiatives in Nigeria. The energy recoverable potential from waste in a model community has been estimated to be as high as 8967.13 MJ day -1 (Okeniyi, 2012). Specific agricultural wastes, such as rice husk, cocoa pods, and oil palm wastes, also offer substantial energy production potential (Anyanwu, 2013). These findings collectively suggest that Nigeria has the highest potential for producing energy from waste. The amount of waste generated and collected in Nigeria has been found to indicate that the country has the highest potential for producing energy from waste in West Africa. A few resource and policy-related obstacles to Nigeria's full operationalization of WTE were noted and examined, and conclusions and suggestions for WTE's future paths were provided.

This study conducts a comprehensive analysis of the Waste-to-Energy (WTE) landscape in Africa, with a specific focus on Nigeria. Utilizing a desktop literature review of recent articles from esteemed journals, global and national reports from waste management and energy departments, and renowned databases, we examined the global WTE industry trends, particularly in the EU and UK, and compared them to Nigeria's scenario. Our analysis of proposed, existing, and failed WTE projects in Nigeria enabled us to identify key factors hindering the country's WTE growth and provide recommendations to enhance energy recovery from waste in Nigeria.

Waste management, generation, and composition in Nigeria

Waste management in Nigeria faces significant challenges due to inadequate funding and institutional frameworks. Multiple studies highlight that resources allocated by the government for waste management are consistently meager (Chukwuemeka et al., 2012). This underfunding contributes to poor service delivery, infrastructural inadequacies, and technical incapacity in Nigerian cities (Winter & Ujoh, 2020). Additionally, inadequate environmental policies, low environmental awareness, inappropriate technology, and unplanned development hinder sustainable solid waste management (Amasuomo & Baird, 2016).

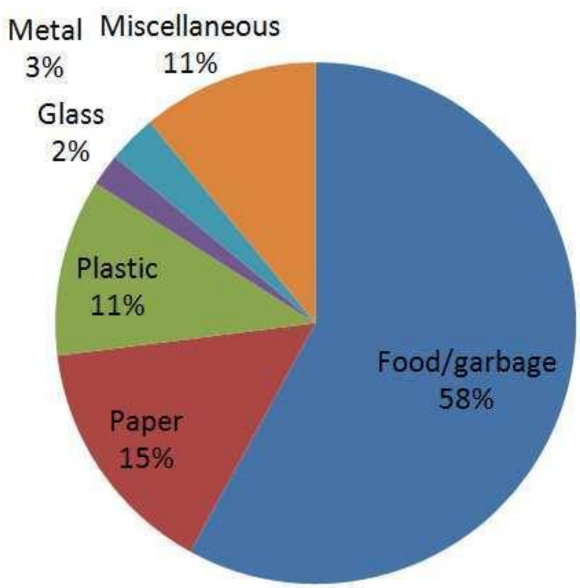

Figure 4: Waste composition in Nigeria(Atta et al., 2016)

Integrated solid waste management (ISWM) in Nigeria faces significant challenges due to rapid urbanization and population growth. Key issues include inefficient collection methods, insufficient coverage, and improper disposal (Ogwueleka, 2009). Waste generation rates range from 0.44 to 0.66 kg/capita/day, with densities between 280-370 kg/m³ (Ogwueleka, 2009). Common constraints include lack of institutional arrangements, insufficient funding, and inadequate enforcement of existing legislation (Kaltschmitt et al., 2008; Ogwueleka, 2009). Current practices often involve indiscriminate disposal of liquid and solid wastes, with hazardous materials co-mingled with municipal waste (Sridhar & Hammed, 2014).

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