Journal of Environmental Engineering and Energy

www.jeee.reapress.com

J. Environ. Eng. Energy Vol. 1, No. 1 (2024) 59–70.

Paper Type: Original Article

Energy Generation in Nigeria: A Literature Review

Chukwuemeka Joshua Okafor*

Mechanical Engineering, Teesside University, United Kingdom; Okaforjoshua87@gmail.com.

Citation:

Received: 11 September 2024 *Revised: 15 October 2024* *Accepted: 20 November 2024*	Joshua Okafor, Ch. (2024). Energy generation in nigeria: A literature review. *Journal of Environmental Engineering and Energy, 1* (1), 59-70.

Abstract

Petroleum accounts for almost the total energy used in the transportation sector by, 90% in 2005, and is expected to also be on the increase to 92% by 2030 as a result of the difficulty in petroleum alternatives. In China and the United States, gas demand is on the high side. The ever-expanding energy demand, decreasing sources of petroleum resources, and worry about contamination levels in the earth have been the significant worries of the world. The Consumption of Energy patterns across the globe today imply that our great nation, Nigeria and most African nations have the least consumption of energy. Nigeria is suffering from an insufficient supply of consumable energy as a result of a lack of persistent government intervention regularly and an increased population. This study explored the sources of energy in Nigeria through a literature review. Finally, emphasis was laid on waste energy.

Keywords: Energy, Energy generation, Energy consumption, Waste energy.

1 | Introduction

The Nigerian electricity system is centered on Nigeria's Power Holding Company (PHCN), which uses both hydro and thermal energy and generates nearly all of the country's electricity (CBN, 2000). Other agencies, like Nigeria Electricity supply Company (NEC) and Transmission Company of Nigeria (TCN), all depend on thermal energy to generate electricity. Furthermore, Nigeria's electricity is generated by natural gas, diesel oil, and fuel oil. Because of the rapid increase in demand, the value of these energy and power supplies for electricity generation has also been diminishing recently, leading to the depletion of the earth's surface.

Nigeria is suffering from an insufficient supply of consumable energy as a result of a lack of persistent government intervention regularly and an increased population. Nigeria is also endowed with long-term energy supplies that include crude oil, natural gas, lignite, and coal, as well as alternative options of energy like breeze, solar, geothermal, hydropower, and biomass trash. Energy consumption in Nigeria is divided into four categories: manufacturing, agriculture, industrial, transportation, as well as individual homes, with the household segment further accounting for approximately 65 percent of the nation's energy consumption

Corresponding Author: Okaforjoshua87@gmail.com

https://doi.org/10.22105/jeee.v1i1.22

because of a small level of advancement in other sectors[1]. This study explored the sources of energy in Nigeria through a literature review.

2 | Literature Review

The universal trend in energy use

The global essential supply of energy has increased from 58% in the last decades, with 7.3 billion barrels of oil (TOE) in 1980 to 11.4 billion TOE by 2005, and with 14.1 billion TOE and is still expected to increase to 17.0 billion TOE by 2030 [1]. Energy-hungry countries that once belonged to the Organization for Economic Cooperation and Development (OECD), however, have been on a declining rate of their population and economic growth than the Non -OECD states.

In 2006, non- OCED accounted for 51% relating to the consumption of energy. Henceforth, the growth of the economy in emerging market countries such as India, the Middle East, and China is expected to increase energy demand. Petroleum oil, which is a critical energy commodity, is forecast to upsurge from 4.0 billion TOE within 2005 to about 5.1 billion TOE by 2030. With an increase in petroleum demand, investigative evolution and investment in natural gas and Crude oil are bound to serve as future energy supply. Also, the demand for energy in the transportation sector is increasing by 57%, from 2.1 billion TOE in 2005 to about 3.2 billion TOE by 2030 [2].

Petroleum accounts for almost the total energy used in the transportation sector by, 90% in 2005, and is expected to also be on the increase to 92% by 2030 as a result of the difficulty in petroleum alternatives. In China and the United States, gas demand is on the high side. The ever-expanding energy demand, decreasing sources of petroleum resources, and worry about contamination levels in the earth have been the significant worries of the world. The consumption of energy patterns across the globe today imply that our great nation, Nigeria, and most African nations have the least consumption of energy.

Fuelwood, charcoal, kerosene, cooking gas, and electricity are the most commonly used energy resources in Nigeria's domestic and commercial sectors [3]. Kerosene and gas are the most commonly used cooking fuels by urban dwellers, whereas electrical cookers are used by a minority [4]. Owing to a weak road network and a high kerosene official pump price, there is no access to electricity or petroleum products in the country's rural areas. According to research, wood is used as a source of electricity by 86 percent of Nigerian rural households [5]. Nigerians consume a small amount of energy per capita, around one-sixth of what developed countries consume.

Electricity production in Nigeria is very disappointing as a result of the low execution of the Nigeria power generation area. Such terrible events can be credited to the high pace of transmission losses, the low pace of generation limit, and poor income assortment in fulfilling energy needs in Nigeria [6]. As a result, Nigeria's poverty rate is high. The most important metrics of a country and its economy are its Gross Domestic Product (GDP) and per capita income are two indices of a country's economic well-being [7].

The globe is changing ceaselessly continuously from fossil fuel and adjusting towards renewable energy assets to replace customary fossil fuel; Nigeria ought not to be absolved from this development. The current green energy options in Nigeria are solar, wind, biomass waste, and hydropower [8]. Biomass Waste, a mainstream type of sustainable power source, is viewed as a valid and green electrical energy source that numerous produced and producing nations turned out to be expanding their latent capacity. Electricity demand and supply turned out to be insufficient in Nigeria. This insufficiency of electricity restricts person, business as well as mechanical profitability together with financial development. What is the utilization of a system free-

[1] Energy Commission of Nigeria (ECN). https://www.databank.energy.gov.ng/

from steady electricity? Indeed, even God made light first. A practical and steady inventory of electricity ought to be one of the needs of the government in the country's advancement.

With the government intervention in an improved power sector, the country's economy will rapidly grow as jobs will be done faster through energy. Putting resources into waste will cause an expansion in the amount of electricity produced in Nigeria. At present, Waste is a sustainable, low-carbon energy emission and has an incredible improvement potential. The improvement and usage of waste to energy with current high and innovations are of extraordinary importance in tackling the energy situation in Nigeria, the two-fold weight of financial development and the natural environmental impact humans are confronted with, enhancing the social economy and biological condition [9]. Also, utilizing waste for energy will help reduce landfill usage and expansion, serve as energy savings for fossil fuel, and be competent in producing combustible fuel commodities like methanol, methane, ethanol, or synthetic fuels.

The current Nigerian electricity situation

Hydropower, which is less expensive than other forms of energy, has been greatly more important than other sources [10] as a result of zero carbon dioxide emission, low fuel cost, and is readily available 24/7 except for seasonal precipitation. The power authority generates electricity using a combination of hydro and thermal energy sources. Nigeria's power generation is centralized and distributed via the national grid, and the grid is controlled by the National Control Centres (NCC) in Osogbo, with about 17 substations across the nation [11]. Nigeria's national energy grid, which forms part of 23 generating stations with a total installed capacity of approximately 11,165.4 MW, is overseen by generation companies (Gencos), independent power suppliers, and the Niger Delta Holding Company (NIPP).

There are 23,753 kilometers of 33-kV cables, 19,226 kilometers of 11-kV lines, and 679 33/11-kV substations in the distribution industry. There are also 680 substation injectors and 1,790 distribution transformers [11]. In 2013, the power plant's total nameplate capacity was 6,953 MW, with 4,598 MW of usable capacity and an average of 3,800 MW provided [12]. Also, by late 2014, the total installed capacity was 7,445 MW, and the available capacity was 4,949 MW, with an average generation of 3,900 MW. By the middle of 2015, a total of 58 license stations were connected to the on-grid generation with a total capacity of 26,4223 MW, which are majorly thermal stations located in the southern part of the country. In late 2018, the Transmission Company of Nigeria generated 125,346 MW while 127,157.7 MW was generated as of early 2019.

So far, Nigeria has recorded a rise of 1811.3 MW in the power generated in January 2019. According to the News Agency of Nigeria (NAN), the current capacity transmitted and the operational network capacity are 9000 MW and 5500 MW respectively. NAN also reported that the peak generation attained so far in Nigeria is 5222.3 MW as its maximum energy generated remains at 109,372.01 MWh, while the national demand forecast stood at 19,100 MW and the installed available capacity was 11,165.40 M. As of the moment, Nigeria now can produce roughly 13,000 MW but can only transfer 7,500 MW, while the transmission companies have access to about 4000 MW of the power production as they distribute to other distribution companies [13].

The per capita electricity generation in Nigeria was reported at 145 kWh per capita, (World Bank), among other countries, Nigeria has the smallest number. Despite the effect of electricity on total GDP, Nigeria appears to be in serious trouble. The country's inability to satisfy its electricity demand is the product of several issues, including a lack of preventive and regular maintenance of facilities, overloading of equipment, poor funding of the organization, vandalizing of PHCN equipment, and many more which has brought about detrimental to economic growth (CBN, 2000). One of the major causes of the country's growing electricity supply and demand gap has been insufficient facilities and equipment to increase electricity supply.

The challenges facing Nigeria's electricity

The need for energy in Nigeria is on the rise as the population is increasing, thereby making demand twice the supply. The current energy guidelines for cities are appalling, as the demand for and availability of

electricity in rural areas do not align with the country's energy development strategy. For their energy needs, individuals living in rural areas rely on woodburning stoves and biomass waste, which causes severe deforestation and pollutes the greenhouse with toxic gasses, resulting in global warming and atmospheric worry. The key problem is supplying energy to cities and areas where industrialization is taking place, resulting in an energy supply imbalance in the political and economic ecosystem. When the current growing population is compared to the amount of available power plant capacity, it is clear that Nigeria will be unable to meet the energy demand. Rural residents continue to be without electricity [14].

Nigeria's energy crisis is caused by shortages in crude oil, especially kerosene and diesel. Even though Nigeria has at least five government-owned refineries, imports account for 75% of the country's petroleum necessities, amounting to 450,000 barrels per day. The subsidy financing the importation of energy, according to the Minister of Power, petroleum products has ranged between 700 and 800 billion naira since 2008 [15]. Furthermore, PHCN, formerly known as NEPA, is a state-owned company that has been unable to supply and provide 8 hours of electricity per day without inequality as a result of transmission losses and distribution losses [14].

Other energy crises include a lack of concern for recovering cost and adequate economic value to engage inefficient energy production. Nigeria relies upon a non-sustainable energy source notwithstanding its huge potential in inexhaustible sources, for example, sunlight-based, wind, waste, and hydro. Also, government intervention is needed to fund and support the PHCN and other self-generating plants that run on a renewable source in generating more power for the nation; adequate measures should be taken care of in maintaining the power station for effective production and supply of electricity.

The absolute capability of these renewables is assessed above 68,000 MW, which is over multiple times the present electricity generated. In contrast to non-renewable energy sources, waste is inexhaustible as, in just a short timeframe is expected to stockpile what has been put to make use of as a source of power. Waste, likewise, is a main sustainable energy source that discharges carbon dioxide. On the off chance that the waste resources are being utilized reasonably, there is no net carbon emanation throughout a pattern of waste production [16].

What are waste resources?

Waste (or wastes) are products that are undesirable or unusable. Waste is any material that is discarded after it has served its purpose or that is unnecessary, insufficient, or unusable. An invention that lifts a waste item's reward above zero can transform it into a side effect, joint item, or asset [17]. They include all marine and terrestrial vegetation, as well as all waste, including solid waste (MSW), metropolitan biomass trash (effluent), organic leftovers (manures), agriculture and livestock residues, and specific forms of environmental waste. Petroleum has long been the lifeblood of the world's energy markets. The only other renewable resource mineral-rich that can be used to offset petroleum products remains waste [18].

The word biomass waste implies to all-natural substance gotten after plants (counting green growth, trees, and harvests). The energy of the sun is absorbed by organic matter, stored in concoction ties and may be called waste capital. As the bonds between adjacent carbon, hydrogen, and oxygen atoms are dissolved by absorption, oxidation, or disintegration, these compounds release their retained compound energy. Waste has always been a major source of energy for humanity, accounting for 10–14 percent of the world's energy supply [19]. The country's population growth has led to a rise in waste disposal with poor management schemes, which is now posing a threat to the environment and health of several people as a result of the creation of illegal dumpsites across the country [20].

Although Nigeria's solid waste management issues are caused by inadequate collection and disposal practices, a shortage of waste management databases, insufficient funding, ignorance of the dangers of poor waste management skills, and lastly, individual ability to comply with the law, despite the threat waste is posing to the human environment, some opportunities can be benefitted from them. These opportunities could result in the recycling, reuse, reduction, and restoration of waste into wealth. Involving the three tiers of the

government in supporting ecofriendly and green waste management technologies and also supporting the private sector will help in boosting the economy and help reduce waste pollution across the country [21].

Nigeria's waste resources

Solid waste production is a daily phenomenon in Nigeria, resulting from an extensive variety of human activities [22] Solid waste generation in Nigerian cities is proportional to population, environment, politics, and commerce. Much of this can be due to the human element; as seen in *Table 1*, a growth in population has, as a result of this, created a rise in waste generation despite adequate waste management.

Table 1. The present and expected waste generation patterns for various regions around the world.

Region	Available Resources			Forecasting for 2025			
	Total City Population (Millions)	City Waste Generated		Estimated Population		Forecasted City Waste	
		Per Capita (Kg/Capita/D Ay)	Total (Tons/Day)	Total Population (Millions)	City Population (Millions)	Per Capita (Kg/Capita /Day)	Total (Tons/Day)
African nations	260	0.65	169,119	1152	518	0.85	441,840
Asia and the Pacific	777	0.95	738,958	2124	1229	1.5	1,865,379
Central Asia and Europe	227	1.1	254,389	339	239	1.5	354,810
Latin America and the Caribbean	399	1.1	437,545	681	466	1.6	728,392
The Middle East and North Africa continent	162	1.1	173,545	379	257	1.43	369,320
OECD	729	2.2	1,566,286	1031	842	2.1	1,742,417
South Asia state	426	0.45	192,410	1938	734	0.77	567,545

Source: [23].

One of the main environmental issues facing developed countries has been described as municipal solid waste [24]. The volume of trash yielded per person per day ranges from 0.4 to 1.72 kg. For well-developed countries, waste generation varies from 2.75 to 4.50 kg/capita/day, and for underdeveloped cities is estimated as 0.5kg/capita/day [25]. The annual population growth has resulted in rising of waste generation in Nigeria, with 6471 Gg of waste generated in 1959, which increased to 26600 Ggt in 2015 and is still expected to rise to 2985 Gg by 2020 and 33500 Gg by 2025.

Every year, over 32 million tons of solid waste are produced in Nigeria, with just 20–30 percent being collected [26]. Individuals, businesses, and industries produce the majority of these wastes by littering the environment, which,, as a result of improper disposal, leads to blockages of drainage and sewage. Sorting, storage, collection, transportation, refining, resource recovery, recycling, and waste disposal all contribute to the production of solid waste [27]. Nigeria's waste disposal and management are regulated by the National Environmental Standards and Regulations Enforcement Agency (NESREA) is ubiquitous but has not achieved success in controlling the disposal and management of waste.

So many cities in Nigeria are still indiscriminating dumping of wastes on the roadside, drainages, and gully erosion sites, as few efforts are made through family clean-up of their immediate surroundings and laws guiding offenders for non-compliance with these regulations [28]. There are various waste management schemes and institutions existing in different cities of the country that help in waste management, disposal, and recycling of waste [27]. For instance, The Ondo State Waste Disposal Agency (OSWMA) is responsible for waste disposal risks, while the Ondo State Integrated Wastes Recycling and Treatment Project (OSIWRTP) is in charge of waste recycling in the state.

The waste generated per person per day is 0.71 kg/person/day (Babayemi and Dauda, 2009). Lagos, Nigeria's most commercialized province, is the region with the second-fastest growth rate in Africa and the seventh-fastest growth rate in the world with about 0.63 kg per day; the per capita waste generation is over 13000 tons of urban waste daily. Despite Lagos State being the leading state in Nigeria in controlling waste, the Lagos State Waste Management Agency (LAWMA) continues to face significant challenges in solid waste management. As a result, the need to hire private waste firm providers and other franchisees to help minimize waste collection and disposal is critical. Also, with a population of six million people and a high rate of waste disposal, Oyo State is one of the most populous states in Nigeria. The state's solid waste disposal is overseen by the Oyo State Solid Waste Management Authority (OYOWMA). *Table 2* shows the per capita per day solid waste generation rates in Nigeria for various cities.

Table 2. Wastes per capita in Nigerian cities.

City	Kg/Capita/Day	City	Kg/Capita/Day
Lagos	0.63 0.56 0.51	Akure	0.43
Kano	0.58	Abeokuta	0.39
Ibadan	0.6	Aba	- 1.02 0.26 - 0.29
Kaduna	0.48 0.53	Ilorin	0.37
Port Harcourt	0.44	Lafia	- 0.62
Makurdi	0.45 - 0.74	Gombe	0.39
Onitsha	0.71	Jimeta	- 1.02
Nsukka	0.54	Abuja	0.60 - 0.66
Ako-Ekiti	0.46		

Source: [29].

Waste utilization

By 2050, waste production would have risen by 70%, from 2.01 billion metric tons in 2016 to 3.40 billion tonnes, resulting in a daily impact of 0.74 kilograms per person. Owing to rapid population and urbanization growth, annual waste production is anticipated to rise by 70% from 2016 to 3.40 billion tonnes by 2050 [29]. Waste can be in various structures like wood wastes, horticulture by-products, and solid waste. Waste, including biofuel and biogas for transportation, can provide thermal energy when properly used. There is enough waste to meet our needs for electricity and other items. According to climatic considerations, Nigeria has a thermal environment that is suitable for the development and breakdown of wastes by microscopic species. There are also plant and animal life developments throughout the entire year, which thus make waste and subsequently produce waste. There are several other ways of generating electricity from biomass wastes (digestion, gasification, etc.); however, this work focuses only on energy recovery from biomass waste through Gasification.

Extraction techniques for waste energy

Waste can be transformed into warm energy, unsolidified, dense, or vaporous energy, as well as other products, through an assortment of transformation forms. Waste can be separated and disposed of in different ways and can be grouped into categories for proper usage. These groups include landfills, incineration, composting, recovery and recycling, animal feeding, reduction, and reuse of waste. There are also smart techniques that could help in sorting out these wastes from one another. They include Trommel Screeners which are used to sift units rotated as a recyclable material when fed into their interior, Cyclones also, is a spiral airflow action that helps in sorting solid waste from non-solid waste, Magnetic Separator make use of strong magnetic fields to separate iron, steel, away from non-metallic bulk materials, and other separation pieces of equipment are the Electrostatic separators, Optical Air jet sorters, Hydro cyclones which are found in the material recycling facilities, owned and operated by the waste management scheme.

Biopower technologies are alternate sources of electricity production in the United States, with a 10GW cap imposed. The entire current cap is contingent on the development of a direct-ignition invention. Co-terminating waste in current coal-terminated boilers, as well as the presentation of high-efficiency gasification, joined cycle system, power device system, and measuring system, will all be part of future productivity

improvements [30]. Direct burning, co-terminating, gasification, pyrolysis, anaerobic absorption, and fermentation are some of the bio-power technologies.

Direct burning

This is the simplest way to separate waste from electricity. Waste fuels that can be consumed by modern waste combustion include biomass, field deposits, wood-pulping alcohol, Urban Solid Waste (MSW), and reject-determined gasoline. Burning waste releases steam, which spins a turbine that converts chemical energy into electricity and produces electricity. Only some kinds of waste materials are used for direct combustion due to the risk of debris formation (which dribbles boilers, decreases effectiveness, and boosts costs). (Levine, 1996).

Gasification

In this system, exposing a solid fuel to high temperatures and low oxygen, gasification transforms it into a gaseous fuel. The process emits carbon monoxide, carbon dioxide, phosphorus, hydrogen, and methane, among other gases. The vapor is used to fuel a high-efficiency combined-cycle gas turbine. There are several advantages of gasification to burning solid fuel. One drawback is that one of the byproduct gases, methane, can be treated and used similarly to natural gas. Another advantage of gasification is that it produces a fuel with fewer impurities, which can result in lower emissions when burnt. It can also contain a gas mixture, a combination of carbon monoxide and hydrogen that, under the right conditions, can be used to generate hydrocarbons (e.g., methane and methanol) to replace fossil fuels. Hydrogen is a promising low-polluting fuel that may quickly replace gasoline and petroleum [31].

Pyrolysis

Pyrolysis, in its most basic form, entails heating waste to eliminate the unpredictable problem while leaving the charcoal behind. Since charcoal, which accounts for a large portion of the heaviness of the first waste, produces a comparable amount of energy, this process has increased the energy thickness of the first content, enhancing the fuel's transportability. Since, the charcoal absorbs at a far higher temperature than the first waste, it's better for adding together varieties. In recent years, increasingly complex pyrolysis methods have been developed to extract volatiles that are already discharged into the environment.

A hydrogen-rich gas (possibly a fuel) as well as carbon monoxide were among the volatiles collected. Methane, methanol, and other hydrocarbons are made from these mixtures. Bio-unrefined, ignitable fuel is delivered using streak pyrolysis. Waste is converted to pyrolysis oil synthetically using heat. The oil is then singed like oil to produce energy since it is easier to store and transport than strong waste material. Pyrolysis can also convert waste into phenol oil, which is utilized in the production of wood cement, molded plastics, and froth defenses [32].

Digestion

Anaerobic bacteria are used to digest waste. These microorganisms are typically found at the bottom of bogs or in other places where there is no oxygen; they contribute to global warming and hydrogen by eating dead natural matter. These microbes were used for our benefit. By identifying the natural crisis, such as throwing animal manure or human waste into digesters and incorporating microorganisms, we are able to capture the radiated gas for use as an energy source. This technique is a highly effective way of extracting useful energy from such waste. Animal manure will typically recover up to 66 percent of its fuel capacity. Methane gas may also be collected from landfills, which is a similar process. The nearby landfill receives a considerable volume of domestic garbage, such as kitchen scraps, garden cuttings, and trimming. Anaerobic microscopic organisms at the base of such tips could continuously deteriorate the natural issue and transmit methane over several years. The gas may be collected and used by burying punctured funnels that accumulate and carry the gas to the surface under an impenetrable layer of dirt.

How electricity is generated from waste

Waste biomass is biomaterial from living or, as of late, living beings, for example, timber, farming waste, and animal fertilizer. The majority of the biopower plants employ the direct burning system. They digest waste straightforwardly to create a lofty-pressure mist that navigates the steam engine to supply electricity. Separated or drained steam from power plants is often used for collecting forms or heating piles in a variety of waste processing facilities. This Consolidated Thermal and Power (CHP) system astoundingly generates greater energy productivity by almost 8% than the traditional waste-to-energy scheme, which has efficiencies of up to 20%. Occasional heating requirements would have an impact on the CHP system's performance. There are just a few key components in a basic waste electric generation scheme. This involves a variation of the following for a steam cycle: Boiler, Pumps, Turbine, Generator, Condenser, Cooling tower, Outlet valves, and Hopper.

There are a few different ways we can get helpful sustainable power sources from waste other than consuming it straightforwardly.

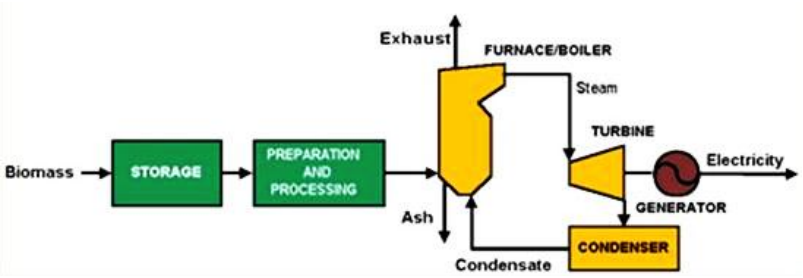

Fig. 1. Direct steam turbine.

To make it possible to generate electricity from waste, a mix of the Gasification Method will be increasingly compelling as the strategy will have the option to give a full electricity yield and to improve assimilation impediment. The fundamental gasification process includes Oxidation, Drying, Pyrolysis, and reduction [33]. During pyrolysis, methane and different hydrocarbons are created from the waste by the activity of heat, which leaves a responsive roast [34]. During combustion, the volatiles and roast are incompletely singed in air or oxygen to produce heat and carbon dioxide [35].

In the decrease stage, carbon dioxide retains heat and responds with the rest of the singe to deliver carbon monoxide (producer gas) [36]. The nearness of water fume in a gasifier brings about the production of hydrogen as an optional fuel part. The two types of gasifiers are stationary bed and fluidized bed gasifiers that can be used to complete this transformation. The transformation of waste into a useful flammable gas includes a two-arrange process. The primary, which is called pyrolysis, happens beneath 600° C when unstable segments contained inside the waste are discharged [37]. These may incorporate natural mixes, hydrogen, carbon monoxide, tars, and water fumes.

Pyrolysis leaves a strong build-up called a roast. In the second phase of the gasification process, this roast is responded to with steam or consumed in a limited amount of air or oxygen to create further burnable gas. Contingent upon the exact plan of the gasifier picked, the item gas may have a thermal estimation of 6 – 19 MJ/Nm^3 [38]. Gasification produces carbon monoxide, carbon dioxide, helium, hydrogen, and other hydrocarbons are also present in this combination, which would then be able to be utilized legitimately in gas turbines and boilers or utilized as forerunners for integrating a wide scope of different synthetic concoctions [39]. What's more, various techniques can be utilized to deliver more excellent gases, including aberrant heating, oxygen blowing, and pressurization. After the proper treatment, the subsequent gases can be singed legitimately for cooking or heat supply or utilized in optional change gadgets, for example, internal combustion engine motors or gas turbines, for delivering power or shaft power.

Why waste energy?

Waste of Energy is a way of killing two birds with one stone at a time [40]. Biomass utilizes its waste product to provide energy, which assists in waste control in Nigeria. Waste can also produce more energy (multiple measures) than that generated by the sun and hurricanes. It will also aid in the reduction of the neighborhood landfill by 90% and the management of emissions released. Waste will prompt an increment in income generation and moderate our outside trade. An increment in energy creation will yield greater efficiency for businesses, and the ratio in which they close down because of the way they use up more power will be diminished too negligible.

Waste management is a challenge in Nigeria, with an estimated 32 million tonnes of MSW per year [26]. Cities with dense populations, such as Abuja, Ibadan, Port Harcourt, and Lagos, contribute the most to MSW. Implementing waste to energy in Nigeria will help in proffering solutions for the electricity challenge in the country. One tonne of MSW gives 500 – 600 kWh of electricity from the Waste generated in Nigeria. The Lagos State Electricity Distribution Company could generate 141.95 to 170.34 million Naira at N28.39 per kWh from the 10,000 tonnes of MSW per day.

Numerous neighborhood production lines/organizations will jump up, and outside speculators will be anxious to put resources into Nigeria with little worry about electricity. The Foundation of bio-power plants will, without a doubt, create more employment and, in a roundabout way, decrease the number of people living in demand, which is increasing at an alarming pace every day. Most of Africa's crowded nation requires more than multiple times its flow of electricity yield to ensure proper and adequate distribution for its 200 million individuals - about a portion with no hope to get access by any means, according to babatunde fashola, the minister of power in Nigeria, waste is potential, energy promising - with a massive venture, partner participation, and advancement of indigenous innovations.

Nigeria, which is facing a shortage of electricity, has the potential to increase its energy demand by exploring the waste in the energy system as it helps to control waste management and is considered an electricity generation means. This is achievable through government policies in facilitating innovation and ensuring its implementation.

3 | Conclusion

This study concludes by exploring the benefits and limitations of waste energy generation as shown below:

Waste energy generation benefits

Some of the advantages of using waste as a source of electricity are described below:

I. Waste vitality is a plentiful, reliable, environmentally sustainable, and renewable energy source.

II. Since waste absorbs the same volume of carbon during its development that it emits when burnt, it does not emit carbon dioxide into the environment.

III. Adverse impacts such as acid rain, mine spoils, open pits, oil leaks, hazardous waste dumping, and river damming are not associated with waste resources.

IV. It may be utilized in the same facilities or power plants that are already consuming fossil fuels to generate electricity.

V. Waste fuels are safe for the atmosphere. Waste fuels are made from renewable plants that fix carbon dioxide as they grow, so their use does not add to the carbon footprint.

VI. Also, burning trash as fuel prevents polluting landfills.

VII. Alcohols and other fuels derived from waste are efficient, viable, and relatively clean burning.

VIII. In most parts of the world, waste is readily available and can be grown.

Limitations towards waste energy generation

The following are the shortcomings of biomass waste energy production, which is also in line with the view of [16]:

I. Waste is still a costly source of energy, both to produce and to turn into alcohol since a large amount of waste is required.

II. Because a lot of energy is needed to develop the plant mass, and waste is difficult to store in its natural state, there is almost inevitably a net energy loss on a small scale.

III. One of the drawbacks of waste is that it can be detrimental to the environment if it is burned directly because it emits carbon dioxide, which leads to atmospheric warming and future changes in the atmosphere.

IV. Burning releases soot and other toxins into the environment.

V. Excessive wood collection can lead to forest destruction. Soils that have been stripped of their trees are prone to eroding and do not retain rainfall. Increased rainfall has the potential to cause flooding downstream.

VI. When plant and animal wastes are used as fuel, they cannot be used as fertilizer.

VII. Waste produces less energy than a similar amount of fossil fuels; soil devoid of fertilizer is nutrient-depleted and produces fewer crops.

VIII. Waste has less energy than a similar volume of fossil fuels.

Author Contributions

Chukwuemeka Joshua Okafor conducted the primary research, reviewed existing literature, and synthesized key findings on energy generation in Nigeria. The author contributed to writing the manuscript and formulating the study's conclusions.

Funding

This research did not receive any specific funding from public, commercial, or non-profit organizations.

Data Availability

Not applicable.

References

[1] Colgan, J. D. (2009). The international energy agency. *Challenges for the 21st century. gppi energy policy paper*, *6*(6), 1–20. https://www.files.ethz.ch/isn/109115/GPPiPP6_IEA_final.pdf

[2] Adeniran, A. O., Muraina, M. J., & Ngonadi, J. C. (2023). Energy consumption for transportation in sub-saharan Africa. In *Achieving net zero* (Vol. 20, pp. 203–231). Emerald Publishing Limited. https://www.emerald.com/insight/content/doi/10.1108/S2043-052320230000020009

[3] Famuyide, O. O., Anamayi, S. E., & Usman, J. M. (2011). Energy resources' pricing policy and its implications on forestry and environmental policy implementation in Nigeria. *Continental j sustainable development*, *2*, 1–7. https://www.academia.edu/download/4153534/Vol_2_-_Cont._J._Sust._Dev..pdf_1-7n.pdf

[4] Abiodun, R. (2003). Fuel price hike spells doom for Nigeria's forest. *Available at htt: www. islamonline. net/english/index. shtml*.

[5] Williams, C. E. (1998). *Reaching the african female farmers with innovative extension approaches: success and challenges for the future* [presentation]. International workshop on women agricultural intensification and household food security at university of cape coast, ghana, 25th-28th june (p. 600).

[6] Komolafe, O. M., & Udofia, K. M. (2020). Review of electrical energy losses in Nigeria. *Nigerian journal of technology*, *39*(1), 246–254. https://www.ajol.info/index.php/njt/article/view/194123

[7] Karekezi, S., & Ranja, T. (1997). *Renewable energy technologies in Africa.*

[8] Aliyu, A. K., Modu, B., & Tan, C. W. (2018). A review of renewable energy development in Africa: a focus in south africa, egypt and Nigeria. *Renewable and sustainable energy reviews*, *81*, 2502–2518. DOI:10.1016/j.rser.2017.06.055

[9] Akhator, E. P., Obanor, A. I., & Ezemonye, L. I. (2016). Electricity generation in Nigeria from municipal solid waste using the swedish wasteto-energy model. *Journal of applied sciences and environmental management*, *20*(3), 635–643. https://www.ajol.info/index.php/jasem/article/view/147058

[10] Famuyide, O. O., & Adu, A. O. (2004). Socio-economic impacts of deforestation in the sudano-sahelian belt of Nigeria. *Journal of forestry research and management*, *1*(1–2), 94–106.

[11] Adhekpukoli, E. (2018). The democratization of electricity in Nigeria. *The electricity journal*, *31*(2), 1–6. DOI:10.1016/j.tej.2018.02.007

[12] Ohajianya, A. C., Abumere, O. E., Owate, I. O., & Osarolube, E. (2014). Erratic power supply in Nigeria: causes and solutions. *International journal of engineering science invention*, *3*(7), 51–55. https://www.researchgate.net/profile/Anthony-Ohajianya/publication/318685479_Erratic_Power_Supply_In_Nigeria_Causes_And_Solutions/links/5977ba450f7e9b277721cf33/Erratic-Power-Supply-In-Nigeria-Causes-And-Solutions.pdf

[13] Esiedesa, O. (2020). *Post privatization: Nigeria stranded power rises 263% to 3,742 MW". vanguard news Nigeria*. https://www.vanguardngr.com/2021/01/post-privatisation-nigerias-stranded-power-rises-263-to3742mw/

[14] Adenikinju, A. (2005). *Analysis of the cost of infrastructure failures in a developing economy: the case of the electricity sector in Nigeria*. African economic research consortium.

[15] Iwayemi, A. (2008). Nigeria's dual energy problems: policy issues and challenges. *International association for energy economics*, *53*(1), 17–21.

[16] Sriram, N., & Shahidehpour, M. (2005). Renewable biomass energy. *IEEE power engineering society general meeting, 2005* (pp. 612–617). IEEE. https://ieeexplore.ieee.org/abstract/document/1489459/

[17] Messerli, P., Murniningtyas, E., Eloundou-Enyegue, P., Foli, E. G., Furman, E., Glassman, A., … Moatti, J. P. (2019). *Global sustainable development report 2019: the future is now–science for achieving sustainable development*. United Nations.

[18] Allen, S. A. A., Ree, A. G., Ayodeji, S. A. M., & Deborah, S. A. E. (2016). Lignocelluloses: an economical and ecological resource for bio-ethanol production-a review. *Management*, *1*(3), 128–144. https://www.academia.edu/download/104613576/SOKAN_PUBLICATION_LIGNO_new_10.11648.j.ijnrem.20160103.18.pdf

[19] Perlack, R. D. (2005). *Biomass as feedstock for a bioenergy and bioproducts industry: the technical feasibility of a billion-ton annual supply*. Oak ridge national laboratory.

[20] Ferronato, N., & Torretta, V. (2019). Waste mismanagement in developing countries: a review of global issues. *International journal of environmental research and public health*, *16*(6), 1060. https://www.mdpi.com/1660-4601/16/6/1060

[21] Amuda, O. S., Adebisi, S. A., Jimoda, L. A., & Alade, A. O. (2014). Challenges and possible panacea to the municipal solid wastes management in Nigeria. *Journal of sustainable development studies*, *6*(1). https://scienta.asia/index.php/jsds/article/view/644

[22] Ezechi, E. H., Nwabuko, C. G., Enyinnaya, O. C., & Babington, C. J. (2017). Municipal solid waste management in Aba, Nigeria: Challenges and prospects. *Environmental engineering research*, *22*(3), 231–236. https://koreascience.kr/article/JAKO201730048507852.page

[23] Arowolo, A. O., Deng, X., Olatunji, O. A., & Obayelu, A. E. (2018). Assessing changes in the value of ecosystem services in response to land-use/land-cover dynamics in Nigeria. *Science of the total environment*, *636*, 597–609. DOI:10.1016/j.scitotenv.2018.04.277

[24] Ayuba, K. A., Manaf, L. A., Sabrina, A. H., & Azmin, S. W. N. (2013). Current status of municipal solid waste management practise in FCT Abuja. *Research journal of environmental and earth sciences*, *5*(6), 295–304. https://pdfs.semanticscholar.org/4d71/74d1f056a2103ea696073780f67093417763.pdf

[25] Yusuf, R. O., Adeniran, J. A., Mustapha, S. I., & Sonibare, J. A. (2019). Energy recovery from municipal solid waste in Nigeria and its economic and environmental implications. *Environmental quality management*, *28*(3), 33–43. https://onlinelibrary.wiley.com/doi/abs/10.1002/tqem.21617

[26] Bakare, W. (2016). *Solid waste management in Nigeria*. BioEnergy consult, powering clean energy future. https://www.bioenergyconsult.com/tag/nigeria/

[27] Abila, B., & Kantola, J. (2013). Municipal solid waste management problems in Nigeria: evolving knowledge management solution. *International journal of environmental and ecological engineering*, *7*(6), 303–308. https://www.academia.edu/download/81930828/4713.pdf

[28] Oloruntade, A. J., P. A. Adeoye, P. A., & F. Alao, F. (2013). Municipal solid waste collection and management strategies in akure, south-western Nigeria. *Caspian journal of environmental sciences*, *11*(1), 1–10. https://cjes.guilan.ac.ir/article_1111.html

[29] David, V. E., Wenchaoa, J., Johna, Y., & Mmerekib, D. (2019). Solid waste management in Monrovia, Liberia: Implications for sustainable development. *The journal of solid waste technology and management*, *45*(1), 102–110. https://www.ingentaconnect.com/content/jswt/jswt/2019/00000045/00000001/art00010

[30] Xu, Y., Yang, K., Zhou, J., & Zhao, G. (2020). Coal-biomass co-firing power generation technology: current status, challenges and policy implications. *Sustainability*, *12*(9), 3692. https://www.mdpi.com/2071-1050/12/9/3692

[31] Bai, Z., Liu, Q., Lei, J., Li, H., & Jin, H. (2015). A polygeneration system for the methanol production and the power generation with the solar–biomass thermal gasification. *Energy conversion and management*, *102*, 190–201. DOI:10.1016/j.enconman.2015.02.031

[32] Zaman, C. Z., Pal, K., Yehye, W. A., Sagadevan, S., Shah, S. T., Adebisi, G. A., … Johan, R. Bin. (2017). Pyrolysis: a sustainable way to generate energy from waste. *Pyrolysis*, *1*, 3–36. https://books.google.com/books?

[33] Portha, J. F., Parkhomenko, K., Kobl, K., Roger, A. C., Arab, S., Commenge, J. M., & Falk, L. (2017). Kinetics of methanol synthesis from carbon dioxide hydrogenation over copper–zinc oxide catalysts. *Industrial & engineering chemistry research*, *56*(45), 13133–13145. https://pubs.acs.org/doi/abs/10.1021/acs.iecr.7b01323

[34] Roos, C. J. (2010). *Clean heat and power using biomass gasification for industrial and agricultural projects*. Northwest CHP Application Center Olympia, WA, USA.

[35] Molino, A., Chianese, S., & Musmarra, D. (2016). Biomass gasification technology: the state of the art overview. *Journal of energy chemistry*, *25*(1), 10–25. DOI:10.1016/j.jechem.2015.11.005

[36] Zhang, J., Weng, X., Han, Y., Li, W., Gan, Z., & Gu, J. (2013). Effect of supercritical water on the stability and activity of alkaline carbonate catalysts in coal gasification. *Journal of energy chemistry*, *22*(3), 459–467. DOI:10.1016/S2095-4956(13)60060-1

[37] Shen, D., Xiao, R., Gu, S., & Luo, K. (2011). The pyrolytic behavior of cellulose in lignocellulosic biomass: a review. *RSC advances*, *1*(9), 1641–1660. https://pubs.rsc.org/en/content/articlehtml/2011/ra/c1ra00534k

[38] Akia, M., Yazdani, F., Motaee, E., Han, D., & Arandiyan, H. (2014). A review on conversion of biomass to biofuel by nanocatalysts. *Biofuel research journal*, *1*(1), 16–25. https://www.biofueljournal.com/?_action=articleInfo&article=4747&vol=542

[39] Rahimpour, M. R., Arab Aboosadi, Z., & Jahanmiri, A. H. (2012). Synthesis gas production in a novel hydrogen and oxygen perm-selective membranes tri-reformer for methanol production. *Journal of natural gas science and engineering*, *9*, 149–159. DOI:10.1016/j.jngse.2012.06.007

[40] Opaluwa, E. (2019). *Waste to Energy: Killing two birds with one stone. Energy and Environment*. https://www.amazon.com/?_encoding=UTF8&tag=mntzr-20&linkCode=ur2&linkId=fbdfb9b1ea167046640ea9a6800add6e&camp=1789&creative=9325&subId=M7445782126433140803