Conversion of organic wastes to electricity in Nigeria: legal perspective on the challenges and prospects

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Abstract

This study explores the need for conversion of wastes to energy for a sustainable power sector and environmental development in Nigeria, to decrease greenhouse gas emissions and to offer incentives for investments in renewable energy sources, and to mitigate the concerns on disposal of hazardous wastes in the country. The study adopts a library-based doctrinal legal research technique with a conceptual approach, relying on existing literature. It explores the potency of existing laws and other legal provisions binding on the practice of waste management to power in Nigeria. Also, it carries out a comparative appraisal of the renewable system through organic wastes to electricity in other countries. The key finding of the study is that if practical measures are taken by the Nigerian government to control waste disposal, it will minimise wastes from the various sources in conformity with the legal and regulatory requirements and this can be utilised to generate electricity. The study proposes a model for converting wastes to electricity to sustain the ever-intensifying demands for energy and to combat ecological issues in Nigeria. The research concludes with recommendations for the fusion of regulations and non-regulatory incentives for conversion of wastes to electricity in Nigeria's power sector and advocates coherent legal framework on sources of energy with stringent enforcement of energy laws for stable electricity generation and sustainability in Nigeria's power sector.

Keywords Biomass energy · Electricity · Environment · Waste conversion · Waste disposal · Waste generation

JEL Classification Q4 · Q5 · K32 · K12 · K2 · P28 · K42

Abbreviations

MW	Megawatts
MJ/KG	Megajoules per kilogram
NERC	Nigerian Electricity Regulatory Commission
EPSR	Electric Power Sector Reform
TWh	Terawatt-hour
Mtoe	A unit of energy used to describe the energy content of all fuels, typically on an enormous scale

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Introduction

The world is shifting towards low carbon energy through the conversion of wastes to useful resource for man's use (Li et al. 2020). However, it seems that Nigeria has not taken advantage of her endowed renewable energy resources to generate electricity to solve the problem of an ongoing power outage in the country (Oke 2016). This deficit of stable electricity in Nigeria has impeded the nation's economic growth (Aderoju et al. 2017). Nigeria generates approximately 4000 MW of electricity which is not adequate for its populace of over 206.14 million energy demands. Equally, the need to meet the rising demands justifies the adoption of other alternatives such as the conversion of wastes to energy to address power supply shortage in the economy (Okeniyi et al. 2012; Akinyemi et al. 2019a, b).

As the legal regime under the Electric Power Sector Reform Act, 2005, introduced, the Power Holding Company of Nigeria which was unbundled into 18 electrical firms as part of the reform processes in the sector but this has not crystallised to stable electricity supply in the country as

over 50% of Nigeria's population still lacks stable electricity (Oke 2016). This justifies the premium put into the current research, to explore the values embedded in the conversion of waste to energy.

The current research sought to provide the legal and regulatory framework on renewable energy and conversion of wastes to electricity. The research takes a look at the prospects of wastes to electricity in Nigeria's power sector, challenges of conversion of wastes to energy in Nigeria power sector. The article also took a cursory look at the overview of the global policies on biomass energy utilisation, and lessons Nigeria can replicate in the conversion of wastes to electricity from some advanced countries, bioenergy strategies in the UK, bioenergy and allied policies in Italy, Netherlands and Sri Lanka. The study then presented a discussion of findings and a concluding section suggesting a few salient recommendations.

Materials and methods

This prompted this study for the conversion of wastes to energy, a policy that has been embraced by several countries in the world to promote electricity security and sufficiency (Jiang et al. 2012). The study explores extant literature to unpack the trends of waste management practices, the challenge of power supply and the use of organic waste to generate energy in Nigeria. The research relies on relevant literature from internet sources, a comprehensive appraisal of academic writing and analysis of significant statutory provisions with comparative analysis of the conversion of wastes to energy in the UK, Italy, Netherlands and Sri Lanka among others. This is aimed to project learning on the current trends on the practice of conversion of waste to energy, and possibly suggest a suitable approach on how to replicate it in the Nigerian power sector. The study also adopts secondary sources, such as bulletins, textbooks and primary sources. Other sources such as judicial authority reports and some unstructured consultations with some electricity consumers and regulatory bodies in the power sector were considered. This is to gain valuable knowledge, to propose reform and to suggest the need to use the lessons learnt from the literature in the research process. It is also to promote energy security and stable electricity supply in Nigeria.

Results and discussion

The key finding of the study is that if practical measures are taken by the Nigerian government to control waste disposal, it will minimise wastes from the various sources in conformity with the legal and regulatory requirements and this can be utilised to generate electricity. The study proposes a

model for converting wastes to electricity to sustain the ever-intensifying demands for energy and to combat ecological issues in Nigeria.

It is apparent that Nigeria, as a nation, has abundant wastes to be converted to power to generate electricity to combat ongoing electric power outage in the country. Still, little or nothing has been done in this regard due to over-dependence on hydroelectric and thermal energy sources. This trend was emphasised by Akhator et al. (2016), who noted that conversion of wastes to energy technology is still at infancy stage in Nigeria's power sector, compared to other countries where it has been utilised to generate heat and electricity in commercial quantity for the benefits of their citizens.

Conversion of wastes to electricity will improve electricity supply in Nigeria as the demands for electricity supply in the country is more than the current 4000 MW in the national grid. This aligns with the notion of Oniemola and Sanusi (2007) stressing that renewable energy benefits are more than its environmental and social impacts which in this stead is essential for generating an adequate supply of electricity.

The privatisation and commercialisation of the Nigerian power sector have low impacts in promoting efficiency in the sector due to poor maintenance of electrical equipment. Oke (2013) had earlier emphasised that electricity supply in Nigeria relied significantly on hydropower, which has resulted in frequent outages of electricity due to underinvestment in other sources of energy. This was stressed by Oke (2016) stating that in Nigeria, constant electricity supply remains a problem, despite the huge capital investment in the sector.

Electricity generation from waste is sustainable as long as the appropriate technology is utilised. On the issue and concerns of appropriate technology (Akhator et al. 2016) noted that conversion of wastes to energy technology is still at infancy stage in Nigeria's power sector compared to other countries where it has been utilised to generate heat and electricity in commercial quantity for the benefits of their citizens.

The advantages of wastes to energy are a quantum such as a decline in wastes generation, cleanliness and decontamination, energy efficiency and stability in the power sector. These benefits were also summarised by Ibrahim (2002); and Sharmina et al. (2012) describing organic wastes as defective materials or materials made in the course of manufacture and utilisation of goods, especially those that are traceable by-products from plants and animals.

The current research sought to provide the legal and regulatory framework on renewable energy and conversion of wastes to electricity. To this end, the following are considered pertinent to the subject matter.

To intensify biomass impact as a renewable energy basis, decrease greenhouse gas emission and enhance ecological countryside growth. For biomass to be sustained, the following yardsticks must be met: Stakeholders such as the waste manufacturers, monitors, lawmakers, professionals, procedure and equipment merchants, educationalists, mass media and the citizens must be engrossed in domestic waste administration strategies and procedures (Ufua et al. 2019). This is essential for efficient domestic waste management guidelines and approaches by incorporating the obligations of all stakeholders in making wastes control efficient in Nigeria. Legislation at the national level mainly offers the essential legal framework for waste management (Olujobi and Olusola-Olujobi 2020). These legislations and policies should border on the formation of institutions for underpinning environmental strategies and policies with more focused on environmental legislations (Ufua et al. 2020a).

Conversely, lack of funding hampers execution of these laws, which sometimes lack public participation which is

a constraint to uniformity in the standard of waste management services. Also, there is a need for increased in budgetary allocations and human resources skills for waste management (Agboola 2011). There is the need for public acceptability of energy from wastes, as waste to power has many advantages it can render an economy. Recycling has many ecological benefits: it utilises less energy causing less pollution; it decreases the request for new resources; it reduces the quantity of waste landfilled. This necessitates the need for electricity to be provided efficiently without any detriment to the environment, the populace as uninterrupted power propels economic development and growth in a society. The concept of sustainable development includes the development of cleaner fuels and the need to improve the efficiency of energy use from the demand side.

There is the need for stringent legal framework on energy policy for sustainable economic growth which will set the nation on the firm ground of development for the interest of the present and future generations. Such procedure is expected to be technically efficient, economical and equitable in the sector (Fig. 1).

Fig. 1 Map of Nigeria exhibiting geographic allocation of renewable energy sources in the country. Source: https://www.google.com/search?tbs=simg:caqsyqejwkpunrznleavqeicmwpwagypgcamskmehxgffb78h1giza9ahzqfcb-ej-z-coec_18d6wofo_15j_1xpug_15t8amkaevgpfyixjatw4l0zeo6zjju9zwxqia94jjwinlkxhfvbnns7ldu3da1uh02iaedasqjq7-cbokcggiariedvnywlej3twqkang

[oxcgvhdgxhc9qlipydcgoil20vmgnybmykgwoicgfyywxszwzapyj2awks9t1zazmhpmgbw&q=nigeria+wind+map&tbs=isch&sa=x&ved=2ahukewio_-mcz9trahwrmfwkhtiscyiqwg4oahocagqjg&biw=1366&bih=657#imgsrc=2ug35xdo7bj3um](https://www.google.com/search?tbs=simg:caqsyqejwkpunrznleavqeicmwpwagypgcamskmehxgffb78h1giza9ahzqfcb-ej-z-coec_18d6wofo_15j_1xpug_15t8amkaevgpfyixjatw4l0zeo6zjju9zwxqia94jjwinlkxhfvbnns7ldu3da1uh02iaedasqjq7-cbokcggiariedvnywlej3twqkang). (Accessed September 6, 2020)

The gap in the literature

Most electricity generation in Nigeria come from the hydropower and thermal with minimal electrical energy produced from renewable energy bases. This is the primary source of electricity in Nigeria's power sector without considering renewable energy option with much energy potentials (Oyedepo 2012). The conventional energy sources tend to favour unified energy generation, which often steers to large-scale projects, substantial fiscal weight on Nigeria's economies and adverse ecological effects. The necessity for the decrease in greenhouse gas emissions may offer real encouragement to utilise other renewable energy sources such as the conversion of organic waste to electricity in Nigeria (Oke 2016; Egbertokun et al. 2018, 2020). A critical challenge facing the power sector in Nigeria is the absence of significant backing from the regulatory authorities in regulating the power sector. Another issue is the challenge with the development of competitive policies of electricity markets and to exercise their supervisory roles over the regulators, who are assigned to manage the sector to prevent abuse of discretionary powers by the officials on issues affecting electricity supply and generation in Nigeria (Olujobi and Olusola-Olujobi 2019).

Conversion of organic wastes to electricity is a viable option in Nigeria's power sector, better than other alternatives such as fossil fuel that tends to more expensive and not environmentally friendly (Okeniyi et al. 2012). Considering the volume of wastes generated in Nigeria through human undertakings and their toxic effects on the ecosystem and human health, triggered the need to embrace other technical schemes for safe discard of wastes, by converting it to electricity to end power outage for meaningful economic growth in the country (Olaleye and Fagbenle 2013). Studies have revealed that over 60–70% of the Nigerian masses does not have access to stable power (Oyedepo 2012). This problem may continue except if the Nigerian government expands its energy supply base and embrace wastes to energy know-how to decrease energy depletion and to save cost in the sector. Some of the significant problems with Nigeria's power sector are non-existence of precautionary and regular maintenance of electrical equipment. These have resulted in energy deficits and recurrent damage to electrical equipment due to vandalism and inadequate funding (Onyekwena et al. 2017). Lack of transparent billing system of energy consumption has occasioned illegal application of estimated billing system, due to lack of transparency (Oyewunmi and Olujobi 2016). These issues, coupled with the supply gaps in the sector, tended to have contributed to the inadequate development, which has resulted in incidences of the prolonged power outage in the country (Oyedepo 2012).

Moreover, it is also speculated that the determination of the Nigerian government to keep electricity price down, and cheap at the detriment of cost recovery. This has put the generation companies, transmission company of Nigeria and distribution companies in low revenues turn out, high operational debt profiles and inadequate electricity supply in the country (Onyekwena et al. 2017; Kopnina 2018). This observation tends to suggest the conflicting interest of the key stakeholder groups has also compounded the challenges further as the government on the hand, wishes to fulfil their policy, which the power generation companies struggle with operational cost challenges and the consistent incidences of failure demand (Seddon 2008; Ufua et al. 2020b).

The relevance of cradle to cradle theory

Cradle to cradle theory was propounded by McDonough and Braungart (2002). The theory emphasises the designing of intelligent products, processes and systems by considering the entire life cycle of the product, optimising material health, recyclability, renewable energy use, water efficiency and quality, and social responsibility (Ankrah et al. 2015). Cradle to cradle theory takes its inspiration from nature, in which all materials used can provide "nutrition" for nature or industry, maximise material value and safeguard ecosystems (Kopnina 2018). Cradle to cradle concept eliminates the concept of the waste. The purpose of the cradle to cradle Design is to restore continuous cycles of biological as well as technical nutrients with sustainable impacts on the environment and human health. The ideal cradle to cradle product is designed so that all of its materials are selected to cycle within either a biological or technical metabolism safely and to be reused or recovered at their highest possible value (Minkov et al. 2018). Material selection is an essential part of the development of a cradle to cradle product (Bach et al. 2018). A designer needs to understand the human and ecological health characteristics of the materials under consideration. The principles of cradle to cradle design can be applied to a different range of units and the entire city.

This work is anchored on the cradle to cradle theory. It is designed to stop the cycle of use-waste-pollute syndrome which suggests that certain products could be reused endlessly to make similar products (cradle to cradle), rather than recycled into lower-grade products until the last stop is a landfill (cradle to grave). This means that products can be used, recycled, and used again without losing any material quality-in cradle to cradle cycles. Therefore, the theory suggests that Nigeria can take advantage of her endowed renewable energy resources to generate electricity to solve the problem of the ongoing power outage in the country (Oke 2016). Furthermore, based on this theory there is an indication that Nigeria's abundance sunlight, hydro, biomass

and wind among others sources of renewable energy which is available in the country can be harnessed in full capacity to solve the problem of electricity supply shortage (Aderoju et al. 2017).

Literature review

In Nigeria, constant electricity supply remains a problem, despite the huge capital investment in the sector. Lack of access to electric power supply has impeded development in Nigeria (Oke 2016). Organic wastes are materials that are considered not to have any use in terms of its objectives, invention, conversion or utilisation which one wishes to alienate. Wastes may be produced during the removal of raw substances, the utilisation of final merchandises, and other human undertakings (Muhammad et al. 2013). According to Ibrahim (2002), organic wastes are undesirable materials or materials made in the course of manufacture and utilisation of goods, especially those that are traceable by-products from plants and animals. It is beneficial for wastes with a high proportion of organic non-biodegradable sustenance with little humidity contents (Lovley 2008; Sharmina et al. 2012).

There are various types of wastes: domestic waste; domestic waste, industrial waste and demolition waste, there are also hazardous wastes such as industrial waste, agricultural wastes, explosives wastes, bio-medical wastes such as medical wastes and radioactive wastes among others (Kothari et al. 2010; Arshad et al. 2018).

Currently, electricity supply in Nigeria relied significantly on hydropower, and this has resulted in frequent outages of electricity due to underinvestment in other sources of energy (Oke 2013). The average calorific value of wastes in Nigeria was approximately 9.6 MJ/KG based on the waste energy facility about 3000 MW of electricity could be produced from waste to complement the existing power sources in Nigeria. Therefore, there is the need for efficiencies in collection, transportation and management of wastes (Atta et al. 2016). Majority of these scholars failed to discuss exhaustively on the fundamentals of conversion of wastes to electricity. Still, it only adumbrated on others bases of renewable energy, for instance, solar, wind and nuclear energy, among others.

Also, according to Oniemola and Sanusi (2007), renewable energy benefits are more than its environmental and social impacts. The present study is focused on the need for enactment of the legal framework with the incentive for utilising renewable energy as substitute sources of energy to encourage investors in the sector. These are gaps in the literature that the study intends to address in the Nigerian power sector. According to Akhator et al. (2016) conversion of wastes to energy technology is still at infancy stage in

Nigeria's power sector compared to other countries where it has been utilised to generate heat and electricity in commercial quantity for the benefits of their citizens.

Legal and regulatory framework on renewable energy

The National Energy Policy, 2003, is to encourage renewable energy resources and to decentralise energy supply in the country to ensure that 75% of Nigerians have access to electricity (Oyedepo et al. 2018). The challenge of the policy is the lack of adequate sanctions that commensurate with current economic reality in the sector and weak enforcement by the statutory agencies in the sector (Olujobi et al. 2018). Also, the Electricity Power Sector Reform Act, 2005 is to promote investments in renewable energy sources and to promote public and private sector collaborations in the provision of electricity to the rural communities in Nigeria. However, the law tended not to have achieved its objectives due to weak enforcement and lack of adequate incentives for investments in renewable energy sources to serve as assurance or security to foreign investors of getting returns on their investments (Olujobi 2017; Olujobi and Oyewunmi 2017). This is arguably a systemic challenge that extends beyond operational and structural challenges that would require a comprehensive approach to effectively address (Ufua et al. 2018).

The Nigerian Electricity Regulatory Commission (NERC) was instituted by Electric Power Sector Reform (EPSR) Act, 2005 to create, promote, and conserve productive energy market formations for optimum utilisation of energy sources for electricity services. The Nigerian Renewable Electricity Policy, 2006 is to promote independent renewable electricity systems for the provision of electricity in communities not covered by the national electricity grid for the sustainability of the power sector. This prompted the need to promote investment in renewable energy sources through private and public partnerships to promote access to electricity in all nooks and crannies in Nigeria. However, despite legal enactments guiding the operations of the Nigeria power sector, the challenge of sufficient power generation and the guarantee for reliable power supply has remained critical that has called for continuous attention, which justifies the effort put in the current research (Olujobi 2020b).

Current trends in the conversion of wastes to electricity

Biomass energy sources such as organic waste materials from the community wastes from agricultural produce and residues, as well as forestry resources such as wood wastes,

are available extensively in Nigeria for the production of biofuel (Ngumah et al. 2013a). Conversion of wastes into electricity is speculated to reduce the volume of greenhouse gases, displacement of the higher cost of energy sources and costs of managing and disposing of wastes (Zsigraiová et al. 2009).

Besides, municipal solid wastes need to be appropriately managed in order not to impair sustainable development as it has been discovered that power generation from wastes incineration contributes extensively to replenishing energy generated from fossil fuels and decrease emissions (Olujobi and Olusola-Olujobi 2019; Matthew et al. 2020; Ufua et al. 2020b). Unfortunately, high capital and operating costs, feedstock collection cost, and feedstock variability and availability have prevented widespread use (Ogwueleka 2009). While the paradigm is changing, the challenge remains to develop a technology that is efficient and reliable, which requires minimal operating labour and maintenance and feedstock flexibility, and produces valuable commodities, to moderate caloric gas that is suitable for process heating, steam generation, or combustion in a reciprocating engine or gas turbine for generating electricity (Ngumah et al. 2013a).

Researchers (e.g., Hossain et al. 2018) reckon that substantial amounts of agronomic scums are made yearly in Nigeria, and are not optimised due to lack of technology, among other reasons. Models of agronomic scum are the rice pod, which comprises 25% of rice by quantity (Hossain et al. 2018), other residues include sugarcane fibres, coconut pods and hulks, groundnut husks, cereal straw among other things (Oke 2016). Furthermore, animal wastes are bases of biomass energy with animal and poultry manures. In the past, these wastes were convalesced and offered as fertiliser on agronomic land. However, the enactment of stringent ecological rules on air and water effluence means that wastes management are inevitable, which offers encouragements for the conversion of wastes to energy. The best desirable technique for transforming wastes resources to practical usage is anaerobic digestion which offers biogas that can be utilised as fuel for domestic incineration devices, to produce power from micro gas turbines, charbroiled for catering and water boiling (Ufua et al. 2019; Oke 2016).

Prospects of wastes to electricity in Nigerian power sector

The necessity for the reduction of greenhouse gas emissions offers an incentive to utilise bioenergy. Biomass can function as a carbon sink and as an alternative to fossils fuels (Ojolo et al. 2012). Its task is to reduce CO₂ in the exosphere it is acknowledged under the Kyoto Protocol Articles 3.3 and 3.4. Biomass guarantees emissions diminutions through replacement of fossil fuels and is not hampered by

the capacity of controlled biomass carbon sinks (Oke 2016). The replacement may be concluded with substantial carbon appropriation in untidiness and lands, varying on land-use transformations. The quantities of carbon replacement and appropriation will hinge on the plant type and other connected regulatory customs, plus soil categories.

Following the Kyoto Protocol, the objective is a decline of 8% of greenhouse gas emissions. Biomass could aid to avoid CO₂ emissions by providing part of the energy demands in Nigeria, which would then be primarily met with fossil. Swelled application of biomass could make an extensive impact on the decrease in CO₂ emissions and satisfy the Kyoto Protocol objectives (Chichilnisky and Hammond 2016). The technical preferences obtainable can be classified into two: Conventional steam cycle centred on plants and those centred on wood gasification knowledge (Food and Agriculture Organisation of the United Nations 2017). The conventional steam cycle power plants are centred on established know-how. The general plant productivity of the scheme is in the range of 18–22% dimensions accessible with this conventional know-how fluctuate between 10 kW and a few hundreds of Mega Watt (International Renewable Energy Agency 2017). It offers energy proficiency in the range of 30% or above for average-sized power plants, wood gasification-based technology utilised in biomass-based plants bearing in mind the technical practicability within Nigeria, plants functioning on conventional steam cycle machinery are uncovered to be suitable for biomass-based electricity generation system (Ufua et al. 2018).

There are efficiencies of generating plants functioning on conventional steam cycle based on ascertained technologies. The energy cost connected with biomass-based plants operating on traditional steam cycle technologies is similar to sizeable conventional gas turbine plants functioning on auto diesel. With the reduction in capital costs of biomass-based plants, the generally the prices are probable to reduce soonest (International Finance Corporation 2017). Consequently, biomass-based electricity production can become economical in Nigeria's electricity production system where fossil fuel-based production has a powerful module. As energy demands surges, fossil fuel stores decline, and coal having terrible pollution defects is not an option. Since biomass is mostly from plants, as long as fertile soil, sunshine, water, and carbon dioxide are available; biomass should sustain (Herrmann et al. 2018). To upsurge biomass influence as a renewable energy source, decrease greenhouse emission and enhanced green pastoral area growth. There are the needs for more excellent comprehension of the fiscal and ecological consequences of the diverse biofuel chains, their function in a progressing energy sector, and local growth. Biomass as a sustainable development tool is much easier to sustain in contrast to other sources of energy. As the bulk of the resources needed for the achievement of biomass are

gotten from waste which cost little to acquire, biomass is easier to maintain (Aderoju et al. 2017). Currently, biomass has drawn extensive interest as an essential energy basis for electricity production, owing to its prospective as low cost, home-grown source of energy as well as owing to ecological values complementing biomass-based generation equipment (Aderoju et al. 2017).

The adoption of biomass as a sustainable energy tool will help in the achievement of the objective of the Kyoto Protocol by helping countries to reduce their emission levels produced from fossil fuels (Defra 2006). Nigerians are demanding a review of energy policy due to the anxieties over the outlook, security and variety of the energy resources which are utilised to produce power. Energy from wastes plants could play a restricted, but an enhanced role in generating electricity and offering heat to neighbourhoods (Atta et al. 2016). With fossil fuel prices intensifying in recent years, the desirability of energy from wastes module of the portfolio is expected to develop. A comprehensive review of energy policy is inevitable to drive proposals for waste plants to maximise the benefits of conversion of wastes to electricity in Nigeria (Oniemola and Sanusi 2007).

It will improve air quality, reduce emissions, and promote the conducive living acquisition of carbon credits and compliance with international climate agreements among others which are some of the gains that can be derived from the conversion of wastes to energy (The World Bank 2013). It is an ecological waste management mechanism that will end the habit of wastes collection and dumping in the site in an uncontrolled manner. This will extensively develop Nigeria's energy fusion and subsidise energy access for the future (Olujobi et al. 2020b) (Fig. 2).

The prospective of biogas in Nigeria's power sector

The country generates approximately 542.5 million tons of organic waste every year with the prospects of about 25.53 billion m³ (cubic metres) of biogas nearly 169,541.66 MW estimated at ₦1.01 trillion and 88.19 million tons of bio fertiliser in a year with the capacity to decrease ecological and public health anxieties, deforestation and greenhouse gas emissions (Ngumah et al. 2013a) (Table 1).

Challenges of conversion of wastes to energy in Nigeria power sector

Wastes disposal data in Nigeria are mainly unavailable or has not been published by environmental regulatory agencies due to lack of proper waste management controls and lack of political will and sincere commitment of the Federal Government to establish waste conversion to electricity facilities or plants (Imam et al. 2008). The value of renewable

Fig. 2 Potentials of conversion of wastes to energy. Sources: Opportunities in the Waste-to-Energy Sector: https://www.google.com/imgres?imgurl=http%3A%2F%2Fdi-vietnam.com%2Fupload%2Ftuc%2F1532400156wte.jpg&imgrefurl=http%3a%2f%2fdi-vietnam.com%2finvestment-opportunities%2fvietnamopportunities-in-the-waste-to-energy-sector.html&tbnid=iu9x0atun79ezm&vet=10ce4qmyijawoxchmiqn7-v9_66wivaaaaab0aaaaaeai..i&docid=a5lozcpagqvijm&w=763&h=570&itg=1&q=clearer%20pictures%20of%20conversion%20of%20wastes%20to%20electricity%20in%20nigeria&hl=en&ved=0ce4qmyijawoxchmiqn7-v9_66wivaaaaab0aaaaaeai. (Accessed September 21, 2020)

energy technology appears to be more than the traditional fossil fuel generation because it is a new technology which may require huge capital to start up (Shahrouz 2014). Also, the issue of land ownership structure in Nigeria under the Land Use Act 1978 confers ownership of land on the State Governors. They held the land in their states in trust for the people of that state as bioenergy plants would necessitate enormous land for farming of energy crops this may remain as an impediment to enormous scale farming if the consent of the Governors of the states is not sought which can impede the accessibility of primary substance for the bioenergy production by private investors and the Federal Government (Babatunde et al. 2012). Also, the animal manure for biofuel if left untreated in large quantities can have adverse effects on the environment. Feed-lots can produce wastes that are more concentrated than raw domestic sewage, and when such wastes are escapes into the water supply, the consequences can be disastrous (Ikpefan 2010) (Table 2).

An overview of global policies on biomass energy utilisation

Bioenergy potential in some countries is essential to learn from to foster policy for the development of Nigeria's power sector. The ecosystem and agronomy cross-cutting concerns are applicable in the meaning of harmonised act for bioenergy in numerous emerging countries; biomass is the only user-friendly and inexpensive basis of energy. In Africa,

Table 1 Potentials of biogas in Nigeria's power sector. *Source:* Ngumah et al. (2013b)

S. No.	Organic waste	Amount of units (millions)	Total biomass generated (million tons year ⁻¹)	Estimated biogas potential (billion m ³ year ⁻¹)
1.	Urban solid waste		39.1	33,150
2.	Crop remnants		83	117,000
3.	Human faeces	130	52	65,910
4.	Slaughterhouse remnant	–	83.3	103,350
5.	Poultry droppings	112.9	32.6	64,350
6.	Pig excrement	9.6	15.3	21,450
7.	Sheep and goat excreta	100.9	39.6	62,790
8.	Cattle excreta	21	197.6	142,350
	Aggregate	25.53	15.65	610,350

Some organic wastes with enormous potentials in Nigeria are cattle faeces, sheep and goat dropping, pig excrement, poultry dropping, slaughterhouse leftover, human excrement, crop remainder, and urban solid wastes

Table 2 Power plants in Nigeria utilising renewable energy sources but not optimally. *Source:* Oluoti et al. (2014)

S/N	Power plants	Energy sources	Category	Capacity (MW)	Situation	Date of completion
1.	Mambilla Power Station	Hydroelectric	Reservoir	3050	Functioning but not optimally	2018
2.	Kiri Power Station	Hydroelectric	Reservoir	100	Functioning but not optimally	2016
3.	Zamfara Power Station	Hydroelectric	Reservoir	35	Functioning but not optimally	2015
4.	Kano Power Station	Hydroelectric	Reservoir	100	Work in progress	2015
5.	Shiroro Power Station	Hydroelectric	Reservoir	600	Work in progress	1990
6.	Jebba Power Station	Hydroelectric	Reservoir	540	Work in progress	1985
7.	Kainji Power Station	Hydroelectric	Reservoir	800	Work in progress	1968

biomass relates to half of the whole energy provision. Furthermore, to wood fuels, other biomass fuels such as forest and crop scums as well as animal wastes are usual bases of bioenergy in developing nations, where outdated types of machinery tend to be used in generating electricity (Thomsen 2014). Moreover, the quantity of biomass that is accessible in the form of scums, and the capacities for better quality and effectiveness in technology being currently useful several nations yet to designate lands for energy farmsteads (Chanakya and Malayil 2012). Incorporating biomass crops for energy targets with forestry and agronomic undertakings is alternative. In several areas, utilisation of biomass still needs to become ecological where traditional and contemporary machinery is useful (Ofoegbu and Emengini 2013).

Biomass is a vital energy source in several businesses, for instance, in the manufacture of ceramics, drinks, dehydration and processing of foods. The companies offer a necessity base and preliminary for accomplishing bioenergy projects in emerging nations with other proven profit-making undertakings (Food and Agriculture Organization of the United Nations 2017). These chances are often elapsed due to deficiency of technical know-how to

enhance bioenergy systems, non-existence of supportive energy strategies, lack of supervisory capability and conventional energy development practice. The utilisation of solid biomass has had progressive growth in Organisation of Economic Cooperation and Development (OECD) nations, exhibiting yearly upsurge of 1.8% in contrast to 1.5% in non-OECD nations (Doornbosch and Steenblik 2007).

These countries were selected as a case study because they possess a structured legal regime on the conversion of organic wastes to electricity and with their requisite field experience on the conversion of wastes to electricity. Also, due to their relatively stable power supply generated via organic wastes in the country.

The central aims of the European Union in the energy sector, comprising energy utilisation in the transportation system, are to comply with the Kyoto Protocol goals to enhance energy efficiency security and mixture energy source, to improve efficiencies in the power sector and to create employment. A topical mandate on the endorsement of biofuels for transportation targets of substituting 2% of

fossil fuels in transportation with biofuels (European Commission 1997).

The European Union renewable energy objective for biomass necessitates a substantial quantity of land and other sources. Agricultural land between 10 and 15% has been devoted to non-food crops due to indicated growth in agricultural land, and countries are probable to record remarkable improvement ineffectiveness as a product of growing fiscal tension and contest (PricewaterhouseCoopers EU Services EESV's Consortium 2017). Thus, agriculturalists may appreciate the divergence to non-food energy crops. As fuel production continue to upsurge in Europe and healthier forest administration and the establishments of a new forest could add appreciably to more wood fuel. To intensify biomass support for renewable energy source, decrease greenhouse discharge and encourage rural ecological growth. There is the need for better comprehension of the fiscal and environmental consequences of various biofuel chains, their function in a progressing energy sector. The encouragement of bioenergy should be driven by stringent strategies directed at appropriating the ecological and countryside growth and advantages of bioenergy in a sustainable model (Olujobi and Olujobi 2020a, b).

The UK greenhouse gas emissions decline target is a 20% decrease, and when it comes to renewable energy generation, the objective is 10% (National Strategy for Climate and Energy 2009). The government has introduced several policies to achieve this; for instance, about one-third of the renewable energy is anticipated to originate from biomass, which may necessitate up to 12,500 ha of energy crops for power production. The non-fossil fuel has aided the market for renewable energy predominantly winds power, but there is a little motivation for emerging renewable energy bases. The aim is to offer a fraction of their electricity from renewable energy bases (Alterner 2001). The green fuels issues, biodiesel, will entitle to 20%-litre fuel incentive. Bioethanol is also eligible for 20 pence per litre incentive. The UK's government is in the course of aligning its target within the European biofuels mandate, and other devices may be necessary to aid in sustaining the objective. The UK's Department of Environment, Food and Rural Affairs earmarked £30 million for the establishment of energy crops and the formation of almost 6000 ha of energy crops (European Environment Agency 2002). There are also prospects for finance exhibition arrangements through finances sprung from the Climate Change Levy, but there is no distinct unified approach for the advancement of bioenergy mainstreaming long-term consideration. Such consideration should comprise analysis of ecological and socio-economic effects on the energy and agricultural sector in addition to regional advancement (Olujobi and Olusola-Olujobi 2019; Olujobi et al. 2020a).

In Italy, the government has endorsed a white paper on renewable energy and national strategies for the decline

of greenhouse gases. The white paper specifies an objective of 8–10 Mtoe for vital energy from biomass 24 Mtoe for entirely renewable energy. This strategy is harmonised with biomass execution programme at the domestic level for renewable energy via biomass by the Ministry of Agriculture. Financial encouragements are encouraged on biodiesel for transportation which 300,000 are relieved from taxes for 3 years. Biodiesel for heating purposes is also exempted from tax with laudable objectives for biofuels energy demands.

Also, in Netherland, the country has adopted an utterly pre-emptive stand on energy and ecosystem concerns and set 5% renewable target, rising from about 13% to about 70% yearly. The Dutch government is currently in the course of establishing objectives for the Netherlands within the European Union biofuels directive.

Likewise, in Sri Lanka, biomass accounts for 51% of energy supply in Sri Lanka (Wijayattunga et al. 2005). Biomass has drawn relevance as the primary energy basis for power production, owing to its prospective as a low cost, a home-grown supply of energy as well as due to ecological benefits complementary biomass-based generation technology. Besides this global advantage, there are local benefits such as reduction of soil erosion, restitution of degraded lands, and enrichment of local influences of fossil-fired power production. This has enhanced the stable power supply in these selected countries, which Nigeria can replicate to end power outage in the country.

Limitations of the study

There is dearth of accurate information on energy generation and consumption in Nigeria due to the confidentiality agreement executed by some regulatory agencies in the country with their business partners in the sector.

Also, some independent and private investors' are unwilling to make available the required data on energy consumption due to corruption and a lack of verifiable data.

Conclusion

The study has discussed the potentials of the transformation of wastes to energy in Nigeria and the need to explore alternative energy sources to reduce over-dependence on fossil fuel which is not environment friendly and exhaustible. Biomass has the prospect to become the primary basis of Nigeria's power sources for electricity production and other energy facilities. The extent to which bioenergy application will happen, and its percentage of realisation, will hinge on the supply, accessibility, financial and ecological supports, as well as policy, appraise stemming from climate change and enthusiasm to boost energy provisions self-reliance.

Consequently, bioenergy encouragements must account for the eco-friendly features of the fuel chain from the production of the fuel to the energy service offered. A diversity of market-based devices can be utilised at several phases of the fuel chain to accelerate growth. In the case of energy crops, procedures need to be developed with greater collaboration among energy, agronomic and ecological strategies to inspire agrarians to produce biomass resources in an environmental modus.

However, biomass energy utilisation in Nigeria has been low, and in default of the impact of biomass, it will be challenging to sustain the carbon secretion decrease envisioned by the Kyoto Protocol.

It is suggested that the country should decentralise its energy sector and promote biomass utilisation to deliver electrical power supply, put stringent regulations in place for successful conversion of wastes to energy and enhance the reliability of the power sector.

Recommendations

The relevant legal framework should be enacted and enforced to encourage conversion of wastes to electricity considering over 14 million tonnes of combustible wastes in Nigeria with about 4.4 Terawatt-hour (TWh) of electricity could be generated annually from waste if the necessary financial supports and technologies are giving to the sector by the Federal Government. The National Environmental Standards and Regulations Enforcement Agency should wake up to its statutory responsibility of preserving and conserving the environment from pollutions. Likewise, the Nigerian Electricity Regulatory Commission should regulate the conversion of wastes to energy to benefit Nigerians by reducing air pollution and emissions of greenhouse gases. The introduction of mini-grids for power from scraps would end the problem of electricity outage in the pastoral communities that are not linked to the state-owned grid in the nation.

Financing power sector investment is one of the main problems facing the sector as finance from commercial banks is unavailable, or the interest rate is high (Akinyemi et al. 2019a, b; Okorie et al. 2020). Enhancing electricity provision in Nigeria and combating the hurdles to energy mix targets will require: tackling payment risk, financing energy investments in renewable energy sources in the power sector as well as overhauling of the pricing and tariff structure and energy market regulations.

There is a need for sensitisation of the public on the benefits of developing waste to an energy source for electricity in Nigeria. Waste to energy as the capacity to reduce landfill dumping and land designated as dumpsites in Nigeria. Such properties can be used for other purposes, while incineration

of waste can produce desired electricity and reduce the quantum of wastes. Conversion of waste to electricity will reduce over-dependence on fossil fuels as energy sources. It can reduce gas emissions and pollution caused by the burning of fossil fuels. Conversion of wastes to energy is attainable in Nigeria's power sector, taking into consideration the country populace and enormous waste generated in the country which is not efficiently handled.

There is the need to develop stringent policies on energy efficiency to help in dealing with the hazard of waste production, to decrease greenhouse gas productions and to earn carbon credits to promote energy mix in Nigeria's power sector. Future research should consider towards coherent legal framework on renewable energy in Nigeria's power sector.

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Compliance with ethical standards

Conflict of interest The authors declare that there is no conflict of interest.

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