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UTILIZATION OF BIOMASS-BASED RENEWABLE ENERGY FOR ELECTRICITY GENERATION IN BENUE STATE, NIGERIA

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Abstract: *Biomass consists of organic materials that are plant or animal based, including but not limited to dedicated energy crops, agricultural crops and trees food, and fibre crops residues, aquatic plants, forestry and wood residues, agricultural wastes, bio-based segments of industrial and municipal waste, by products and other non-fossil organic materials. In view of this Benue State is end owed with rich natural and mineral resources which has placed the state in vintage position in the country as the nation's "Food Basket". The rich energy crops, agriculture crops and trees in the state provide a good platform for the government of Benue State that if utilized, will do away with the electricity deficit in the state. This study examines the Biomass potentials in the state and enumerates the local government areas in the state for the government to take advantage of.*

Keywords: *Utilization, Biomass-Based, Renewable Energy, Electricity, Generation, Benue State*
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I. INTRODUCTION

Regular and adequate power supply is the hallmark of a developed economy (Onochie et. al. 2015a). Any nation whose energy need is inadequate in supply, prolongs her development and tasks losing potential investors (Onochie et. al. 2015b). The importance of energy services to the socio-economic development of a country has been extensively documented in literature (Alchator *et. al.*, 2016) During the last few years the "energy issue" has been assuming a more and more important role among any other choice, strategy and policy concerning human survival and development (Oyedepo *et. al.*, 2018) modern societies and strongly depend on reliable, affordable and sustainable energy supplies. In fact, energy is an obligatory input for most production processes and other economic development (Oyedepo, 2014)

1.1 THE NIGERIA SCENARIO

The existing fleet of power of power plants in Nigeria is a mix of plants built before the 1990's and plants built (or being built) since the mid 1990's. The poor performance of the power plant has led to acute shortage of electricity across the country with power outages of several hours per day (adegbulugbe, 2007). Generating plant availability is low and demand-supply gap is crippling. Poor services have forced most industrial customers to install their own power generators, at high costs to themselves and the Nigerian economy (oyedepo, 2014b). Inadequate transmission infrastructure is among the constants the on-grid power generation has over the years. The Nigerian electricity transmission system consists of about 5,523.8km of 330kv lines and 6,801.49km of 132kv lines, 6,098MVA transformer capacity at 330/132kv and 8,090MVA transformer capacity at 132/33kv (Okafor, 2017). The existing transmission system is weak and is majorly radial, which means that it's a single path of transmission with a power source at one end. Also, electricity consumption per capital in Nigeria for the period 1971-2013 is presented in Figure 1.

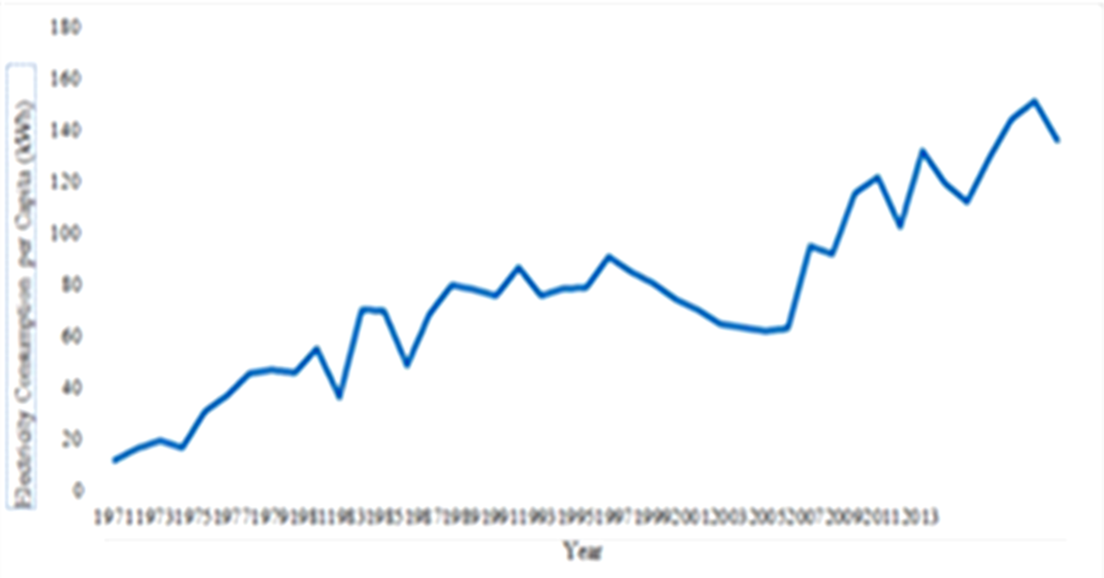

Figure 1 Electricity Consumption Per Capita (Kwh) from 1971-2013 sources: adapted from Oyedepo et. al. 2018

The value valid from 29kWh + 0156kwh, the highest value ever recorded was 156kwh in 2012 (CIA, 2014). There was a drop in this lowest electricity consumption on a per capita basis in the world. Table 1 shows the comparative energy consumption of selected countries as at 2015. At 134kwh per capita, Nigeria Lagos significantly behind other developing nations in terms of electricity consumption based on the country's current demographics and global trends, electricity consumption should be four or five times higher than 134kwh. For instance, the global minimum average electricity consumption per capita developing economics is 500kwh, about 4 times Nigeria's. Ghana's per capita consumption stand at 403kwh about 3 times Nigeria, while South Africa with 4,363kwh consumes 30 times Nigeria's power. The rate of thumb is that an industrial nation requires 1,000mw per million in habitants. This would imply that Nigeria requires 180,000 MW for full power, which is a massive distance away from the federal government's targets of 10,000MW by 2020 (Usman and Soglu, 2015). Today 2020 is here yet the target seems as if we have not started since the country is still grappling with a little above 4,000MW.

Table 1. Comparative Energy Consumption of some selected Countries as at 2015. Adapted from Oyedepo et. al. 2018.

Country	Population	Installed Generating	Generation	Energy Consumption	Energy Consumption per
	(Million)	Capacity (GW)	Capacity (GW)	(billion kwh)	Capita (kwh)
USA	321,368,864	1,074	1,053	3,883	12,083
Germany	80,854, 408	204	178	583	7,204
UK	64,088,222	95	76	304	4,740
South Africa	53,675,563	47	44	234	4,363
China	1, 367,485,388	1,646	1,505	5,523	4,039
Brazil	204, 259,812	156	119	479	2,344
Egypt	88,487,396	39	27	129	1,462
Indonesi a	255,993,674	53	41	156	609
India	1,251,695,5 84	309	223	758	605

Ghana	26,327,649	5	3.0	11	403
Nigeria	**172,562,056**	**10**	**7.6**	**23**	**134**

Source: World Factbook 2016

According to Abam et. al. (2014), the electric power generating factor in Nigeria is relatively small when compared with the teeming population and consequent energy consumption. The overall electricity production and consumption from 2000 to 2014 are presented in table 3. The electricity production increased from 4.75 billion kWh in 2000 to 24.87 billion kwh in 2014 while consumption increased from 13.72 billion kwh in 2000 to 20.38 billion kwh in 2014. Therefore, the level of energy consumption in Nigeria is alarmingly low compared to other countries with corresponding energy resources and population sizes, despite being Africa's most populous country, retaining large reserves of energy resources (Shaaban & Petimn, 2014). While Nigeria's electrical energy demand is high, its actual generation is considerably below demand. With a protected rate of fossil fuel depletion in 40 years and potentially devastating environmental problems associated with its use, it is imperative for the government to explore alternative energy resources. At present, nuclear energy, renewable energy and even coal energy have no noticeable role in Nigeria's energy mix. Therefore, there is urgent need to tap Nigeria's huge natural renewable energy resources to evade stumbling into energy supply crisis (Oyedepo, 2012).

1.2 Benue Scenario

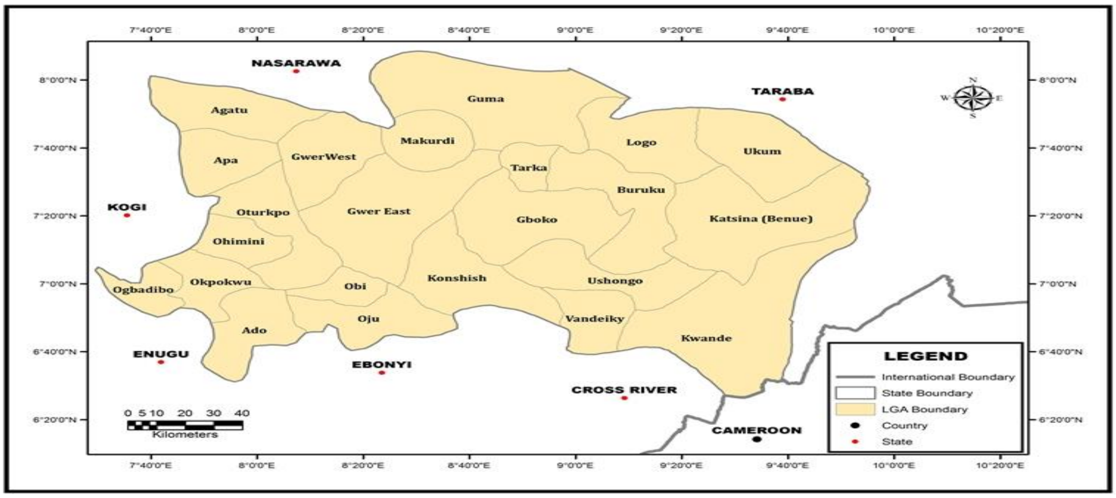

Figure 2. Map of Benue State

Benue state is one of the north-central states in Nigeria with a population of about 4,253,641 in 2006 census. With an average population density of 99 persons per km^2, this makes Benue the most populous states in Nigeria. The state's capital is Makurdi which has over 380 persons per km^2; the males are 49.8 percent of the total population while females constitute 50.2 percent (Wikipedia 2020). Benue lies within the lower Benue tough in the middle belt region of Nigeria. Its geographical coordinates are longitude 7^{o}47 and 10^o East latitude 6^{o}25 and 8^{o}8 north and shares boundaries with five states. Benue occupies a landmass of 34,059 square kilometres. The state is blessed with rich natural and mineral resources like limestone, kaolinite, barite, Gypsum, etc. and natural resources in the form of Agricultural produce like yam, rice, beans, cassava, soya beans etc. agriculture is the mainstay of the economy, engaging over 75% of the state farming population. It is very disappointing that with the abundant mineral and natural resources in the state electricity has been a mirage to the people. In a study Nigerian energy situation (energy Pedia, 2020), the number of households as of 1997 in the stat was 788,111, out of this number only 17% of the entire population in the state had access to electricity making a total of 135,003 households with electricity. Thus the annual growth rate of consumers was 7.49%. In the same study, predictions were made for electricity consumption in Benue State for 2006, 2010 and 2020. Table 2 shows that the percentage of households with electricity will grow by 25%, 30% and 46% respectively resulting to 258,565,345,145 and 710,537. Number of households to be linked with electricity respectively.

Table 2: Trends in Electrification Rate Per State (adopted from Energy Pedia, 2020

No.	State	No. of Households as of 1997 (*1)	% of Household with Electricity as of 1997 (*2)	No. of Households with Electricity as of 1997	Annual growth rate of consumers (%)	% of Household with Electricity			No. of Household with Electricity		
						2006	2010	2020	2006	2010	2020
1	Taraba	432,880	12	50,301	7.80	17	21	34	98,888	133,542	283,012
2	Jigawa	823,164	12	99,685	7.77	18	22	35	195,520	263,766	557,554
3	Zamfara	593,479	13	77,924	7.71	20	23	37	152,101	204,752	430,492
4	Sokoto	686,178	13	90,095	7.71	20	23	37	175,859	236,734	497,734
5	Kebbi	592,137	13	77,807	7.71	20	23	37	151,866	204,431	429,794
6	Katsina	1,074,392	14	145,902	7.69	20	24	38	284,184	382,194	801,663
7	Gombe	426,284	17	72,553	7.49	25	30	46	139,031	185,628	382,367
8	Bauchi	819,259	17	139,438	7.49	25	30	46	267,198	356,753	734,857
9	Benue	788,111	17	135,003	7.49	25	30	46	258,565	345,146	710,537
10	Yobe	400,682	19	75,729	7.39	27	32	50	143,826	191,270	390,098
11	Ebonyi	416,196	25	102,759	7.06	39	46	69	189,857	249,413	493,343
12	Enugu	608,334	25	150,198	7.06	39	46	69	277,505	364,554	721,096
13	Cross River	547,224	29	159,954	6.80	40	47	68	289,196	376,273	726,572
14	Nassarawa	345,773	31	108,607	6.68	43	49	71	194,326	251,669	480,372
15	Plateau	602,456	31	189,231	6.68	43	49	71	338,583	438,495	836,973
16	Kano	1,663,337	32	538,256	6.62	44	51	72	958,709	1,239,106	2,353,218
17	Borno	725,970	34	248,935	6.51	46	53	75	439,310	565,469	1,062,926
18	Adamawa	601,745	35	210,069	6.48	47	54	76	369,621	475,140	890,189
19	Akwa-Ibom	689,703	36	246,638	6.43	47	55	77	432,200	554,578	1,034,327
20	Niger	693,215	42	288,932	6.10	54	61	83	492,124	623,542	1,126,789
21	Kaduna	1,126,632	43	479,607	6.05	55	62	84	813,402	1,028,655	1,850,037
22	Kogi	614,828	50	309,996	5.60	62	70	90	506,218	629,499	1,085,526
23	Bayelsa	321,102	52	167,069	5.51	64	71	91	270,706	335,469	573,511
24	Rivers	912,575	52	474,813	5.51	64	71	91	769,348	953,408	1,629,926
25	Abia	547,888	52	287,587	5.48	53	58	75	464,946	575,611	981,623
26	Imo	711,551	61	433,833	5.00	72	78	96	673,132	818,258	1,333,107
27	Delta	741,568	62	462,294	4.92	73	79	96	712,530	863,590	1,396,589
28	Edo	621,770	63	388,855	4.91	73	79	96	598,757	725,382	1,171,814
29	Kwara	443,257	68	299,509	4.63	77	83	98	450,021	539,288	847,795
30	Osun	617,802	71	436,539	4.45	80	85	99	646,094	769,082	1,188,952
31	Abuja	106,397	71	75,436	4.44	80	85	99	111,517	132,676	204,841
32	Ogun	668,065	72	483,813	4.35	81	86	99	709,928	841,842	1,289,056
33	Ekiti	439,644	72	318,698	4.35	81	86	99	467,484	554,265	848,386
34	Ondo	643,968	72	466,812	4.35	81	86	99	684,748	811,860	1,242,673
35	Anambra	800,534	78	621,295	4.06	85	88	99	888,786	1,042,097	1,551,263
36	Oyo	988,395	78	771,541	4.03	85	89	100	1,101,286	1,289,986	1,915,566
37	Lagos	1,638,903	96	1,577,936	3.00	96	96	97	2,058,848	2,317,252	3,114,193
	Total Nigeria	25,475,400	44	11,263,648	6.04	53	58	75	17,776,220	21,870,672	37,168,770

(Remarks)
(*1) No. of Households as of 1997 was extraporated based on the result of 1991 Census.
(*2) % of Household with Electricity as of 1997 was quoted from the result of General Household Survey 1997/98.

Average number of persons per household	4.13
Annual growth rate of consumers (Highest)	7.80 %
Annual growth rate of consumers (Lowest)	3.00 %

Unfortunately, 2020 is here and just like our father land the state is barely grappling to generate 10mw of energy for citizens with a population growth over 4milllion. Therefore while the energy demand of the state is increasing, the electricity generation is decreasing making it impossible to meet the electricity demands of people. Currently the state does not have any functional power plant to generate power for the ever increasing demands despite the enormous renewable energy sources. The implication of this reality is that Benue state power sector is extremely vulnerable to the availability of gas and adequate gas infrastructure, since their only source of power is from the national grid. But Nigeria electricity supply system is an interconnected national grid system (Akimbami, 2001). And access to electricity is however 10w-about 40% on the average and as low as 18% in the rural areas (Nussbaurner et. al., 2011) because of the low amount of electricity produced in Nigeria (IEA, 2012). Benue state too is one of the rural communities suffering from the reason outlined above. Therefore the persistent energy crisis in Benue state has weakened industrialization in the state. This is evident of the fact that there is no functional company or industrial activity in the state which has significantly undermined efforts to achieve sustained economic growth, increased competitiveness of indigenous industries in domestic, regional and global markets as well as unemployment generation (Iwayemi, 2008).

The above assertion is true in Benue state since a large population of the people have engaged over 75% in agriculture. Indigenous companies like; Taraku mills located in Taraku-Gwer east LGA, otukpo burnt bricks in otukpo LGA, Benue cement company Gboko, Fruit juice company wannune Tarka LGA etc. have all folded-up or left the state.

Dangote Cement Company is the only private company that operates within the state and provides a little employment for the people and is dependent 90% on private power plant for electricity supply. As a result of this, a rough estimate from (Wikipedia, 2020) puts the employment percentage in the state as 75% farmers, 10% traders, 6% civil servants and 9% orivate. The irony of the situation from the statistics is that Benue state is well endowed with larger quantities of renewable energy resources. The need to act on the energy policies in Benue state has come very necessary. Alternatively energy sources are at the present the only panacea that will rescue the state from its shadows.

Renewable energy is also called non-convectional energy that is continuous replenished by natural process. It is a clean and inexhaustible energy (onochie et. al. 2015). Renewable energy resources include; Biomass, hydropower, solar wind, tidal, ocean thermal and geothermal energy. Renewable energy resources in Benue state is abundant but has not been fully exploited. Benue state should not be hanging behind in following this viable path other visionary and proactive nations ate doing to scare their countries from impending energy cataclysm.

Long term investments in renewable energy like biomass, solar and wind have the potentials to contributing significantly to electricity generation (onochie et. al. 2015).

Hence, rural communities electricity need have to be met through sustainable and economical means, typically the renewable energy technologies (RET's) particularly its decentralised system (with less or no gridlines network and without fossil fuel sources). This is because RET's have been used in providing sustainable electricity to rural areas in developing countries. Also, decentralised RET's have merits in determining when and where power energy is truly required; helps in mitigating greenhouse gas (GHG) emission associated with fossil and create more employment especially biomass source (Evans et. al. 2010). Studies by mahapatra and Dasappa, 2012 revealed that of all the renewable energy sources available solar PV, biomass and small-hydropower systems are the most used. Studies have been conducted in respect of sustainable electricity provision to rural areas in developing countries using decentralise RET's. Typically, the study by Dassappa (2011) reported that biomass is among the optimal alternative energy sources for sustainable electricity provision in sub-Saharan African (SSA) are cost competitive with fossil fuel sources again, several research institutions and international agencies such as the ESMAP programme administered by the world Bank (ESMAP, 2007), rated biomass as one of the cheapest available renewable energy resource for power generation.

Using biomass to generate energy has positive environmental implications and creates a great potential to contributing considerably more to the renewable energy sector, particularly when converted to modern energy comers such as electricity, liquid and gaseous fuels (IBEP, 2006). Findings by order of priority revealed that biomass, solar PV, small-hydro power and wind are the best means for providing sustainable electricity in Nigerian rural areas (Garba et. al. 2016). However, Evans et. al. (2010) argued that BETs are cheaper than solar PV but more expensive than grid extension system. Hence, from the above, it is fair to conclude that BET's are the best means of electricity provision in rural areas.

Therefore, producing electricity from biomass is one of the various ways of responding to the challenges of energy crisis in Nigeria. Total biomass potentials Nigeria, consisting of animal, agricultural and wood residues were estimated to be 1.2 PJ in 1990 (obioh & Fagbenle, 2009). In 2005, research revealed that bio-energy/ potential of Nigeria stood at fuel wood 13071,464 hectares, animals waste, 61million tonnes per year, crop residue, 83 million tonnes (Agba et. al. 2010). According to (Oladipo, 2010), Nigeria has a total of 1,160 constituted forests reserves, concerning a total area of 10,752,702 hectares, representing about 10% of the total land area. Most of the forests in Nigeria are man-made for the purpose of timber exploitation, and in some cases for fuel wood and furniture making industries. Fuel wood is the most widely used domestic renewable energy resources in rural Nigeria and especially by low income groups in the urban areas (Onochie et. al. 2015)

1.3 Biomass Potential In Benue State

Benue state has rich and abundant renewable energy resources scattered round the 23 local government areas in the state, according to ASABE S593.1 standard (ASABE, 2011), biomass consists of organic materials that are plant or animals based, including but not limited to dedicated energy crops, agricultural crops and trees, food and fibre crop residues, aquatic plants, forestry and wood residues, agricultural wastes, bio based segments of industrial and municipal wastes, processing by product and other non-fossil organic material (Simonyan and Fasina, 2013). Three main categories of Biomass are primary, secondary and tertiary Biomass (ASABE, 2011).

Primary biomass is produced directly by photosynthesis and harvested or collected from the field of forest where it is grown. Examples ate grains, perennial grasses and wood crops, crop residues and residues from logging and forest operations.

Secondary Biomass consists of residues and by-product streams from food, feed, fibre, wood and materials processing plants (such as sawdust, black liquor and cheese whey), and manures from concentrated animal feeding operations.

Tertiary Biomass sources are post-consumer residues and wastes such as fats, greases, oil, construction and demolition wood as well as other wastes wood from urban environments as well as packaging wastes, murucipal solid wastes and land full gases (ASABE, 2011).

The assertions made above for Biomass categories are the correct description of Benue state. This is because of its rich agricultural produce which include yam, rice, beans, cassava, sweet-potato, maize, soya bean, sorghum, millet, sesame, cocoyam, etc. (Wikipedia, 2020). The state accounts for over 70% of Nigeria's soybean production. The states also cultivate important cash crops like peanuts mango varieties, citrus. Other cash crops include palm oil, melon, African pear, chilli pepper, tomatoes etc. this has made Benue State the major source of food production in the nation (Wikipedia, 2020). In spite of these rich agricultural products, the state has not utilized it for the renewable (biomass) electricity production. Mechanization and plantation agriculture and agro forestry are still at its infancy. Farm inputs such as fertilizers, improved seed, insecticides and other foreign methods are being increasingly used. However, cost and availability is still a challenge. These challenges would be summoned if biomass is utilized by the state government. Animal production includes cattle, pork, poultry and goat but no diary and dairy products yet in the state. Putting the huge quantities of biomass resources, mostly in the form of agricultural residues and wastes which are currently disposed by burning or dumping to energy production could potentially increase the energy mix and balance in Nigeria (Simonyan and Fasina, 2013) and by extension Benue state. There are also environment benefits of reducing greenhouse gas emissions by generating electricity from biomass as well as supply of electricity in the rural areas (Pereira et al. 2012).

1.4 Biomass Resources In Benue State

Biomass feedstock can be obtained from two principal different categories convectional agricultural products such as sugar or starch-rich crops, and oilseeds; and lignocellulosic products and residues (Girard and fallot, 2006). Lignocellulosic feedstock (such as trees, shrubs, grasses, agricultural forest and forest residues) are potentially more abundant and cheaper than feed stocks form convectional agriculture because, they can be produced with fewer resources and on marginal and poor lands (simonyan and Fasina, 2013). Also, agricultural current harvesting activities without the need for additional land cultivation, the type of biomass resources available in Nigeria varies with climatic region in the country. For example, the rain forest zone will generate the highest quantity of woody biomass while the savannah zones will generate more crop residues (Olaoye, 2011). Benue state has great potential for Biomass resources in terms of classification asserted to by olaoye, 2011 in the following respect.

1.4.1 Agricultural Resources in Benue State

The Nigerian agricultural production is characterised by large number of dispersed small scale producers employing traditional manual tools based on rain-fed crops but providing the major food needs of the country. Benue state in terms of the provision of these crops, contributes up to 50% of the nation’s agriculture produce with 70 of Nigeria’s soybean vary with the agro-ecological zones as given by Gbadegesin and Akinbola (1995) in Nigeria namely:

i. Sahel
ii. Sudan savannah
iii. Guinea savannah
iv. Derived savannah
v. Rain forest
vi. Fresh water swamp
vii. Mangrove swamp

Benue state is located within the southern guinea savannah zone and is rich in agricultural produce which include; yam, rice, beans, cassava, maize, soybeans, sorghum, millet, sesame, cocoyam, cowpea, groundnuts and melon. Table 3 summarises the production data information for these major agricultural crops produced in Nigeria.

Table 3: Production Data for Major Agricultural Crops in Nigeria, 2010 (adapted from Simonyan & Fasina, 2013)

Agricultural resource	Production area (thousand ha)	Total production (thousand metric tons)	State with highest production	Production in the state with highest (thousand metric tons)
Cowpea	2860	3368	Benue	428
Cassava	3482	42533	Benue	3792
Maize	4149	7677	Kaduna	436
Cotton	399	602	Zamfara	155
Soybeans	291	356	Benue	79
Groundnut	2785	3799	Niger	547
Sorghum	4960	7141	Kano	746
Millet	4364	5171	Sokoto	714
Rice	2433	4473	Kaduna	732

Source: NASS (2012).

Table 3 shows that Benue state produces the highest amount of cowpea, cassava and soybeans, with production area of 2860 hectares, the total production amounting to 3,368 metric tonnes and individual production of 428 thousand metric tons for Benue state only for cowpea, for cassava, Benue state contributes 3,792 thousand metric tons making 79 thousand metric tons of soybeans to also make it the biggest producer in the country. The government of Benue state should utilize this opportunity to invest by way of patterning with national and international agencies in order to harness these enormous Biomass resources in the domain to overcome the energy crisis in the state in particular and also contribute to the national grid. The potential size of the Biomass resources in the form of agricultural crop in the state is quite large on a global scale, and the ability to utilize existing residue streams that may provide low cost feedstocks offers attractive near-term opportunities for Biomass use. In the long term, the development of sustainable, dedicated Biomass energy plantations may further expand the resource base and help reduce the cost if energy produced from Biomass.

1.4.2: Agricultural Crop Residues in Benue State

Agricultural residues are organic materials produced as by-product during the harvesting and processing of agricultural crops. Agricultural residues which are produced at the time of harvest are primary or field base residues while those produced along with the product during processing are secondary or processed based residues (Simonyan and Fasina, 2013). Agricultural residues are heterogeneous, varying in bulk density, moisture content, particle size and distribution depending on the mode of handling. They are usually fibrous, low in nitrogen and vary with geographical location (Smith, 1989) agricultural crop residues are used as fertilizers; some are used for erosion control and as folder for livestock. Unfortunately close to 50% of the residue are however burnt on cropland before the start of the next growing season. Process residue offer high promises as energy source (cooper and Liang, 2007). Chemical composition of a crop residue varies depending on factors such as variety, age of residue or stage of harvest, physical composition including length of storage and harvesting practices (OECD/IEA, 2010). The proximate compositions of some major crop residues available in Nigeria are presented in Table 4.

Table 4: Proximate Composition of Major Crops Residues (adapted from Simonyan & Fasina, 2013)

Crop residue	Moisture content, %	Crude protein	Organic matter	Crude fibre	Ether extract	Ash	Nitrogen free extractives
Maize stover	10	2.8	85–91	28–46	1–2	9–15	35–53
Sorghum stover	10	3–6	96	31–35	1–2	4	50–56
Rice straw	10	2–9	75–90	20–45	1–4	10–25	29–48
Groundnut haulms	10–12	11–17	87–90	21–29	1.5–2.5	10–13	51–57
Cassava tops	70–80	17–27	89–90	8–26	3–8	6–11	35–60
Sugar cane tops	70–80	5–8	81–95	28–34	1.5–2.5	5–9	44–54
Cocoa pods	75	2–9	75–90	20–45	1–4	10–25	33–56
Empty oil palmfruit bunch	56	3–4	95	–	6–8	5	–

Table 4 presents proximate composition of major crop residues produced in Nigeria, Benue state fortunately is rich in agricultural crop residues for Biomass energy. As shown in table 3, Benue state produces high quality crop like cassava with low nitrogen of 35-60 and high fibre amount of 8-26. Also the state produces crops like maize, sorghum, rice, groundnut, and palm oil which show promising quality of agriculture residues that can be used as Biomass energy reduction. Since majority of Biomass resources are located close to rural areas and includes agricultural crops and their residues, animal dung, forestry residues and other energy crops, and municipal solid waste (IRENA, 2012), Benue state is placed on a better platform to benefit from the nation if there is an interest in establishing a Biogas plant by the Nigerian government of course the interest first has to come from the state government. Biomass is mostly plant derived materials, capable of being transformed to different forms of energy (electricity, heat and fuel) and can quickly regenerate into different environment (Evans et. al. 2010).

II. AQUATIC WEEDS

Benue state is blessed with a dominant River Benue which is one of the few large rivers in Nigeria. The Katsina-Ala river is the largest tributary, while the smaller tributaries include MU, Mkomon, Konshisha, Amile, Duru, Be, Aya, Apa ogede, Okpokwu, Apa and Ombi. Benue state is blessed with many other ponds, streams and lakes. These water bodies have abundance of fast growing weeds that can be harvested for energy purposes. The common ones are;

1. **Water hyacinth:** this has productivity, competitive ability and wide tolerance range (Bamboye, 2012). From studies, water hyacinths are suitable for Biogas production

2. **Water lehuse (pistiastratiotes linn):** is a force growing aquatic herb with succulent leaves. This too can be used for Biogas.
3. **Brackenfem:** this also abundant in the swampy region of Nigeria. It is terrestrial weed which can be bio digested to produce biogas.

Biogas can better be produced using aquatic weeds than when the substrate was terrestrial weeds but the best way to produce high quality yield of Biogas is to combine the three in varying proportions.

Algae

Agriculture (farming algae) for making vegetable oil, Biodiesel, Bioethanol, Bio gasoline, Biomethanol, Biobutanol and other Biofuels using land that is not suitable for agriculture is what is referred to as agriculture. Interesting characteristics of the algal fuels ate, that, they can be grown with murumal impact on freshwater resources (yang et. al. 2010); they can be produced using ocean and waste water; they are also biodegradable and they are relatively harmless to the environment if spilled (Audu & Aluyor, 2012). Algae can produce up to 300 times more oil per acre than conventional crop such as rapeseed, palms, soybeans, or jatropha. Algae's have a harvesting cycle of 1 to 10 days; their cultivation permits several harvests in a very short time-frame, a strategy differing from that associated with yearly crops (Christi, 2007). Algae can grow on land, unsuitable for other established crops, for instance arid land, land with excessively saline soil, and drought-stricken land. This maximizes the issue of taking away piece of land for cultivation of food crops (Schenk et. al., 2008). Algae can grow 20 t0 30 times faster than food crops (Duku et. al. 2011).

Benue state occupies a landmass of 34,059 square kilometres and has vast land for farming since algae's can grow on land in suitable for farming other conventional crops and lands that are drought-stricken, the government of Benue state show cash in on this and utilize the many potentials of algae's which can produce both and other by-products for the development of the state. With appropriate renewable energy policy and master plan, the state with its vast arable land can earmark land in some of all the 23 local government areas, who have potentials to grow algae. In fact, the study if algae are very important owing to the fact that it is not exploited in large scale around the country, it is cost effective and will have a lot of benefit to the state if properly exploited.

Energy Crops

Energy plantations are grown and harvested specifically for energy. Example of energy crops that are grown in Nigeria are jatropha, eucalyptus and poplar (populous spp) (Simonyan and Fasina, 2013). Jatropha is inedible to animals and therefore can be used in the home as gardens. It is a multipurpose shrub that grows wildly in Nigeria with little or no maintenance. The two varieties found in Nigeria are Jatropha curcas is a hardly and perennial plant that grows in diverse climatic conditions and different soil-type, it can survive in arid and semi-arid or drought conditions and can therefore be grown in any part of the country, and allows for intercropping (Simonyan & Fasina, 2013). Jatropha seeds contain around 30% to 40% oil, thus, depending on seed; yields up to 3,000L of oil per hectare can be achieved. Raw oil can be obtained by simple cold pressing of the seeds. The oil can be used directly as fuel and better stull when further proceeds into biodiesel (ECN, 2008). The distribution, establishment, management, harvesting and uses of energy crops have not been well documented in Nigeria. Only a small amount of land is currently used for energy crops production in Nigeria. This is the reason why the Benue state government should take advantage of the opportunity and cash in on growing and harnessing the energy crops for the main purpose of producing Biomass energy. And maybe collaborate with the federal government to map out strategies on cultivating, harvesting and managing energy crops for energy purposes.

Benue state falls within the savannah region in the country and has large expanse of land that is good for growing of energy crops like eucalyptus and satropha. The 23 local government areas have currently large numbers of jatropha and eucalyptus scattered around, ready to be harnessed. Apart from harvesting and using energy crops for biomass energy alone, other raw materials like the residues produced can equally be used for the benefit of the people of the state. Benue state's potentials in the business of biomass energy production is very high due to the fact that it has high forest and Guinea savannah vegetation's and it is a rich agricultural zone. Some of the crops grown in high quantity include maize, potatoes, cassava, soybeans, Guinea corn, flax, yams, sesame, rice, groundnuts etc. (Jijingi & Simeon, 2017). Table shows some of the Agricultural crops Nigeria grows for Biofuels production from some energy crops.

Table 5 Nigeria's Biofuel Production from some Energy Crop, 2017 (adapted from Matermilola et. al. 2019)

Energy crop	Element	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Sugar cane	Area harvested (Ha)	43,000	44,000	47,000	63,000	71,890	73,060	73,060	74,000	74,000	74,000
	Yield (Hg/Ha)	198,605	207,727	210,000	239,048	196,421	191,853	191,623	195,946	195,946	195,946
	Production(tonnes)	854,000	914,000	987,000	1,506,00	1,412,07	1,401,68	1,400,00	1,450,00	1,450,00	1,450,00

					0	0	0	0	0	0	0
Cassava	Area Harvested (Ha)	3,531,000	3,782,000	3,810,000	3,875,000	3,778,000	3,129,030	3,481,900	3,737,090	3,850,000	3,850,000
	Yield (Hg/Ha)	110,011	109,902	120,003	112,026	118,004	117,679	122,155	140,225	140,260	140260
	Production (tonnes)	38,845,000	41,565,000	45,721,000	43,410,000	44,582,000	36,822,250	42,533,180	52,403,455	54,000,000	54,000,000
Sorghum	Area harvested (Ha)	7,031,000	7,284,000	7,308,000	7,812,000	7,617,000	4,736,830	4,960,130	4,891,150	5,500,000	5,500,000
	Yield (Hg/Ha)	12,200	12,600	13,500	11,595	12,233	11,145	14,397	14,101	12,545	12,182
	Production(tonnes)	8,578,000	9,178,000	9,866,000	9,058,000	9,318,000	5,279,170	7140,970	6,897,060	6,900,000	6,700,000
Maize	Area harvested (Ha)	3,479,000	3,589,000	3,905,000	3,944,000	3,845,000	3,350,560	4,149,310	6,008,470	5,200,000	5,200,000
	Yield (Hg/Ha)	16,002	16,598	181,82	17,049	19,571	21,961	18,502	15,279	18,096	20,000
	Production(tonnes)	5,567,000	5,957,000	7,100,000	672,4000	7,525,000	7,358,260	7,676,850	9,180,270	9,410,000	1,0400,000
Oil, palm	Production(tonnes)	1,094,000	1,170,000	1,287,000	1,309,000	1,330,000	1,233,050	970,820	930,000	940,000	960,000
Soybeans	Area harvested (Ha)	587,000	601,000	630,000	638,000	609,000	592,000	281,890	608,650	570,000	600,000
	Yield (Hg/Ha)	8995	9401	9603	9091	9704	7206	10,112	9263	10,175	10,000
	Production(tonnes)	528,000	565,000	605,000	580,000	591,000	426,590	285,050	563,810	580,000	600,000
Millet	Area harvested (Ha)	4620000	4685000	4,971,000	5,056,000	4,904,000	3,787,730	4,364,140	2,889,020	3,800,000	3,800,000
	Yield (Hg/Ha)	14,500	15,300	155,00	16,001	18,483	13,016	11,848	4400	13,158	13,158
	Production(tonnes)	6,699,000	7,168,000	7,705,000	8,090,000	9,064,000	4,929,950	5,170,430	1,271,100	5,000,000	5,000,000
Cocoa, beans	Area harvested (Ha)	1,062,000	1,088,698	1,104,000	1,359,550	1,349,130	1,354,340	1,272,430	1,240,000	1,196,000	
	Yield (Hg/Ha)	3879	4051	4393	2652	2720	2684	3137	3153	3202	
	Production(tonnes)	412,000	441,000	485,000	360,570	367,020	363,510	399,200	391,000	383,000	
Coffee, green	Area harvested (Ha)	3580	3670	3710	2000	2100	1800	2000	2100	2200	
	Yield (Hg/Ha)	13,017	13,597	14,394	12,600	14,286	11,333	12,000	12,381	12,727	
	Production(tonnes)	4660	4990	5340	2520	3000	2040	2400	2600	2800	
Groundnuts, with	Area harvested (Ha)	2,097,000	2,187,000	2,224,000	2,202,638	2336,400	2,643,330	2,789,180	2,342,810	2,420,000	2,360,000

shell	Yield (Hg/Ha)	15,498	15,903	17,199	12,927	12,296	11,265	13,621	12,646	12,690	12,712
	Production(tonnes)	3,250,000	3,478,000	3,825,000	2,847,373	2,872,740	2,977,620	3,799,240	2,962,761	3,071,000	3,000,000
Rice, paddy	Area harvested (Ha)	2,348,000	2,494,000	2,725,000	2451,000	2,382,000	1,836,880	2,432,630	2,579,540	2,685,000	2,600,000
	Yield (Hg/Ha)	14199	14302	14833	12,999	17,544	19,306	18,386	17,706	18,000	18,077
	Production(tonnes)	3334000	3567000	4042000	3,186,000	4,179,000	3,546,250	4,472,520	4567,320	4,833,000	4,700,000
Cotton lint	Production(tonnes)	171,000	190,000	208,000	165,000	180,000	130,000	220,000	103,000	111,500	
Cottonseed	Production(tonnes)	302,000	323,000	350,000	280,000	305,000	225,000	370,000	175,000	189,000	130,000
Taro (cocoyam)	Area harvested (Ha)	640,000	667,000	712,000	739,000	728,000	482,460	520,130	455,301	500,000	500,000
	Yield (Hg/Ha)	74,000	75,982	76,868	67,605	73,997	62,872	56,853	71,727	69,000	69,000
	Production(tonnes)	4,736,000	5,068,000	5,473,000	4,996,000	5,387,000	3,033,340	2,957,090	3,265,740	3,450,000	3,450,000

Table 5 confirms that Benue state has very high potential for Biomass energy production from energy crops since all the crops have advantage as present in the table. (Terdoo et. al., 2016) researched in annual cropped area expansion and agriculture production. Implications for environmental management in Benue state, Nigeria. The study was to assess the relationship between annual cropped area expansion and annual output of some selected crops in Benue state, Nigeria. The data collected was from secondary sources where he looked at five selected crops namely, cassava, yam, rice, sorghum and maize. The study also looked at the annual output of each of the crops spanning the period of 1988-2011. Data was sourced from the Benue state agricultural development Authority (BNARDA), Makurdi which was validated with the report of the agricultural production surveys (APS), 2010 of the national programme for agriculture and food security (NPSFS), federal ministry of agriculture and rural development. The data was analysed with the aid of a statistical package for social sciences (SPSS) vision 16. Person correlation statistical tool was employed as the principal analytical tool. The result revealed that cassava crop had the highest output (69501.66mt), in the state, followed by yam crop (55066.61mt), then rice crop (6252.76mt), sorghum crop (4225.16mt) and maize crop (3170.54mt) respectively. Which the annual trend revealed a steady increase in output of two crops i.e. cassava and yam out of the five selected crops from 1989 to 2011. The output is shown in table 6 and the trend is shown in Figure 3.

Table 6: Descriptive Statistics of the Output of the five selected Crops in Benue State from 1989-2011. (Adapted from terdoo et. al., 2016).

Name of Crops	Total Output('000mt)	Mean	Standard Deviation
Cassava	69501.66	3021.81	973.64
Yam	55066.61	2394.2	753.55
Rice	6252.76	271.86	39.32
Sorghum	4225.16	183.70	22.91
Maize	3170.54	137.85	34.92

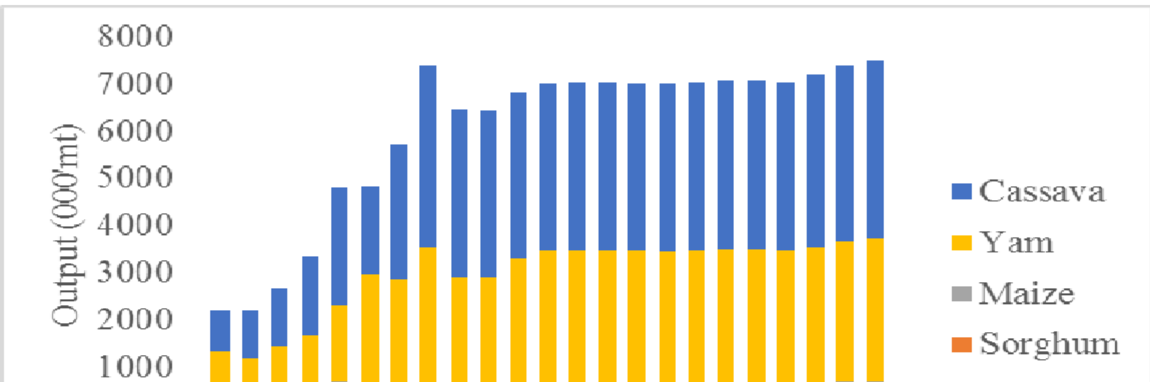

Figure 3.Trend in output of the five selected crops in Benue state, between 1989-2011.

The future is bright for biomass energy in Benue state of the state government and by extension the federal government of Nigeria willing to key into it. These estimates presented above affirm the availability of Biomass resources for biofuel production in Benue state.

2.1.1 FOREST RESOURCES IN BENUE STATE

Nigeria's land covers range from the tropical rain forest in the south to Sahel savannah in the northern part of the country (FAO, IFAD, 2005). The rain forest area generates more woody-Biomass than the savannah areas which generates mostly crop residues (Simonyan & Fasina, 2013). Also, the classification of forests in Nigeria by Beak consultants (1998) for FORMECY recognised eight major forest types found in 28 states of the country; savannah woodland forest, lowland rain forest, freshwater swamp forest, mangrove forest, montane forest, repanan forest, plantain (agriculture) and plantain (forest). The eight arid states in the northern part of the country: Sokoto, Zamfara, Katsina, Jigawa, Yobe, Borno, Gombe, and Bauchi were excluded (simonyan & Fasina, 2013). Tables 7 and 8 shows the forest resources and forest products in Nigeria, respectively.

Table 7: Forest Resources in Nigeria, 2010 (adapted from simonyan & Fasina, 2013) Source: Beak consultants – 1998)

Forest types	**Area in forest reserves (ha)**	**Portion of total forested area in reserves (%)**	**Area in free forest areas (ha)**	**Total areas of forest types in FRS study area (ha)**	**Portion of total forested area in FRS study area (%)**	**Portion of total forested area in FRS study area (%)**
Savanna woodland	1,424,029	52.0	6,922,662	9,736,158	58.8	58.0
Lowland rainforest	832,237	30.4	1,580,928	2,881,755	13.4	17.2
Freshwater swamp forest	226,242	8.3	1,430,436	1,656,499	12.1	9.9
Mangrove forest	48,859	1.8	945,592	997,451	8.1	5.9
Montane forest	18,271	0.7	466,036	685,150	4.0	4.1
Riparian forest	46,583	1.7	431,537	509,415	3.7	3.0
Plantain agriculture	0	0	0	0	164,100	1.0

Table 8: Production of Forest Products in Nigeria, 2010 (adapted from Simonyan & Fasina, 2013)(Source FAOSTAT (2012)

	Production	
Product types	**m³**	**tons**
Chemical wood pulp	-	14,000
Industrial round wood	2,279,000	-
Woodfuel	63,214,728	-
Wood charcoal	-	3.940.089
Paper board	-	18,000
Particle board	40,000	-
Plywood	56,000	-
Printing /writing paper	-	1,000
Pulp wood/round/split	39,000	-
Recovered paper	-	8,000
Sawn logs + Veneer logs	7,100,000	-
Sawn wood	2,000,000	-
Veneer sheets	1,000	
Wrapping +packaging +board	-	18,000

About 9.5% of Nigeria's total land area is occupied by forest (osaghae, 2009). But approximately 1200km^2 of the forest is lost annually. Table 9 supports this claim.

Table 9: The extent of Nigeria's Forest as seen in table 8

	Unit	Value
Forest area	1000 ha	9041
% of land area	%	10
Area per 1000 people	ha	60
Annual change rate (1990-2000)	1000 ha	—410
Annual change rate (2000-2010)	% 1000 ha %	— 2.7 410 — 3.7

Table 10: inventory from 1998 showing forest plantation distribution across Nigeria (FAO, 2010). (adapted from Bentoo et. al. 2016).

State	Area (ha)	Underbark Volume (m³)
Lagos	1049	281,869

Ogun	40147	16,830,603
Oyo	6743	2,169,967
Osun	9259	2,625,817
Ondo and Ekiti	23574	8,321,814
Edo	21522	10,609,067
Delta	4014	1,291,681
Rivers and Bayelsa	0	0
Cross Rivers	14364	7,716,584
Akwa-Ibom	2229	659,413
Imo	1252	692,197
Abia	3714	2,007,058
Anambra	3827	1,896,140
Enugu/Ebonyi	13750	7,598,434
Benue	2226	3,023,116
Kwara	9720	4,708,102
Kogi	5503	1,794,826
Niger	5619	2,496,654
Kebbi	891	2,89,821
Kauna	5866	1973,468
Kano	1761	484,782
Plateau/Nasarawa	6938	2,465,098
Adamawa	1249	370,328
Taraba	1394	398,131
Total	186611	80,704,970
Average (m3/ha)		432

Result for Table 10 places Benue state in the sixth position in nigeria with a very high under bark volume of 3,02116m^3 of forest plantation. According to the koppen classification scheme, Benue state falls within the Savannah climate, a tropical climate with two distinctive wet and dry seasons. The state generally has 8-10 months of rainfall. The climate of the state accumulates a wide range of agricultural production such as fruits crops, grain crops and tuber crops. While the vegetation of Benue state is typically that of the Guinea savannah biome, characterised by sparse grasses and numerous species of scattered trees (Terdoo et. al. 2016). Furthermore, the vegetation of the southern parts of the state housing local governments like Apa LGA, Ado LGA, Agatu LGA, Okpokwu LGA, Ohimini LGA, Oju LGA, Obi LGA etc. is characterised by forests, which yield trees for timber and provide a suitable trees for forest Biomass energy production in the state. The state also enjoys some scattered forests in the North-East (Benue) area housing; Konshisha LGA, Vandeikya LGA, Kwande LGA, Katsina-ala LGA, Ukum LGA, Logo LGA, Ushongo LGA etc, while Benue north-west consisting of : Gboko LGA, Buruku LGA, Tarkaa LGA, Makurdi LGA, Gwer-East LGA, Gwer-west LGA, etc. enjoy some quality trees rich in Biomass energy production too. Daniella Oliveri is the predominant timber species found in the Benue North-East region with the natural forest as the main source of timber (Ekhuemelo & Atondo, 2015). Benue north-east part of the state to enjoy sparsely distributed natural forest for forest biomass energy production. The state, thus possess potential for the development of viable forest biomass energy production for electricity distribution amongst the rural communities. Forest biomass is categorised into above ground biomass, and below ground biomass. Above-ground Biomass comprises all living Biomass above the soil, which includes barks, branches, foliage, seeds, stems and stumps (FAO, 2010). The concentration of woody above ground biomass in Nigeria is shown in table 11. Below-ground Biomass is all living biomass live roots. Sometimes, fine roots of less than 2mm diameter are not included as they often cannot be empirically differentiated from soil organic matter or litter. (Ben-two et. al. 2016). Forest is a major source of Biomass that has the potential of contributing substantially to a nation's Biofuel resources.

Table 11: Biomass Stock in Forest (FAO, 2010) (adapted from Ben-two et. al. 2010).

FRA 2010 category	**Forest Biomass (million metric tonnes oven-dry weight)**			
	1990	**2000**	**2005**	**2010**
Above-ground biomass	3,459	2660	2261	1861
Below-ground	830	638	543	447

biomass Total living biomass	4289	3298	2804	2308
Dead wood	601	462	392	323

Global forest resources assessment (FRA) of Nigeria forest Biomass is presented in table 11.

Table 12: Production and Consumption of Forest Resources in Nigeria in 2008 (FAO, 2011) adapted from Ben-two et. al. 2016

Product	**Production (1000 m³)**	**Consumption (1000 m³)**	**Exports (1000 m³)**
Wood fuel	62,389	62,387	2
Industrial round	9418	9379	40
Sawn wood	2000	1994	8
Pulp for paper	23	57	1
Wood based panels	95	161	3
Paper and paper board	19	375	1

The wealth of Biomass can be harnessed by utilizing its resources for industrial purposes. Forest based industries have the opportunity of maximising renewable energy resources to stir development, create reliable fibre supply, and contribute to the domestic economy. For example, forest-based companies are now in the market producing liquid Bio-fuels and other Bio materials through the development of Bio-refineries (FAO, 2011). The government of Benue state should utilize this opportunity presented by its natural forest to collaborate with Federal government of Nigeria, or even through public private partnership to set up a Bio refinery in the southern-part of the state where there is very rich vegetation that will readily provide the raw-materials for the production of energy. This is because, many countries are providing support for the development of biofuel which the government of Benue state can take advantage of, and bioenergy all of which are somewhat directed towards the forestry sector. It is believed that the forest industry has a feasible future, particularly with the increasing emphasis on “green economy” (Ben-two et. al. 2016)

FOREST RESIDUES

Forest residues are waste woods or residues from logging of trees and wood-processing operations in the forest (Agbro & Ogie, 2012 in matemilola et. al. 2019) and may range from materials like forestry trimmings, wood chips, sawdust to tree barks (Disi, 2013). Forest residues can either be logging residues or wood processing residues also called primary milks residues. (matemilola et. al. 2016). The forest residues, consisting of logging residues (tops branches) and process residues, consisting a large potential which might be available at lower prices compared to logs (simonyan & Fasina, 2013). Forest residues are largely untapped Biomass energy resources in most part of Africa (osaghae , 2009). They consists of wood processing co-products such as wood waste and scrap not useable as timber, that is, sawmill rejects, veneer rejects, veneer log cores, edgings, slabs, trimmings, saw dust, and other residues from carpentry and joinery. They also include green waste from biodegradable waste which can be captured and converted into Biofuel through gasification or hydrolysis (Elbeheri et. al. 2013). We can further define the, logging residues as residues resulting from accumulation of unused material usually left in the woods during logging activities. Such materials may include tree branches, leaves stumps, off-cuts, and sawdust. While, wood-processing residues are generally generated when round woods are processed into final wood products at the sawmills, veneer mills, plywood mill, or pulp mill. Wood processing residues may include materials wood shavings, sawdust, discarded logs and bark (matemilola et. al. 2019). Forest residues high potential for the generation of electricity, heat, liquid fuels and solid fuels such as pellets, briquettes, or charcoal briquettes (agbro & ogie, 2012), like agricultural residues. They can be harvested alongside forest resources, and so do not need additional land for cultivation.

According to Agbro & Ogie (2012), 100 tonnes of timber can generate up to about d42 tonnes of sawdust which put the potential for annual sawdust generation in Nigeria at about 1.8million tonnes. The availability of forest residues depends on the productivity of the industry where they are obtained typically residues yields from a tropical sawmill for export is between 15 and 20% of the total Biomass (full tree), or 30 to 45% of the actual Biomass (for example, logs) delivered to the sawmill. These Biomass types vary in composition, volume and quality (especially moisture content-from 12% to 55% on a dry basis), depending on the processing steps and soils of origin (Simonyan & Fasina, 2013).

Presently, this form of Bioenergy is poorly exploited in Nigeria thus wood waste constitutes an important source of environmental problem. If the government of Benue State with the enormous source of forest resources, tap them, and utilize the wood waste that are presently constituting environmental problem, we will do away with such problem and further provide electricity to the entire populace of the state.

2.2 Biomass Conversion Technologies

Generally, Biomass –to – energy conversion technologies have to deal with a feed stock which can be highly variable in mass and energy density, size, moisture content, and intermittent supply. (sharma et. al. 2014). While several technologies for generation's bioenergy heat and power already exist, there is a need to extend the use of most efficient technologies available today and to complete the development and deployment of a number of new technologies options (Simonyan & Fasina, 2013). Biomass can be converted to energy fuels and products through two main conversion pathways V12; thermochemical and Biochemical conversion pathways. Table 13 shows processing technologies involved.

Table 13: Primary Processing Technologies and the ability to process different Biomolecules (adapted from Simonyan & Fasina, 2013)

Conversion technology	Fats and Oils	Protein	Sugars and Starch	Lignocellulosics
			Biomass resource	
Direct combustion	√			√
Anaerobic digestion	√	√	√	Cellulose only
Fermentation		√	√	Cellulose only
Vegetable oil transeterification	√			
Pyrolysis	√	√	√	√
Gasification	√	√	√	√

Source: Barber and Warnken (2008).

The appropriate conversion technology for a biomass is influenced by factors such as type and quantity of biomass feedstock, the desired form of energy (end-use requirements, environmental standards, economic considerations and project specific factors) (Mckendry, 2002). Also the Biomass conversion efficiency depends on the material, size and shape of the particles, gas flow and types of reactors (Pereira et. al. 2012). The Biomass conversion technology should be tailored to the biomass type to achieve optimum outcomes (Barber & Wamken, 2008).

2.3 BIOCHEMICAL PROCESS

The use of micro-organism for the production of ethanol is an ancient art. However, more recent times such organisms have to become regarded as biochemical "factories" for the treatment and conversion of most forms of human generated organic waste (Sharma et. al., 2014). Microbial engineering has encourage the use of fermentation technologies (acrobic and ancrobic) for use in the production of energy (biogas) and fertilizers and for the use in the removal of unwanted products from water and waste steams (cross, 1995).

Biochemical conversion involves breaking down the hemicellulose fraction and making the remaining cellulose materials more accessible for reaction. The lignin components of the original Biomass remain unrelated throughout the biochemical process. The lignin can be recovered and used as fuel by the thermochemical conversion process. The two biochemical process options ate anaerobic digestion and fermentation (Mackendary, 2002).

ANAEROBIC DIGESTION

Anaerobic digestion is the microbial digestion of feedstock releasing heat, methane, hydrogen sulphide, carbon dioxide and under specific conditions hydrogen gas. This process takes place over several days in large tanks where the ideal conditions ate maintained. In anaerobic digestion, high moisture content (85 to 90%) Biomass is converted into biogas by microorganisms in the absence of oxygen to produce a mixture of carbon dioxide and methane with small quantities of other gases such as hydrogen sulphide (European commission, 1999). Raw biogas has to be cleaned and upgraded before it can be used in engines or heaters. This is because of the impurities (hydrogen sulphide, dust, water halogenate hydrocarbons) that are present in the biogas that cause corrosion problems in processing, handling and storage facilities and equipment's. The biogas produce has an energy content that is about 20 to 40% of the lower heating value of the feedstock (Mckendary, 2002).

Benue state has the climate conditions to produce starchy feedstock's. The state can therefore has the capacity to supply a major part of the fuel gasoline based cars and generators for electricity with ethanol from sugar cane and other high sugar-productivity crops such as sugar beet, sweet sorghum and various fruits.

FERMENTATION

Ethanol is mainly used as substitute for imported oil in order to reduce their dependence on imported energy supplies. The substantial gains made in fermentation technologies now make the production of ethanol for use as a petroleum substitute and fuel enhancer, both economically competitive (given certain assumptions) and environmentally beneficial. The most commonly high productivity when supplied with sufficient water. Where water availability is limited, sweet sorghum or cassava may become the preferred feedstock's.

1.5.2 THERMOCHEMICAL PROCESS

This involves any of the following process options; combustion, pyrolysis, gasification and conversion to other energy products (Lim et. al., 2012, Goyal et. al., 2008).

COMBUSTION

Combustion used mostly for Biomass with moisture content less than 50% unless it is pre-dried, converts the chemical energy stored in biomass into heat, mechanical power or electricity in stoves, furnaces, boilers, steam turbines or turbo-generators (Simonyan & Fasina, 2013). Miguez et. al. (2012) classification based on system capacity includes; fixed bed (less than 40KW) moving grate (between 40 -150KW) and retort system (greater than 150KW). Biomass can be co-fired in existing coal power plants or combusted in a dedicated combined heat and power (CHP) plants. When Biomass is co-fired at less than 10% of coal, only minor changes in handling equipment and boiler is needed. Higher quantity of biomass with requires separate burners and dryers for the Biomass. Use of low cost Biomass has a short pay back in herbaceous crops may produce far and cause slagging and filling that may affect plant reliability and increase costs. Dedicated CHP plants and limited to 1110 the size of typical coal power plants (500MW) because of cost of transforming and availability of feed stock (IEA, 2007).

GASIFICATION

This is the conversion of Biomass into combustible gas mixture by the partial oxidation of Biomass at temperatures of about 800^0Cto 900^0C under a controlled amount of air. The gas (often called synthesis or syngas) produced consists of mixture of carbon monoxide (CO) (18 to 20%), hydrogen (H_2) (18 to 20%), carbondioxide (CO2) (18-20%), methane (CH4) (2 to 3%), small quantities of other light hydrocarbons (C5H10), and steam (H2O) including nitrogen (N2) present in the air that was supplied for the reaction (Pereira *et. al.*, 2012). The low calorific value gas produced (about 4 to 6 MJ/NM2) can be burnt directly or used as a fuel for gas engines and gas turbines for electricity and can be used as a feed stock in the production of chemicals (Mckendary, *et. al.*, 2012). The composition of the syngas is influenced by gasification conditions such as temperature, equivalent ratio and pressure (El-Emam *et. al.*, 2012). Generally, gasification systems (GAS) convert Biomass through partial oxidation into a gaseous mixture of syngas/product gas consisting of hydrogen, carbon monoxide, methane and carbon dioxide (Wang *et. al.*, 2008). Therefore, considering the low energy utilisation of rural communities, only the downdraft-fixed bed gasifier is suitable for small scale power generation ranging from 10kW to over 100kW and has been fully commercialised (IRENA, 2012).

PYROLYSIS

This involves thermal decomposition of Biomass under pressure, in the absence of oxygen and at temperatures of 350 to 550^0C to produce three fractions-liquid fraction (often called bio-oil), solid (mostly ash) and gaseous fractions. The bio-oil can be used in engines, turbines and feed stock refineries (Lim *et. al.*, 2012). Two studies on bio-oil production were carried out in Nigeria. Bamyboye and Oniya (2003) found that comcobs produced in Nigeria can be converted into bio-oil. Ogunsina *et. al.* (2009) also used thermo-chemical conversion of cashew nut shells into fuel products. The heating value of the shells was 16.69MJ/Kg while the tar oil produced had heating value 13.17MJ/Kg.

III. CONCLUSION

There exist great opportunities for exploitation of different types of Biomass in Nigerian in general and Benue State in particular with an estimated 2.01EJ (47.97MTOE) Biomass residues and wastes available in the state through the 23 local government areas can be exploited annually. The government of Benue State has to make frantic and deliberate effort to utilise the various Biomass discussed in this paper in order to reposition the state back to the road of progress and development. The conversion of Biomass to energy is one that will be of great benefit to the people of Benue State giving the large availability of the Biomass resources in the State. Utilisation of Bioenergy has not been given serious implementation in Nigeria not to mention the Benue State Government given the fact that they are enjoying the fossil fuels being produced in the country. But they should not forget that, fossil fuel is not without end, there is a time lime when Nigeria will run out of the fossil fuel but Renewable Energy will always be there if properly managed. It is important for Nigeria and the Benue State Government to begin to pay attention to the renewable resources available especially in the form of Biomass which is in abundance all over the 23 LGAs so as to begin to trace a roadmap for our future leaders in terms of electricity generation in order not to put them in jeopardy when their time comes. The energy crisis in Benue State will be a thing of the past if the abundant Biomass resources in the state is utilised and transformed into electricity for house hold and industrial consumption. This, when utilised by the Benue State Government will ambivalently lead to a better allocation of energy resources among the population, which would in turn alleviate the misfortunes of the rural communities currently groaning under acute shortage of electricity. And it will eventually ameliorate the energy outlook of Nigeria's 9th most populous State.

Utilization of Biomass-base renewable energy for electricity generating in Benue state Nigeria

REFERENCES

[1]. Abam, F.I., Nwankwojike, B.N., ohunakin, S.O., & Ojumu, S.A. (2014) Energy Resource structure and ongoing sustainable development policy in Nigeria: A review international journal of Energy and Environmental Engineering, 5(2), 2-16. http://doi.org/10.1007/s40095-014-0102-8

[2]. Adegbulugbe, A.O. (2007). Balancing the acts in the power sector: The unfolding story of 188 Nigeria independent power project presented at the 2007 27th USAEE/IAEE North American conference. Available at: http:usaee.org./usaee2007/submission/online proceedings/as %20 momodu %paper.doc (Accessed 29 April 2009).

[3]. Agba, A.M., Ushie, M.E., Abam, F.I., Agba, M.S., & Okoro, J (2010). Developing biofuel industry for effective Rural Transfomation. European Journal of Scientific Research 40(3), 441-449.

[4]. Agbro, E.B., & Ogie, N.A. (2012). A comprehensice review of biomass resources and biofuels production in Nigeria. Research journal in Engineering and Applied Sciences, 149-155. Doi.10.1515/reveh-2015-0015.

[5]. Akhator, E.P., obanor, A.I., & Ezemonye, L.I. (2016). Electricity generation in Nigeria from municipal solid waste using the Swedish waste-to-energy model. Journal of Applied Science and Environmental Management, 20(3), 635-643. Doi:http:/dx.doi.org/10.4314/ jasem.V2013.18.

[6]. Akinbami, J.K. (2001). Renewable energy resources and technologies in Nigeria: present situation, future prospects and policy frame work mitigation and adaption strategies for global change, 6, 151-181.

[7]. ASABE, (2011). Terminology and definition for biomass production, harvesting and collection, storage, processing, conversion and utilization. ANSI/ASABE 5593.1. January 2011. PP 821-824.

[8]. Audu, T.O.K., & ALuyor, E.O. (2012). Potential of Bioenergy and Biofuels technology development in Nigeria. Petroleum techn. Dev. J. 1-7.

[9]. Bamgboye, A.I. & Oniya, O. (2003). Pyro lytic conversion of corn cobs to medium grade fuels and chemical preservatives FUTAJEET, 3(2), 50-53.

[10]. Bamgboye, I.A. (2012). The potential producing of biofuels form biomass in Nigeria. In Jekayinfa S.O. (Ed). Building a non-oil export based economy for Nigeria: the potential of value-added products from agricultural residues. Cuvillier vertag Gohingen. PP. 35-41.

[11]. Beak consultants (1998). Forest resources study. National report (draft). Vol. 1. FORMECU federal department of forestry. Abuja Nigeria.

[12]. Ben-two, J., Manovic, V., & Long hurst, P. (2016). Biomass tesources and biofuels for the production of transportation fuels in Nigeria. Renewable and sustainable Energy Reviews, 63, 172 – 192. http:/dx.doi.org/10.1016/ J. rser.2016.05.050.

[13]. Christi, y. (2007). Biodiesel from microalgae. Biotechnol. Adv 25: 294-306.

[14]. CIA, (2013-2014). The world fact book: Nigeria. Available http://www.CIA.gov./library/publication/the-world-factbook/geos/ni-htme.

[15]. Cooper, C.J., & Laing, C.A. (2007). A macro analysis of crop residues and animal wastes as a potential energy source in Africa. J. energy southern Africa, 18(1), 10-19.

[16]. Cross, B. (ed). (1995). "The world Directory of Renewable Energy Suppliers and services 1995". James & James Science, London, United Kingdom.

[17]. Dassapa, S. (2011). Potential of biomass energy for electricity generation in sub-saharan Africa. Energy for sustainable development, 15(3), 203-213.

[18]. Demirbas, A. (2009). Bio refineries: current activities and future developments. Energy converts management, 50, 2782-2801. http:/dx.doi.org/10.1016/J. enconman. 2009.06.035.

[19]. Diji, C. (2013). Electricity production from biomass in Nigeria: options prospects and challenges. Advanced materials Research, 824, 444-450. Doi.10.4028/www.scientific.net/AMR. 824.444

[20]. Duku, M.H., GU, S., Hagan, E., & Ben, A. (2011). A comprehensive review of biomass resources and biofuels potential in Ghana. Renewable and sustainable Energy Reviews, 15, 404-415. http:/dx.doi.org/10.1016/J.rser. 2010. 09.033.

[21]. Ekhuemelo, D.O., & Atondo, T.M. (2015). Evaluation of lumber Recovery and waste generation in selected wasmills in the local government areas of Benue state, Nigeria. Applied tropical Agriculture. A publication of the school of Agriculture Technology, the federal University of Technology, Akure, Nigeria. Retrieved from …

[22]. Elbehri, A., sergerstedt, A., & Liu, P. (2013). Biofuels and the sustainability challenge: a global assessment of sustainability issues, trends and policies for biofuels and related feedstocks.

[23]. El-Emam, R.S., Dincer, I. & Naterer, G.F. (2012). Energy and energy analyses of an intergrated SOFC and coal gasification system. International Journal of Hydrogen Energy, 37, 1687-1697.
[24]. Energy commission of Nigeria (ECN) (2008). Communiqué of National workshop on sustainable Jatropha for energy development 6th-7th may, Mambayya house, Kano: www.energy.gov.ng. Accessed on 3rd January 2013.
[25]. Energypedia (2020). Nigeria energy situation. Retrieved on the 2015/2020 from http:/energypedia.infor/index.php?title=Nigeria-Energy-situation & oldid= 314576
[26]. ESMAP (2007). Technical and economic Assesment of off-grid Muni-gid and Grid electrification Technologies. ESMAO technical paper 121/07. Energy sector management Assistance program (ESMAP), world Bank Washington, D.C.
[27]. European Commission (1999). Biomass conversion technologies_aclu-elements and prospects for heat and power generation. Luxembourg: office for official publications of European Communities EUR 1802. P. 178.
[28]. Evans, A., Strezov, V., & Evans, T.J. (2010). Sustainability considerations for electricity generation from biomass renewable and sustainable energy reviews, 14(5), 1419-1427.
[29]. FAO, (2010). "Climate smart" agriculture policies, practices and financing for food security, adaption and mitigation. Rome, Italy: viale delle Terme di Caracalla.
[30]. FAO, IFAD. A review of cassava in Africa with country case studies on Nigeria, Ghana, and the United Republic of Tanzania. Uganda and Benin. Proc. Valid. Forum Glob. Cassava Dev. Strategy Rome: international fund for Agricultural development/Food and Agriculture organisation of the United Nations: 2005.
[31]. FAO. State of the world's forests. (http:/dx.doi.org/10.1103/physRev Lett. 74.2694): 2011.
[32]. FAOSTAT (2012). FAO statistics division, http://www.faostat.fao.org. Accessed 31/08/2012.
[33]. Garba, A., Kishk, M., & Moore, D.R. (2016). A comparative study of biomass energy technologies for sustainable electricity in Nigeria rural areas. In PW Chan and C.J Nelson (Eds) proceedings of the 32nd Annual ARCOM conference, 5-7 September 2016, Manchester, UK, Association of Researchers in construction management, vol. 2, 1161-1170.
[34]. Gbadesgesin, A., & Akinbola, G.E. (1995). Nigeria: Reference soil of the southern guinea savannah of south western Nigeria. Soil brief Nigeria 7. University of Ibadan, Ibadan and international soil reference and information centre. Wageningen. P.13.
[35]. Girad., P. & Fallot, A. (2006). Review of existing and emerging technologies for the production biofuels in developing countries energy sustainable Development, 10(2), 92-108.
[36]. Goyal, H.B., seal, D., & Saxena, R.C. (2008). Biofuels from thermochemical conversion of renewable resources: a review Renewable sustainable Energy Reviews, 12,504-517.
[37]. IBEP (2006). Introducing the international Bioenergy platform, food and Agriculture organisation of the United Nations, Rome, on line at: http://esa.un.org/un-energy/pdf/FAO%20bioenergy%20platform. Pdf.
[38]. IEA (2007). Biomass for power generation and CHP. IEA Energy Technology Essentials. Report ETE. 03.
[39]. IEA (2012). Energy balanced for Nigeria. OECD/IEA. http//data.Iea.org. Accessed 1st September 2012.
[40]. International Renewable Energy Agency (IRENA) (2012). Renewable energy Technologies: cost analysis series
[41]. Iwayemi, A. (2008). Nigeria's dual energy problems: policy issues and challenges. Int. assoc. energy Econ. 53, 17-21.
[42]. Jijingi, H.E., & Simeon, P.O. (2017). Need for meaningful mechanization strategies to enhance sustainable agricultural production in Benue state-Nigeria. Scientific series management, economic engineering in agriculture and rural development, 17(1), 259-264.
[43]. Lim, J.S, Manan, Z.A., Wan Alwi, S.R. & Hashim, H. (2012). A review on utilization of biomass from rice industry as a source of renewable energy. Renewable and sustainable energy reviews, 16, 3084-3094.
[44]. Mahapatra, S., & Dassapa, S. (2012). Rural electrification: optimising the choice between decentralise renewable energy sources and grid extension. Energy for sustainable development, 16(2), 146-154.
[45]. Matemilola, S., Elegbede, I.O., Kies, F., Yusuf, G.A.,m Yangani, G.N., & Garba, I. (2019). An analysis of the impacts of bioenergy development on food security in Nigeria: challenges and prospects. Environmental and climate Technologies. 23(1), 64-83.
[46]. Mckendry, P. (2002). Energy production from biomass (part 2): conversion technologies. Biosresource technology, 83,47-54.
[47]. Miguez, J.L., Morian J.C., Granada, E., & porteiro, J. (2012). Review of technology in small-scale biomass combustion systems in the European market. Renewable and sustainable energy reviews, 16(6), 3867-3875.

[48]. Nussbaumerm P., Bazilian, M., Modi, V., & Yumkella, K.K. (2011). Measuring Energy poverty: Focusing on what matters. Oxford poverty and Human Development Initiative (OPHI) working paper No 42: 27p.
[49]. Obioh, I., & Fagbenle, R.O. (2009). Energy systems: vulnerability adaption Resilience (VAR). hello international
[50]. OECD/IEA (2010). Sustainable production of second-generation biofuels. Potential and perspectives in major economies and developing countries, information paper, http://www.Iea.org/papers/2010/second-generation-biofuels.Pdf. Accessed 5th August 2012.
[51]. Ogusina, B.S., Ojolo, S.J., Bamboye, A.I. Muritala, A.O., Femi falade, O., Imoudu, D.e., & Fashogbon, S.K. (2009). Thermochemical conversion of cashew nut shell into alternative energy sources. Proceedings of 3rd international conference of WASAE and 9th international conference of Nigerian institution of Agricultural Engineers. OAU Ile-Ife. Nigeria
[52]. Okafor, F.N. (2017). Improving electric sector performance: the role of Nigeria electricity regulatory commission. Nigerian Academy of Engineering 2017 public lecture held on march 29, 2017 at university of Lagos, Akoka, Lagos, Nigeria, 1-14.
[53]. Oladipo, D. (2010). The state of Nigeria's Forest. IITA Research to Nourish Africa.
[54]. Olaoye, J.O. (2011). An analysis of the environmental impacts of energy crops in Nigeria towards environmental sustainability. In: Ogunela, A.O. (Ed). Tillage for Agricultural productivity and Environmental sustainability proceedings of Nigerian Branch of international soil Tillage Research organisation. PP 204-212.
[55]. Onochie, U.P. Itoje, H.J., & egware, H.O. (2015): the Nigeria Renewable Energy resources and potentials: a paper presentation at the 5th annual and international conference on Renewable & alternative Energy society of Nigeria (RAESON) in conjunction with Gregory Universities, from 17th-20th june, 2015 in uturu, Abia state.
[56]. Onochie, U.P., Egware, H.O., & Eyakwanor, T.O. (2015a). the Nigeria electric power sector (opportunities and challenges). Journal of Multidisciplinary Engineering science and Technology, 2(4),
[57]. Onochie, U.P., Obanor, A., & Aliu, S.A. (2015). Electricity crisis in Nigeria: the way forward. American journal of Renewable and sustainable energy, 1(4), 180-186.
[58]. Osaghae, O.J. potential biomass based electricity generation in a rural community in Nigeria. 2009.
[59]. Oyedepo, S.O. (2012). On energy for sustainable development in Nigeria. Renewable and sustainable Energy Reviews, 16(5) 2583-2598.
[60]. Oyedepo, S.O. (2014a). Towards achieving energy for sustainable development in Nigeria. Renewable and sustainable energy reviews, 34, 255-272. http://doi.org/10.1016/J.rser.2014.03.019.
[61]. Oyedepo, S.O. (2014b). Development of small-hydropower: a pathway towards achieving sustainable energy development in: Rupert, C.E. (Eds) hydropower types, development strategies and environmental impacts, Nova science publishers, I,c, New York: 67-119.
[62]. Oyedepo, S.O., Babalola, O.P., Nwanya, S.C., Kilanko, O., Leramo, R.O., Aworinde, A.K., Adekeye, T., Oyebanji, J.A., Abidakun, A.O., & Agberegha, O.L. (2018). Towards a sustainable electricity supply in Nigeria; the role of decentralized renewable energy system. European journal of sustainable development 2(8), 1-31.
[63]. Pereira, E.G., Dasilva, J.N., De oliveira, J.L., & Machado, C.S. (2012). Sustainable energy: a review of gasification technologies. Renewable and sustainable energy reviews, 164753 – 4762. http:/dx.doi.org/10.1016/J.rser.212.04.023.
[64]. Schenk, P.M., Thomas-hall, S.R., stephens, E., marx, U.C., Muss gnug, J.H., posten, C., Kruse, O., & Hankamer, B. (2008). Second-generation biofuels: High-efficiency microalgae biodiesel production. Bioernergy Res. 1: 20-43.
[65]. Shaaban, M., & Petinrin, J. (2014). Renewable energy potentials in Nigeria: meeting rural energy needs. Renewable and sustainable energy reviews, 2972-84.
[66]. Sharma, s., meena, R, Sharma, A., and Goyal, P.K. (2014). Biomass conversion technologies for renewable energy and fuels; a review note. IOSR journal of mechanical and civil engineering, 11(2), 01-08.
[67]. Simonyan, K.J., & Fasina, O. (2013). Biomass resources and bioenergy potentials in Nigeria. African journal of Agricultural Research 8(40), 4975-4989.
[68]. Smith, O.B. (1989). Utilization of crops residues in the nutrition of sheep and goats in the humid tropics of West Africa, in Atta Krah A.N. and Reyholds L. sheep and goat meat production in the humid tropics of West Africa,. Yamoussoukro 21-25 september 1987. FAO arumal production and heath paper. http.//www.fao.org/library-home/en/
[69]. Tersoo, F, Gyang, T., & Iorlamen, T.R. (2016). Annual cropped area expansion and agricultural production. Implications for environmental management in Benue state, Nigeria. Ethiopian journal of environmental studies and management, 9(4), 430-442. Doi:http:/dx.doi.org/10.4314/ejesm. V914.4.

[70]. Unilorin (2012). Jatropha: a goldmine plant. www.nwe.unilorin.edu.ng/unilorin/index.php/jatropha-plant. Accessed on 30/10/12.
[71]. Usman, Z.G., & Abbasoglu, S. (2015). An overview of power sector Laws, Policies and Reforms in Nigeria. Asian transactions on Engineering, 4(2), 6-12.
[72]. Wang, L., Weller, C.I. jones, D.D., and Hanna, M.A. (2008). Contemporary issues in thermal gasification of biomass and its application to electricity and fuel production. Biomass and Bioenergy, 32, 573-581.
[73]. Wikipedia. (2020). Benue state. Retrieved from www.wikipedia.com. Retrieved on the 19/5/2020
[74]. Yang, J., XU, M., Zhang, X., Hu, Q., (Summerfield, M., & chen, Y. (20100. Life-cycle analysis on biodiesel production from microalgae: water footprint and nutrient balanced. Bio resource. Technol.doi:10:1016/j. biortech. 2010.07.017.

