American Journal of Modern Energy
2017; 3(3): 50-57
http://www.sciencepublishinggroup.com/j/ajme
doi: 10.11648/j.ajme.20170303.12

Review Article

Bioenergy Potential of Under-Utilized Solid Waste Residues from Oil Palm Mills in Nigeria

Sylvester Chibueze Izah*, Adesola Stephen Ojesanmi

Department of Biological Sciences, Niger Delta University, Wilberforce Island, Nigeria

Email address:
chivestizah@gmail.com (S. C. Izah)
*Corresponding author

To cite this article:
Sylvester Chibueze Izah, Adesola Stephen Ojesanmi. Bioenergy Potential of Under-Utilized Solid Waste Residues from Oil Palm Mills in Nigeria. *American Journal of Modern Energy*. Vol. 3, No. 3, 2017, pp. 50-57. doi: 10.11648/j.ajme.20170303.12

Received: May 13, 2017; **Accepted**: June 6, 2017; **Published**: July 14, 2017

Abstract: This study estimated bioelectricity potentials of under-utilized oil palm processing solid wastes (chaff, empty fruit bunch, palm press fibre and palm kernel shell) in Nigeria. The potential challenges of bio-power production from these solid wastes were also evaluated. Quantitative approach was employed for data generation. Historical data study of oil palm growth rate between 2004 to 2013 was used and projections at three scenarios (high, low and current status) were made. The findings showed that bioelectricity from total possible gatherable under-utilized oil palm processing solid wastes in Nigeria were 3.234 to 5.175 MWh in 2004, which could have reached 3.796 to 6.073 MWh in 2013. Based on projections at high, low and current growth rate scenarios, 5.728 to 9.165 MWh (high growth rate), 4.720 to 7.536 MWh (low growth rate) and 4.242 to 6.787 MWh (current growth rate) of electricity at efficiency of 80% (for combustion), 65% (for pyrolysis) and 50% (for gasification) could be achieved by 2029. After considering all the challenges associated with each type of conversion process, only 40% of these values are attainable. The study identified technological, policy/political and economic framework as potential challenge of bioelectricity generation in Nigeria. Hence the study concludes by suggesting means of overcoming the hurdles under Nigeria setting.

Keywords: Bioelectricity, Bioenergy, Nigeria, Oil Palm Processing Solid Wastes

1. Introduction

The demand for fossil energy has been increasing over the years due to industrialization [1], growth in global population and economical activities [2]. Energy is basically used in all sectors of any nation's economy such as agriculture, industries, telecommunications, healthcare, and transportation. Currently, the demand for energy is met mostly by fossil fuels (e.g., coal, petroleum, natural gases). Atadashi et al. [3], Escobar et al. [4] reported that petroleum products are mostly utilized energy sources especially in the transportation sector. High price and adverse environmental impacts of conventional fuels have made the biofuels production to reach unparalleled extent [5, 6]. Patel [7] noted that bioenergy derived from biomass is a promising energy alternative that can reduce the greenhouse gas emissions generated from non-renewable fuels.

Renewable energy from biomass is environmentally friendly when compared to fossil fuel resources; hence they are agent of sustainable development. Biomass fuels have environmental and social benefits [8]. Panwar et al. [9] considered biomass as carbon neutral, due to the fact that the amount of carbon released is equivalent to the amount absorbed during its life time. Biomass has been widely considered as major source of energy in both developed and developing nations [10].

Biomass can be converted into useful energy via thermochemical, physicochemical and biochemical technologies. The energy in focus depends on the conversion technology used. For instance, bio-power (electricity generation from biomass) can be carried out by six main technologies including direct fired, co-firing, gasification, pyrolysis, anaerobic digestion and small, modular systems [11]. Patel et al. [7] also listed combustion, gasification, pyrolysis, liquefaction, carbonization, and co-firing as thermochemical conversion technologies of biomass to bio-power. Specifically, three thermochemical technologies are preferred for electricity generation from solid biomass. These thermochemical processes include combustion, gasification and pyrolysis [12].

Gasification is one of the thermochemical technologies that involve the partial oxidation of carbonaceous materials into hydrogen, carbon monoxide, carbon dioxide, nitrogen and low methane gases, small amount of hydrocarbon, char, ashes, tars and oils in the presence of a gasifying agent [13 – 15] at a temperature of 600 – 1200°C [15]. Gasification is the intermediary stage between pyrolysis and combustion [10]. Zhang et al. [16] reported that gasification is similar to combustion but it is frequently considered as partial combustion process. Pudasainee et al. [8] also described gasification technology as one of the promising technologies for syngas production. The fundamentals of gasification, biomass constituents, type of gasifers, operating conditions and cleaning system have been comprehensively documented by Ruiz et al. [14]. Generally, gasification technology is versatile and as such can be used to produce syngas, hydrogen gas and other liquid fuels for electricity or thermal energy generation [14].

Combustion is the process of releasing heat when any combustible materials are allowed to burn in the presence of air or oxygen. During combustion, cellulose, hemicellulose, lignin and other building blocks of biomass are oxidized into hydrogen and carbon releasing water and carbon dioxide as by-products at temperature of about 1000°C [13].

Pyrolysis is another thermochemical process used for the conversion of biomass into liquid fuel or bio-oil, fuel gas and char coal [10, 13, 14]. Bio-oil is sometimes called pyrolysis oil and it burns like fossil fuel when used to generate electricity [11]. Pyrolysis technology are operated in the absence of oxygen [11] at ambient pressure and elevated temperature [10] ranging from 150 - 400 ºC [14], 400 - 600 ºC [13]. Pyrolysis of biomass typically form char (a solid carbonaceous waste) and condensable and non-condensable gases [14]. Ruiz et al. [14] listed the major constituents of gaseous stage to include water, carbon dioxide, hydrogen, small amount of organic acid and hydrocarbons. The hydrocarbon constituents are mostly affected by particle size, temperature, pressure, heating time and residence time [14].

In Nigeria oil palm processing wastes streams have been widely studied. For instance, palm oil mill effluents (POME) have been variously reported with regard to general physico-chemistry and heavy metals [17, 18], microbiology [18, 19] and possible contributions of POME to greenhouse effects [20]. On the gaseous emissions, studies have been conducted by Ohimain et al. [21], Ohimain and Izah [22]. These wastes typically cause attendant environmental impacts. While recent studies have shown the potential thermal energy from the sector in Nigeria [23].

Several technologies exist for the converting oil palm processing wastes into energy thereby preventing the attendant impacts associated with the wastes. On this note, the potential biogas [24], biohydrogen [25], electrical energy and currency equivalent [26] from POME generated in Nigeria have been documented. Similarly, the solid wastes generated which are typically used as boilers fuel in palm oil processing especially boiling [21, 27, 28, 29] have been quantified [23]. The excess solid wastes are discharged into the environment adjacent to palm oil mill, and when the moisture content reduced via sunlight drying, it is combusted in open air. This practice is common among smallholder and semi-mechanized oil palm processors in Nigeria [21, 22]. In advanced oil palm processing nations, intensive research have been carried out for the valorization of oil palm processing solid wastes for energy generation. Most of the notable technologies involve thermochemical approach. Awalludin et al. [13], Zhang et al. [16] reviewed the findings of combustion, pyrolysis and gasification technology for the conversion of biomass into energy.

Nigeria being the fifth largest producer of oil palm in the world [30, 31], generates large solid waste from the sector. Based on the growth rate under Nigeria settings projections have been made under three scenarios [20]. These scenarios have been used to estimate potential thermal energy from solid wastes [23], biogas [24], biohydrogen [25] and electrical energy and currency equivalent [26] from palm oil mill effluents. One other suitable approach of managing the solid wastes is through the production energy especially bioelectricity. This is probably due to energy content/calorific/heating value of oil palm processing wastes. Research has been widely conducted on potential bio-power from oil palm processing wastes. Recently, Nyakuma [32] reported potential of electricity generation from Malaysia oil palm industry. Hence, the aim of this paper is to estimate potential bioelectricity contribution of oil palm processing solid wastes in Nigeria. The paper focused on historical data (2004 to 2013) and projections were made on three scenarios from 2017 to 2029 at three years interval. The outcome of this study could be useful to environmentalist, policy makers, individual involved in environmental and renewable energy sustainability and cleaner production.

2. Methodology

Secondary source were employed for data generation. Information on the growth rate (historical and projected scenario data), mass-balance, heating content, quantity of solid wastes, potential thermal energy from Nigeria oil palm industry have been documented in published journal articles between 2013 – 2016. Based on the historical data and projection scenarios on the growth rate of oil palm in Nigeria, the potential bioelectricity was estimated. The scenarios applied in this study was based on the work of Ohimain and Izah [20], that used oil palm growth rate between 2011 – 2013 (8.6%), 50% of the period data (4.3%) and current growth rate of 2012-2013 economic season to classified high, low and current growth rate respectively.

The total estimated utilized and underutilized potential energy content of oil palm processing solid wastes including chaff, empty fruit bunch (EFB), palm kernel shell (PKS) and palm press fibre (PPF) in Nigeria was modified from Izah et al. [23] and the ratio of utilized to under-utilized was computed

(Table 1). Table 2 presents total possible energy content that will be generated from oil palm processing solid wastes in Nigeria based on three projection categories. For the projection scenario, the potential under-utilized value of 75% was used for the conversion of total oil palm processing solid wastes that would be generated before 2030 in Nigeria. Both historical data and projection resultant values after finding the 75% of the total energy content of oil palm processing wastes (i.e. under-utilized quality) was converted from MJ to GJ.

Table 1. *Estimated total energy content of under-utilized and utilized oil palm processing solid wastes (chaff, EFB, PKS and PPF) in Nigeria.*

	Year									
	2004	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**
Total under-utilized, x10^9 MJ	34.482	34.902	35.756	35.974	37.043	37.043	37.043	37.043	39.59	40.466
Total utilized, x10^9 MJ	11.364	11.538	11.652	11.796	12.227	12.227	12.227	12.227	13.09	13.364
Approximately % under-utilized	75	75	75	75	75	75	75	75	75	75
% Approximately Utilized	25	25	25	25	25	25	25	25	25	25

Source: Adapted from [23]

Table 2. *Total estimated potential thermal energy from oil palm processing solid wastes in Nigeria in projection Scenarios.*

Projection scenario	**Year**				
	2017	**2020**	**2023**	**2026**	**2029**
High, x 10^9 MJ	58.57	63.53	69.03	75.13	81.42
Low, x 10^9 MJ	56.30	58.96	61.44	64.29	66.95
Current status growth rate, x 10^9 MJ	55.16	56.32	58.17	58.78	60.30

Source: [23]

In practice under present Nigeria conditions it is difficult to recover all the solid wastes estimated. Izah et al. [23] estimated that 40 - 60% (mean 50) and 85% of the solid wastes can be recovered from smallholder and semi-mechanized/mechanized palm oil mills respectively. So in considering the fraction of under-utilized oil palm processing solid wastes that will be recovered by all type of processors were further reduced by 33% i.e. hence 67% of the total under-utilized energy content was used to calculate the potential bioelectricity potentials of oil palm processing solid wastes in Nigeria.

The estimation of the total bioelectricity potentials of under-utilized oil palm processing solid wastes were computed based on the methodology previously described by Mendu et al. [33], Nyakuma [32]. The energy content was multiplied by conversion factor of 0.28 and efficiency of 80% (for combustion), 65% (for pyrolysis) and 50% (for gasification) to convert GJ energy into MWh bioelectricity equivalent [32, 33].

3. Results and Discussion

3.1. Bioelectricity Production from Under-Utilized Oil Palm Processing Wastes in Nigeria

The total estimated potential energy from under-utilized and projected oil palm processing solid wastes (EFB, PPF, PKS and chaff) in Nigeria are presented in Figure 1 and 2 respectively. However, the energy content was 3.4482 $\times 10^7$ GJ which could have reached 4.0466 $\times 10^7$ GJ in 2013 economic year. Similarly, at high, low and current status projection scenarios, 6.107$\times 10^7$ GJ, 5.021$\times 10^7$ GJ and 4.523$\times 10^7$ GJ respectively could be produced from under-utilized oil palm processing solid wastes by 2029 (Figure 2). The energy content followed the trend of oil palm expansion in Nigeria.

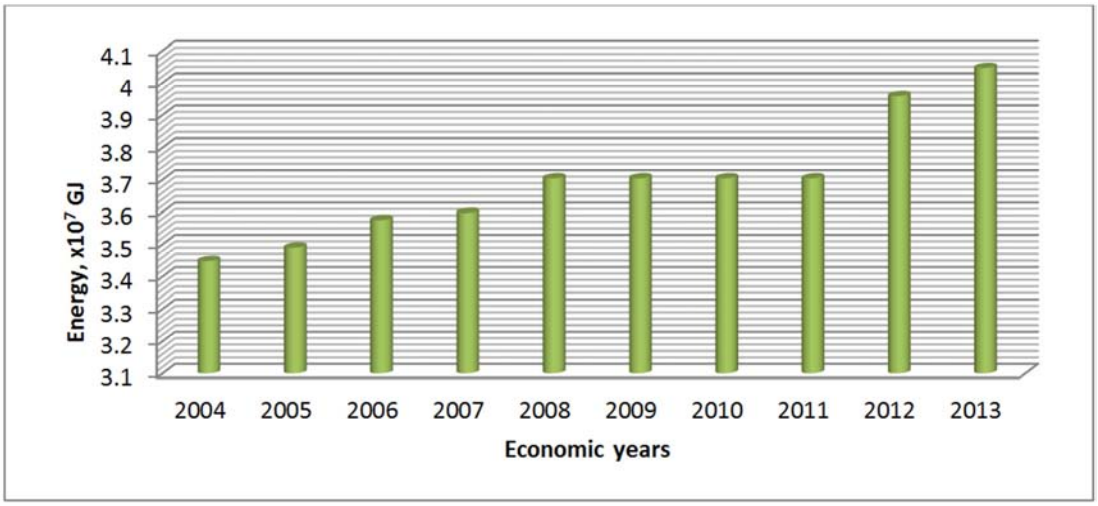

Figure 1. *Estimated total energy content from under-utilized oil palm processing solid wastes in Nigeria between 2004 – 2013 economic year.*

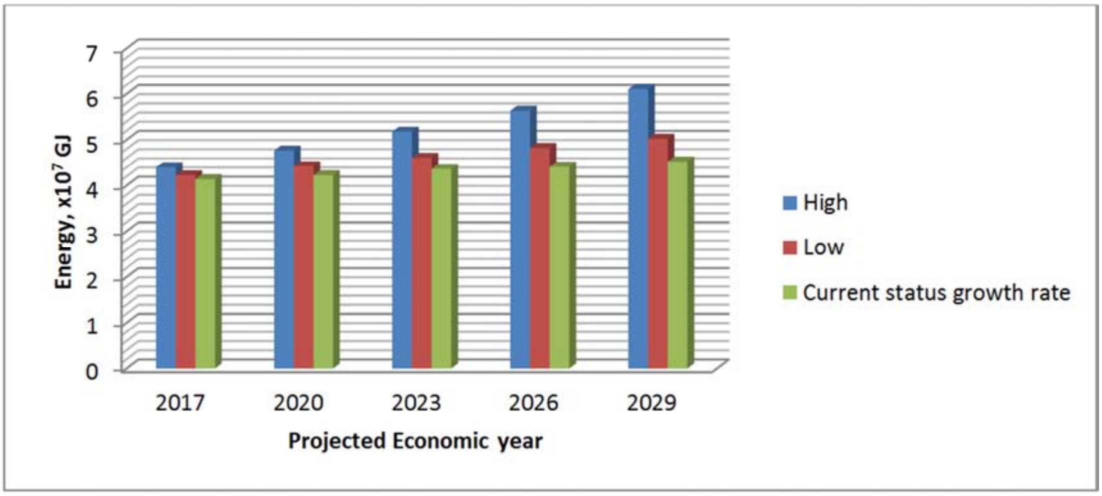

Figure 2. *Estimated total energy content from under-utilized oil palm processing solid wastes in Nigeria in projection scenarios at three intervals.*

Table 3 and Table 4 presents the estimated potential bioelectricity from gatherable under-utilized oil palm processing solid wastes in Nigeria for historical data period (i.e. 2004 to 2013) and projected scenario (i.e. 2017 to 2029) economic years respectively. Thus, the total possible gatherable energy content from under-utilized oil palm processing solid wastes (PPF, EFB, PKS and chaff) in Nigeria were 2.3103 $\times 10^7$ GJ in 2004, which could have reached 2.7112 $\times 10^7$ GJ in 2013 and bioelectricity potential of 3.796 – 6.073 MWh in 2013 (Table 3). For the high, low and current growth rate scenarios, total gatherable energy content from under-utilized oil palm processing solid wastes in Nigeria could reach 4.019 $\times 10^7$ GJ (high growth rate), 3.364 $\times 10^7$ GJ (low growth rate) and 3.030 $\times 10^7$ GJ (current growth rate trend) by 2029. Similarly, energy in MWh could reach 9.165 (high growth rate), 7.536 (low growth rate) and 6.787 (current growth rate trend) for combustion at 80% efficiency; 7.446 (high growth rate), 6.123 (low growth rate) and 5.515 (current growth rate trend) for pyrolysis at 65% efficiency; and 5.728 (high growth rate), 4.720 (low growth rate) and 4.242 (current growth rate) for gasification at 50% efficiency (Table 4). The potential bioelectricity suggests that energy could be generated if the wastes are converted into energy to power the palm oil mill in Nigeria. However, valorization of oil palm processing wastes is prone to technical challenges like fouling, agglomeration, sintering and low conversion efficiencies due to high moisture content, high alkali metal oxide composition, and ash content [34]. After considering all these challenges about 40% of the values estimated could be achieved for each of the conversion technology.

Table 3. *Estimated bioelectricity potentials of gatherable under-utilized oil palm processing solid wastes in Nigeria in historical data period (2004 to 2013).*

Year	Energy, GJ	MWh, GJ × 0.28 × Efficiency*		
		Combustion* (80%)	Pyrolysis* (65%)	Gasification* (50%)
2004	2.3103 $\times 10^7$	5.175 $\times 10^6$	4.205 $\times 10^6$	3.234 $\times 10^6$
2005	2.3384 $\times 10^7$	5.238 $\times 10^6$	4.256 $\times 10^6$	3.274 $\times 10^6$
2006	2.3957 $\times 10^7$	5.366 $\times 10^6$	4.360 $\times 10^6$	3.254 $\times 10^6$
2007	2.4103 $\times 10^7$	5.399 $\times 10^6$	4.287 $\times 10^6$	3.374 $\times 10^6$
2008	2.4819 $\times 10^7$	5.559 $\times 10^6$	4.517 $\times 10^6$	3.475 $\times 10^6$
2009	2.4819 $\times 10^7$	5.559 $\times 10^6$	4.517 $\times 10^6$	3.475 $\times 10^6$
2010	2.4819 $\times 10^7$	5.559 $\times 10^6$	4.517 $\times 10^6$	3.475 $\times 10^6$
2011	2.4819 $\times 10^7$	5.559 $\times 10^6$	4.517 $\times 10^6$	3.475 $\times 10^6$
2012	2.6525 $\times 10^7$	5.942 $\times 10^6$	4.828 $\times 10^6$	3.714 $\times 10^6$
2013	2.7112 $\times 10^7$	6.073 $\times 10^6$	4.934 $\times 10^6$	3.796 $\times 10^6$

Table 4. *Estimated bioelectricity potentials of gatherable possible under-utilized oil palm processing solid wastes in Nigeria in projected scenario (2017 to 2020).*

Year	Projection scenarios	Energy, GJ	MWh, GJ × 0.28 × Efficiency*		
		(67% conversion)	Combustion* (80%)	Pyrolysis* (65%)	Gasification* (50%)
	High	2.946 $\times 10^7$	6.599 $\times 10^6$	5.362 $\times 10^6$	4.123 $\times 10^6$
2017	Low	2.883 $\times 10^7$	6.337 $\times 10^6$	5.149 $\times 10^6$	3.961 $\times 10^6$
	Current status growth rate	2.772 $\times 10^7$	6.209 $\times 10^6$	5.045 $\times 10^6$	3.881 $\times 10^6$
	High	3.192 $\times 10^7$	7.151 $\times 10^6$	5.810 $\times 10^6$	4.469 $\times 10^6$
2020	Low	2.963 $\times 10^7$	6.637 $\times 10^6$	5.392 $\times 10^6$	4.148 $\times 10^6$
	Current status growth rate	2.830 $\times 10^7$	6.339 $\times 10^6$	5.151 $\times 10^6$	3.962 $\times 10^6$
	High	3.469 $\times 10^7$	7.770 $\times 10^6$	6.313 $\times 10^6$	4.856 $\times 10^6$
2023	Low	3.087 $\times 10^7$	6.916 $\times 10^6$	5.619 $\times 10^6$	4.322 $\times 10^6$
	Current status growth rate	2.923 $\times 10^7$	6.548 $\times 10^6$	5.320 $\times 10^6$	4.092 $\times 10^6$

Year	Projection scenarios	Energy, GJ (67% conversion)	MWh, GJ × 0.28 × Efficiency*		
			Combustion* (80%)	Pyrolysis* (65%)	Gasification* (50%)
2026	High	3.775×10^7	8.457×10^6	6.871×10^6	5.285×10^6
	Low	3.231×10^7	7.236×10^6	5.880×10^6	4.523×10^6
	Current status growth rate	2.954×10^7	6.616×10^6	5.376×10^6	4.135×10^6
2029	High	4.019×10^7	9.165×10^6	7.446×10^6	5.728×10^6
	Low	3.364×10^7	7.536×10^6	6.123×10^6	4.720×10^6
	Current status growth rate	3.030×10^7	6.787×10^6	5.515×10^6	4.242×10^6

In Nigeria current oil palm status, over 97% of the energy demand for the production of 1 tonne of fresh fruit bunch (FFB) in palm oil mill is mainly from biomass. For instance, about 2.5% of total energy demand is from fossil fuel, 97.5% from oil palm processing biomass [28], and <1% of manual energy [35] in semi-mechanized palm oil mill in Nigeria. While in smallholder palm oil mills, 98.22 – 98.75% of energy comes from biomass, 1.25 – 1.78% comes from fossil fuel [27] and relatively low human energy (1.2709 MJ) when compared to biomass and liquid fuel reported in literature [36]. The manual energy content translates to <1% of total energy consumed in smallholder palm oil mills in Nigeria.

Hence, the contribution of fossil fuel could be eradicated by converting the oil palm processing wastes biomass into energy resources. Ohimain and Izah [27] have previously listed possible energy (solid, liquid and gaseous fuel) conversion technologies that can be used for energy generation in palm oil mills to make the industry 100% self-sufficient. However, based on three technologies studied for bioelectricity generation from oil palm processing biomass, combustion have a superior effect thus combustion > pyrolysis > gasification. This could be due to the fact that combustion has a higher efficiency. Again, the increment follows the trend of oil palm cultivation over the period of years under study (i.e. 2004 – 2014). Only about 40% of each projections made could be achieved if the oil palm sector are boosted by both private/stakeholder and government participation. Based on the current trends in trying to diversify the economy away from oil and gas, effort are been made in the agricultural sector. As such, it's evident that oil palm plantation/estate have received a boost from small-scale (individual having 1 – 5 hectares of oil palm plantation) and medium (>5 – 20 hectares of oil palm plantation) estate owners especially in some rural communities in south-south Nigeria in the past few decades.

3.2. Potential Challenges and Mitigation Measures for Bioelectricity Production Under Nigeria Setting

Potential bioelectricity under Nigeria setting could be hindered by poor social, environmental, technological, policy/political and economic framework. Presently, electricity supply is epileptic and is characterized by frequent black and brown out [23] at high cost. If bioelectricity is installed it could be challenged by factors such as operational, maintenance and generational cost. This challenge could be overcomed by producing adequate supply commensurate to the size of the power plant. However, potential bioelectricity developers and market should put into consideration that they must be efficient for the sector to be sustained. Diji [37] considered efficiency as an integral factor that reflects the performance of the system as thermodynamic system.

Another major challenge that could hinder bioelectricity production from oil palm processing wastes in Nigeria is technological. According to Ohimain [15, 38], Nigeria planned for the installation of two 1MWe wood biomass (saw dust) gasification power plants in Pategi, Niger and Odogbolu, Ogun states. But due to no experience in operation, cost factor, availability of feedstock among other factors the proposed bioelectricity plants were not operational at as July 2016. Ohimain [38] reported that many nations of world embarked on biopower by the installation of pilot/demonstration plants prior full scale; and without experience, Nigeria will probably purchase and install a turn-key plant. This bioelectricity technologies (combustion, pyrolysis and gasification) under study appears have several benefits for the use of oil palm processing solid wastes. Despite the benefits, have their respective limitations including energy intensive, production of contaminants contaminated products, air pollution, corrosion and unstable thermal energy [13]. Due to high moisture content of the solid wastes such as EFB, the efficiency of the technologies may be hindered. According to Brachi et al. [39], the raw gas is influenced by the type of gasification process, agent and processing temperature. Typically, high moisture content challenge can be prevented by drying the biomass to moisture content of below < 10% prior to gasification. Again, Nigeria need to under study advanced bioelectricity producing nations in other to make significant improvement in the sector.

Gasification and other thermochemical power generation from wood biomass has environmental component. The various by-product of gasification could be toxic to the environment. For instance, hydrocarbon and heavy metals that could be generated have environmental effects. Pudasainee et al. [8] has reported the occurrence of trace metals in straw char and glycol used in gasification. Other by-product include char, tar, ash spent catalysts, and other air emission and noise [38]. A comprehensive study has been conducted on the environmental impact of wood gasification for electricity generation under Nigeria setting by Ohimain [15]. Generally, bioelectricity production from biomass has low environmental impacts [40] compared to fossil fuel. Therefore, the need for the use improved technology and comply with the findings of environmental impact assessment carried out prior to the commencement of the bio-power project. Also, Ohimain [38] have listed possible approach for reducing the potential environmental impacts of bio-power project under Nigeria setting.

Like other biofuel, bioelectricity generation has social impacts. The conversion of oil palm processing solid resides could create jobs opportunities. It could also cause rural urban drift or migration. Again, it could have health effects; this is because oxide of nitrogen could be produced during gasification. Hence, there is the need to frequently monitor this parameter (oxide of nitrogen) within the vicinity of power plant as recommended by Federal Environmental Protection Agency for work of this magnitude.

In Nigeria, several policies changes with regime. There is poor continuity of policies strategy in Nigeria, hence a poor political indicator. Political indicator typically refers to the political will and determination of the government to formulate and implement policies and programmes that will lead to project conception, implementation and development [37]. A notable policy that lack continuation is the Nigeria biofuel policy of 2007. In the electricity sector, the government has rolled out many policies and regulatory frameworks to enhance rural electrification and power generation using renewable sources of energy [41]. Some of these policies and regulatory frame work include the National Energy Policy (2003) with sole target of 75% of Nigerians having access to electricity by 2020, providing electricity to cities and local government headquarters by 2010, and enhancing the involvement of private sector; the Electricity Power Sector Reform Act (2005) with sole aim of providing 40% electricity in rural areas in 2005 to 75% in 2015; Nigerian Renewable Electricity Policy (2006) which aimed at promoting biomass (agricultural residues, animal and human waste) energy resource in rural area, construction of independent renewable electricity systems in areas not covered by the electricity grid; and Renewable Energy Master Plan (2007) with sole aim of increasing Nigeria electricity demand to a total of 14,000 MW by 2015 of which renewable energy will constitute about 5% and also predicting that the total electricity demand will increase to about 29,000 MW of which renewable energy will constitute about 10% by 2025 [41]. Ohimain [38] reported that Nigeria lack policy framework for the effective and sustainable operation of bio-power, and that favorable condition should be enhanced to allow public participation. Some of the suggested policy frame work includes incentives (such as tax holidays, tax exemption and waivers, subsidies, grant etc) and favorable cost compared to conventional fuel electricity [38]. These suggestions made could allow private investors to invest in bioelectricity sector.

4. Conclusion and Future Direction

Nigeria generates millions tonnes of wastes during oil palm processing. These wastes streams have been widely under-utilized, hence causing environmental nuisance. The major method of discharging these wastes is through open combustion releasing pollutant gases to the atmosphere. This study was designed to assess the potential under-utilized oil palm processing solid wastes for bioelectricity generation via gasification, pyrolysis and combustion at 50%, 65% and 80% efficiency. The results showed that 3.234 to 6.073 MWh would have been generated between 2004 to 2013 and on projection; it could reach 4.242 to 6.787 MWh by 2029 on minimum growth rate. If electricity were tapped using gasification, pyrolysis and or combustion between 2004 to 2013 and continues (i.e. projection scenarios), it could create jobs, boost electricity supply in the country and attendant environmental impacts associated with the current predominant means of discharging the solid wastes could be prevented. The study identified economic, environmental, technological and policy problems as potential challenge that could affect bioelectricity generation from oil palm processing solid wastes in Nigeria. Hence, for the potential bioelectricity from under-utilized oil palm processing solid wastes to be utilized, a lot factor and research need to be put into consideration. Hence on Nigeria scenario, research need to be focused on these factors including;

a. Possible policy that could promote both public and private participation in the development and potential marketing of bioelectricity.
b. Studying the mechanism, thermodynamics and operation processes of the particle size, temperature, pressure, heating time and residence among other factors of the conversion technologies.
c. Possible means through which the biomass could be gathered, knowing fully well that the palm oil mills in Nigeria are scattered all over the country especially in southern region where oil palm are found in both wild and plantation.
d. Possible method of avoiding hurdles associated by the feedstock (i.e. high moisture content and other heterogeneous materials).
e. Policy on balancing the economics of bioelectricity with electricity from fossil fuel.

References

[1] S. E. Hosseini, M. A. Wahid, Pollutant in palm oil production process, J. Air Waste Manage. Association 65 2015 773-781.

[2] N. A. Samiran, M. N. N. Jaafar, J-H. Ng, S. S. Lam, C. T. Chong, Progress in biomass gasification technique – With focus on Malaysian palm biomass for syngas production Renew. Sustain. Energ. Reviews 62 2016 1047–1062.

[3] I. M. Atadashi, M. K. Aroua, A. A. Aziz, Biodiesel separation and purification: a review, Renew. Energ. 36 (2011) 437 – 443.

[4] Escobar JC, Lora ES, Venturini OJ, Yanez EF, Castillo EF, Almazan O, Biofuels: Environment, technology and food security. Renew. Sustain. Energ. Reviews 13 2009 1275–1287.

[5] M. Salomon, M. F. Gómez, C. Erlich, and A. Martin, 'Pelletization: an alternative for polygeneration in the palm oil industry,' Biomass Conversion and Refinery, 3 2013 213-229.

[6] J. Popp, Z. Lakner, M. Harangi-Rákos, M. Fári, The effect of bioenergy expansion: Food, energy, and environment, Renew. Sustain. Energ. Reviews 32 2014 559–578.

[7] M. Patel, X. Zhang, A. Kumar, Techno-economic and life cycle assessment on lignocellulosic biomass thermochemical conversion technologies: A review, Renew. Sustain. Energ. Reviews 53 2016 1486–1499.

[8] D. Pudasainee, H-R. Paur, S. Fleck, H. Seifert, Trace metals emission in syngas from biomass gasification, Fuel Processing Technol. 120 2014 54–60.

[9] N. L. Panwar, R. Kothari, V. V. Tyagi, Thermo chemical conversion of biomass – Eco friendly energy routes, Renew. Sustain. Energ. Reviews 16 2012 1801– 1816.

[10] S. M. Shafie, T. M. I. Mahlia, H. H. Masjuki, A. Ahmad-Yazid, A review on electricity generation based on biomass residue in Malaysia, Renew. Sustain. Energ. Reviews 16 2012 5879–5889.

[11] A. A. Bazmi, G. Zahedi, H. Hashim, Progress and challenges in utilization of palm oil biomass as fuel for decentralized electricity generation, Renew. Sustain. Energ. Reviews 15 2011 574–583.

[12] S. Chaivongvilan, Science Technology and Innovation (STI) Challenges of Biomass Implementation, Energ. Procedia 79 2015 549 – 555.

[13] M. F. Awalludin, O. Sulaiman, R. Hashim, W. N. Aidawati, W. Nadhari, An overview of the oil palm industry in Malaysia and its waste utilization through thermochemical conversion, specifically via liquefaction, Renew. Sustain. Energ. Reviews 50 2015 1469–1484.

[14] J. A. Ruiz, M. C. Jua´rez, M. P. Morales, P. Munoz, M. A. Mendı´vil, Biomass gasification for electricity generation: Review of current technology barriers, Renew. Sustain. Energ. Reviews 18 2013 174–183.

[15] E. I. Ohimain, Environmental impacts of the proposed 1mwe wood gasification power plant in Nigeria, Nigerian J. Agric. Food Environ. 7 (4) 2011 12-18.

[16] L. Zhang, C. C. Xu, P. Champagne, Overview of recent advances in thermo-chemical conversion of biomass, Energ. Conver. Manage. 51 2010 969–982.

[17] E. I. Ohimain, E. I. Seiyaboh, S. C. Izah, V. E. Oghenegueke, T. G. Perewarebo, Some selected physico-chemical and heavy metal properties of palm oil mill effluents, Greener J. Physical Sci. 2 (4) 2012 131 - 137.

[18] E. I. Ohimain, S. C. Izah, N. Jenakumo, Physicochemical and microbial screening of palm oil mill effluents for amylase production Greener J. Biol. Sci. 3 (8) 2013 314 – 325.

[19] E. I. Ohimain, C. Daokoru-Olukole, S. C. Izah, R. A. Eke, A. C. Okonkwo, Microbiology of palm oil mill effluents, J Microbiol. Biotechnol. Res. 2 (6) 2012 852 – 857.

[20] E. I. Ohimain, S. C. Izah, Possible contributions of palm oil mill effluents to greenhouse gas emissions in Nigeria, Brit. J. Appl. Sci. Technol. 4 (33) 2014 4705 – 4720.

[21] E. I. Ohimain, S. C. Izah, S. O. Abah, Air quality impacts of smallholder oil palm processing in Nigeria, J. Environ. Protection 4 2013 83-98.

[22] E. I. Ohimain, S. C. Izah, Gaseous emissions from a semi-mechanized oil palm processing mill in Bayelsa state, Nigeria, Continental J. Water, Air Soil Pollution 4 (1) 2013 15 – 25.

[23] S. C. Izah, E. I. Ohimain, T. C. N. Angaye, Potential thermal energy from palm oil processing solid wastes in Nigeria: mills consumption and surplus quantification, Brit. J. Renew Energ. 1 (1) 2016 38-44.

[24] E. I. Ohimain, S. C. Izah, Potential of Biogas Production from Palm Oil Mills' Effluent in Nigeria, Sky J Soil Sci. Environ. Manage. 3 (5) 2014 50 – 58.

[25] E. I. Ohimain, S. C. Izah, Estimation of potential Biohydrogen from Palm Oil Mills' Effluent in Nigeria using different microorganisms under light independent fermentation, J. Environ. Treat Techniq. 3 (2) 2015 97 – 104.

[26] E. I. Ohimain, S. C. Izah, Estimation of potential electrical energy and currency equivalent from un-tapped palm oil mill effluents in Nigeria, Inter. J. Farming Allied Sci 3 (8) 2014 855-862.

[27] E. I. Ohimain, S. C. Izah, Energy self-sufficiency of smallholder oil palm processing in Nigeria, Renew. Energ. 63 2014 426 – 431.

[28] E. I. Ohimain, S. C. Izah, Energy self-sufficiency of semi-mechanized oil palm processing: a case study of Bayelsa palm mill, Elebele, Nigeria, Energ. Economics Letter 2 (3) 2015 35-45.

[29] E. I. Ohimain, S. C. Izah, F. A. U. Obieze, Material-mass balance of smallholder oil palm processing in the Niger Delta, Nigeria, Adv. J. Food Sci. Technol. 5 (3) 2013 289-294.

[30] S. C. Izah, E. I. Ohimain, Bioethanol production from cassava mill effluents supplemented with solid agricultural residues using bakers' yeast [*Saccharomyces cerevisiae*], J. Environ. Treat. Techniq. 3 (1) 2015 47 – 54.

[31] S. C. Izah, A. A. Oduah, E. I. Ohimain, Effects of Temperature and fermentation period on the recovery of second grade palm oil from palm press fiber, Inter. J. Eng. Sci. Innovative Technol. 3 (5) 2014 131-138.

[32] B. B. Nyakuma, Bioelectricity potential of oil palm waste in Malaysia. 3rd International Conference "Research and Education in Natural Sciences", At Shkodra, Albania, 2015.

[33] V. Mendu, T. Shearin, J. B. Campbell Jr, J. Stork, J. Jae, M. Crocker, G. Huber, DeBolt S, Global bioenergy potential from high-lignin agricultural residue, proceedings of the National Academy of Sciences of the United States of America, 109 (10) 2012 4014–4019.

[34] Sikarwar VS, Zhao M, Clough P, Yao J, Zhong X, Memon MZ, Shah N, Anthony EJ and Fennell PS. An overview of advances in biomass gasification. Energy Environ. Sci., 2016, 9, 2939-2977.

[35] E. I. Ohimain, S. C. Izah, Manual energy contribution to palm oil processing by semi-mechanized mill in Bayelsa state, Nigeria, Inter. J. Farming Allied Sci. 3 (7) 2014 729-732.

[36] E. I. Ohimain, S. C. Izah, Contribution of manual energy to palm oil processing by smallholders in Nigeria, Sky J Agric. Res. 3 (7) 2014 137 – 141.

[37] C. J. Diji, Electricity production from biomass in Nigeria: options, prospects and challenges, Inter. J. Eng. Appl. Sci. 3 (4) 2012 84-98.

[38] E. I. Ohimain, The Prospects and Challenges of Waste Wood Biomass Conversion to Bioelectricity in Nigeria, J. Waste Conver. Bioproducts Biotechnol. 1 (1) 2012 3–8.

[39] P. Brachi, R. Chirone, F. Miccio, M. Miccio, A. Picarelli, G. Ruoppolo, Fluidized bed co-gasification of biomass and polymeric wastes for a flexible end-use of the syngas: Focus on bio-methanol, Fuel 128 2014 88–98.

[40] J. N. Ogwo, O. C. Dike, S. O. Mathew, E. U. Akabuogu, Overview of biomass energy production in Nigeria: implications and challenges, Asian J. Nat. Appl. Sci. 1 (4) 2012 46 – 51.

[41] K. Oluoti, G. Megwai, A. Pettersson, T. Richards, Nigerian Wood Waste: A Dependable and Renewable Fuel Option for Power Production, World J. Eng. Technol. 2 2014 234-248.