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**Achieving Sustainable Energy Growth Through the Development and
 Adoption of Biofuels Technology in Nigeria for Enhanced Productivity**

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ABSTRACT

Development and adoption of biofuels holds a diversity of opportunities and potentials for the Nigerian economy. Therefore, the quest for biofuels in Nigeria should in no doubt represent a legitimate ambition. This is so because the focus on biofuel production has assumed a global dimension and the benefits that may accrue from such effort may turn out to be enormous if the precondition is adequately satisfied. One of the benefits is access to clean modern energy services which is an enormous challenge facing the African continent because energy is fundamental for socioeconomic development and poverty eradication. Today, 60% to 70% of the Nigerian population does not have regular supply of electricity and petroleum products. There is no doubt that the present power crisis affecting Nigeria will persist unless the government diversifies the energy sources in domestic, commercial, and industrial sectors and adopts biofuel technologies to reduce energy wastages and to save cost. The research adopted descriptive statistics and utilize secondary sources of data and important literatures. It also reviewed a set of energy policy interventions, which can make a major contribution to the sustainable economic development, environmental factors and how they affect availability of energy crops and social development of Africa's most populated country, Nigeria. Adoption of biofuel technology will increase energy efficiency and leads to important social benefits, such as reducing the energy bills for poor households. From an economic point of view, implementing the country's biofuels energy target will have significant costs reduction and clean energy and will help the country to tackle greenhouse gas emissions.

Keywords: Biofuels, Adoption, Energy crops, efficiency, development

1.0 INTRODUCTION

Nigeria is one of the countries in West Africa sub-region with total population of 170,123,749 in 2012 and annual growth rate of 2.55% (Central Intelligence Agency, 2012). Agricultural land constitutes approximately 74,500,000 ha of the total land area of 91,077,000 ha for the country. About 41.2% of the of agricultural is arable land, 11.3% forest areas and 3.3% permanently cropped areas and close to 70% of Nigerian population are involved in agricultural production with more than 70% are small holders farming population (< 5 ha per person). About 48% of the country's population living below poverty line (Central Intelligence Agency, 2012). Nigeria is the sixth largest crude oil producing countries in the World. Over 95% of

foreign exchange earnings and about 80% budgetary allocation comes from oil (Central Intelligence Agency, 2012). Although the present government has a little bit shifted to non-oil generating sources, even though the oil sector contributes only 30% to gross domestic products (GDP) in comparison to 40% from agriculture (Oniemola and Sanusi, 2007). The GDP for Nigeria in 2011 was \$238.9 billion. Agriculture's contribution to the non-oil sector GDP has been consistently stable at about 40% in the recent years. Industrial production rate in 2011 was 2.5% with industrial sector contributing 33.6% of the GDP while service sectors of the economy

supply 31% of the GDP. Major foreign exchange sources are crude oil, coal, tin, columbite, rubber products, hide and skin, textiles and cement (Central intelligence Agency, 2012).

The estimated total energy consumption in Nigeria 2009 was about 4.6EJ or 111MTOE (International Atomic Energy, 2012). Traditional biomass (Wood Fuel and charcoal) accounted for 85% of total energy consumption which has contributed to desertification, deforestation and erosion in the country. This high percent share of biomass represents its use to meet off-grid heating and cooking mainly in rural areas and by the poor people in urban areas. It has been estimated that about 80% of Nigerian households living in the rural and urban areas use wood fuel and charcoal for cooking and heating (Sambo, 2006).

A major need for industrial and commercial sectors of any country is availability of electricity, Access to electricity is particularly crucial to human development as electricity is indispensable for essential of life, the manufacturing and industrial sectors, and providing reliable public infrastructures (e.g airports, street lights) of the country. Electricity is therefore needed for economic growth national development and improved standard of living (Sambo, 2006). Nigeria electricity system is an interconnected national grid system (Akinbami, 2001). Access to electricity is however low-about 40% on the average and as low as 18% in the rural areas (Nuss baumer *et al.*, 2009) because of the low-amount of electricity produced in Nigeria (International Atomic Energy, 2012). In addition close to 60% (i.e 80 million) Nigerians are not connected to the national electricity grid. There is also frequent power outages that can last 20hrs daily in places connected to the national grid (Akande and Oluronfemi, 2009). The low amount of electricity produced and the electricity grid problems contribute to the low per capita consumption (approx. 100kw/h) of electricity in Nigeria in comparison to consumption of 10,000 kw/h in developed countries (Federal Government of Nigeria, 2000) power unreliability and unavailability have prompted industrial firms, households and

commercial enterprises to depend on private diesel and petrol to fuel their generators (Akinbami, 2001)

which have unfortunately resulted in the death of several Nigerians because of health issue as a result of inhaling carbon monoxide toxic metals and their compounds and some aromatics. The persistent energy crisis in Nigeria has weakened industrialization in the country. This has significantly undermined efforts to sustained economic growth, increased competitiveness of indigenous technology in domestics, regional and global market as well as employment (Iwayemi, 2008). However, the low Productivity of the Nigerian economy being experienced presently is attributed to the fact that the country relies on one major sector as source of energy that is petroleum and they have some devastating effect. The Energy Commission of Nigeria (ECN) recently reported that Nigerian's fossil led economy is under severe pressure. It is important to note that diversification of energy sources, agricultural activities and higher percentages of locally produced energy are goals that can be satisfied by biofuels. Energy plays a critical role in the development process, first as a domestic necessity, but also as a factor of production whose cost directly affects price of other goods and services (NEPAD, 2005). It affects all aspects of development: social, economic and environmental including livelihoods, access to water, agricultural Productivity, health, population levels, education and other related issues. Access to energy has been described as key factors in industrial development and providing vital services that improve quality of life, the engine of economic progress (Singh and Sooch, 2004). With decreasing crude oil reserves, enhanced demand for fuels worldwide, increased climate concerns about the use of fossil based energy the focus has recently turned towards improved utilization of biofuels sources obtained from Biomass. The term biomass literally means living matter. However, biomass is often used to describe any organic material obtained from plant and animals tissue (Schoene *et al.*, 2007). These includes agricultural resources, agricultural residues, forest resources, waste including municipal solid waste, industrial waste, and other waste as well as algae.

These materials are referred to as feedstock in bio-refining and are classified into two or more

generations: first, second, third and fourth. First generation refers to biofuels derived from agricultural products: sugar or starch-based crops

and oilseeds, e.g. sugarcane to produce bioethanol or palm oil for the production of biodiesel. Through the fermentation or trans-esterification, first generation biomass feedstock can be processed into bioethanol or biodiesel respectively.

Countries such as Brazil and Nigeria have significant natural resources to produce transportation biofuels, biopower and bio products from biomass. Nigeria has substantial biomass potential of about 144 million tonnes per year (Shaaban, 2014). According to the United States Energy Information Administration (United States Energy Information and Administration, 2015) most Nigerians, especially rural dwellers, use biomass and waste from wood, charcoal, and animal dung to meet energy needs. In spite of this the food and agricultural organization (FAO) statistics on crop production shows Nigeria is among the top producing countries for the promising energy crops (FAO, 2009). Major energy crops with high biofuel yield for feedstock include sugar cane, sugar beet, maize, wheat, rapeseed, palm oil, Jatropha, switch grass and willow (FAO, 2008). In all these crops, Nigeria is a major producer of palm oil, maize, Jatropha, cassava and groundnut.

1.1 Research Objective

The main objective of the study is to achieve sustainable energy through the development and adoption of biofuels technology in Nigeria as a means of increasing the Productivity of national economy. The specific objectives are as follows:

- Asses the feed stocks and related capacity for biofuels production, sustainability and adoption in Nigeria.
- Determine and encourage the diversification of the country's sources of revenue since additional

taxes could be generated from the commercial activities attributed to the biofuels industries.

- Creation of sustainable job opportunities for the citizens and the empowerment of rural communities who are currently neglected from the enjoying the national cake.
- Improving agricultural Productivity and benefits by advancing farming techniques and agricultural research.
- Encourage the diversification of energy sources to address the energy challenges facing the country presently.

It will lead to reduction in environmental pollution due to fossil fuels since biofuels could drastically

1.2 Energy Situation in Nigeria

Nigeria is Africa's energy giant. It is the continent's most prolific oil – producing country, which along with Libya accounts for two-thirds of Africa's crude oil reserves. It ranks second to Algeria in natural gas (Sambo, 2008). Most of Africa's bitumen and lignite energy reserves, Nigeria is unmatched by any other country on the African continent. It is not surprising therefore that energy export is the mainstay of Nigeria's economy. Also, primary energy resources dominate the nation's industrial raw material endowment.

Several energy resources are available in Nigeria in abundant proportions. The country possesses the world's sixth largest reserve of crude oil. Nigeria has an estimated oil reserve of 36.2 billion barrels. It is increasingly an important province with proven gas reserves of nearly 5, 000 billion m³. The oil and gas reserves are mainly found and located along the Niger Delta, Gulf of Guinea and bight of bonny. Most of the exploration activities are focused in deep and ultra deep of offshore areas with planned activities in the Chad basin and Northeast.

Nigeria has significant biomass resources to meet both traditional and modern energy uses, including electricity generation (Ighodaro, 2010). Table 1 shows Nigeria's energy reserves/potential.

Table 1: Nigeria's Energy Reserves/Potentials

S/N	Reserves	Reserves	Reserves (BTOE) ^c	Reserves (10 ⁷) TJ
1.	Crude oil	36.2 billion barrels	4.896	20.499
2.	Natural gas	166 trillion SCF ^a	4.465	18.694
3.	Coal and lignite	2.7 billion tones	1.882	7.879
4.	Tar sands	31 billion barrels of oil equivalent	4.216	17.652
5.	Subtotal fossil		15.459	64.724
6.	Hydropower, large scale	1,000 MW		0.0341/year
7.	Hydropower, small scale	3,250 MW		0.0101/year
8.	Fuel wood	13, 071,464 ha ^b		
9.	Animal waste	6/million tones/year		
10.	Crop residue	83million tones/year		
11.	Solar radiation	3.5 to 7.0 kwh/m ² 1day		
12.	Wind	2 to 4 m/s (annual average) at 10min height		

(a)SCF standard cubic feet (b) forest land estimate for 1981, (c) BTOE, billion tonnes of oil equivalent. Source: Energy Commission of Nigeria (ECN: 2007)

1.3 Energy Consumption Pattern in Nigeria

As energy situation was considered above to be available but which was grossly underutilized, it is imperatives to discuss energy consumption pattern in the Nigeria. Nigeria and indeed African countries have the lowest rates of consumption. Nevertheless, Nigeria suffers from an inadequate supply of usable resources, which include oil, natural gas, lignite and coal. It is also well endowed with renewable energy source such as wood, solar, hydropower, and wind (Okafor, 2010).

1.4 Current Electricity Situation in Nigeria

The work also considers electricity system in Nigeria which centres on Power holding company(PHCN), this accounts for 98% of the total electricity consumed as reported in Central Bank of Nigeria (CBN:2000).The Nigeria power system is specially interlinked by a transmission network popular known as national grid. The entire electricity generated nationwide is pooled into the national control centre, Osogbo, from where electricity is distributed to all parts of Nigeria. The national electricity grid presently consists of 14 generating stations (3 hydro and 11 thermal) with a total installed capacity of about 8,039Megawatts as shown in table II.

Table 2: Summary of Generation Capabilities of PHCN Power Stations as Operated in (January-December, 2008)

Plant	Operator	(year) age	Type	Installed capacity (MW)	Availability (MW)	AVF	NOUI	CAN
Kainji	PHCN	38-40	Hydro	760	438.86	0.58	8	6
Jebba	PHCN	25	Hydro	578.4	529.4	0.92	6	4
Shiroro	PHCN	22	Hydro	600	488.2	0.81	4	4
Egbin	PHCN	23	ST	1320	694.97	0.53	6	5
AES	AES	7	GT	315	233.91	0.77	9	9

Ajaokuta	STS	NA	GT	110	24.88	0.23	2	2
Sapele	PHCN	26to30	ST/GT	1020	156.6	0.15	10	1
Okapi	AGIP	3	GT/ST	480	394.56	0.88	3	3
Afam	PHCN	8to45	GT	709.6	82.12	0.09	20	3
Delta	PHCN	18	GT	912	211.67	0.24	18	12
Geregu	PHCN	NA	GT	414	305.14	0.74	3	3
Omoku	RS	3	GT	150	87.27	0.87	6	4
Omosho	PHCN	1	GT	335	256.58	0.77	8	2
Olorusogo	PHCN	1	GT	335	271.46	0.81	8	2
Total				8,039	4176.24	0.5	93	45

AVF = Available factor, NOUI = Number of units installed CNA= Current number available. Source: (Power holding company of Nigeria: 2009). As it can be seen in Table II, the existing plants operate at far below their installed capacity as many of them have units that need to be rehabilitated, retrofitted and upgraded (Imo, 2009).

Table 3: Country Statistics of Electricity Generation and PER Capital Consumption

Continent	Country	Population (million)	Generation capacity (MW)	Per capita consumption. (KW)
N. America	USA	250	813,000	3.2
S. America	Cuba	10.54	4,000	0.38
Europe (central)	UK	57.5	76,000	1.1
Europe (eastern)	Ukraine	49	54,000	1.33
Middle East	Iraq	23.6	10,000	0.42
Far East	S/Korea	47	52,000	
African	Nigeria	140	4,000	0.03
	Egypt	67.9	18,000	0.27
	South Africa	44.3	45,000	1.02

Source: (Okafor and Uzuegbu, 2010).

From the table above it can be concluded that Nigeria has lowest electricity generation and per capita this has been caused by a number of problems.

1.5 Enhancing Productivity through Biofuels Development and Adoption.

Productivity describes various measures of the efficiency of production. Productivity measures is expressed as the ratio of output to input used in production process, i.e. output per unit input. Productivity is a crucial factor in biofuels productions and help to enhance performance of firms and nations. Development and adoption of biofuels in Nigeria can translate into increasing national Productivity which can translate into raising the living standards of the citizens because more income improve people's ability to purchase goods and services, enjoy leisure, improve housing and

education and contribute to social and environmental programs. The use of biofuels to power vehicles, industrial activities and our national grid will enhance Productivity growth and also will help business to be more profitable. Biofuels development and adoption in Nigeria will be a source of growth in living standards as more value is added in production and this means more income is available to be distributed. Productivity enhancement through the introduction of biofuel

Technology can be achieved by investing in the following areas:

Physical capital e.g. Machinery, Equipment and Buildings. The more capital workers have at their disposal, generally the better they are able to do their jobs, i.e. producing biofuels with better quality output.

Innovation is the successful exploitation of new ideas. New ideas can take the form of new technologies, new product, new corporate structures and ways of working. The ongoing policies of the government to pursue the development and adoption of biofuel are a welcome development that will boost the Productivity of the national economy.

1.6 Biophysical Capacity for Energy Crops Production in Nigeria

Having discussed above how biofuels can enhance national Productivity it is important to look at the Nigeria potentials to produce energy crops. Agriculture in Nigeria is also influenced by climatic and vegetative zones. Nigeria is classified into eight agro-ecological zones based on temperature and rainfall pattern from the North to South as in table IV. The variation in rainfall, temperature, and humidity and its effect on natural vegetation zones determines the type of indigenous plants that are grown in the country. Apart from the ultra-humid belt along the coast which has an average rainfall of 2,000mm/year, the climate in the North is semi-arid, while that of the south is humid (FAO, 2005).

The humid tropical zone favours the growth of low base saturation and low solar radiation crops such as cassava, rice, sweet potatoes and some grasses (Aregheore, 2005). The country has highly varied landscape and biophysical conditions that differentiate the far South from North. This geographical diversity shows rich biophysical endowments and agro ecological diversity.

The country is on latitude 10⁰ North and 8⁰ East, and covers a 910,768km² of land and 13,000km² of water with climate ranging from equatorial condition in the South to the arid condition in the North (Central Intelligence Agency, 2005). The country currently uses only 36.16 percent of the land area for agricultural purpose. The ultraviolet light intensity and duration of sunshine across the country is suitable for most energy crops cultivation either in the irrigated or rain fed season. Energy crops require the availability of appropriate environmental conditions such as adequate water supply and availability of land (Yang *et al.*, 2009, Zdemir *et al.*, 2009). The high water and land requirement form

part of major requirement for energy crops cultivation and biofuels production all these are available in Nigeria.

According to official of Nigerian National Petroleum Corporation's (NNPC) renewable division, "two potential crops have been identified for fuel ethanol initiative in Nigeria: Sugarcane and Cassava" table V. Furthermore, Nigeria is currently regarded to be the leading producer of Cassava in the World Table V. The other crop sugar cane requires large volume of water for its cultivation and processing of the feedstock. Sugarcane cultivation is suitable across a wide range of the Nigerian landscape from the very deep forest mangrove in the Niger Delta to Guinea savannah. High crop yield and Productivity for Sugarcane is attainable across Nigeria, but the cultivation of this crop has been limited due to utilization of the unprocessed (primary) or semi- processed form for human consumption. So cassava is grown on a commercial scale with Nigeria being largest producer of cassava (Ullah *et al.*, 2015), (GOPA, 2015), (Adeoti, 2010). About 75% of Africa's cassava output is in Nigeria (Food and Agricultural Organization and International Fund for Agricultural Development, 2005). Agricultural areas harvesting cassava increased from 3,531,000ha in 2004 to 3,850,000ha in 2013 with increases in production growing from 38,845,000tonnes in 2004 to 54,000,000tonnes in 2013. Similarly Jatropha is a second-generation dedicated energy crop. Its cultivation does not compete with food and other cash crops for arable land as the plant has the ability to survive in marginal lands. Following the rainfall distribution Jatropha can be grown in all ecological zones in Nigeria. Its rainfall requirement is not heavy. The plant can thrive in average annual rainfall of about 250 mm (Abila, 2010). In Nigeria, Jatropha is yet to be appreciated as a viable economic crop. Its cultivation is still limited to its use as decorative plant or as hedge crops in rural communities. However, various development projects are ongoing across the country for its use as feedstock for biofuel production (Abila, 2012). Environmental concerns on the impact of Jatropha cultivation on soil quality as well as the effect of caustic effluents from processing of

Jatropha oil and the toxicity of Jatropha seeds, cake, and extracted oil were initially evident. However, these concerns were reduced after it was discovered that Jatropha is a viable option for the remediation of metal contaminated soils/land, following the study of Kumar et al. (2008) that assessed the remediation potential of Jatropha on soils contaminated by petroleum exploitation and spillages from petroleum transportation and products distribution in the Niger Delta region of Nigeria. The costs and benefit of investing in biodiesel production from Jatropha is worth another energy crop for the production of biodiesel. Oil palm is a valuable energy crop comprising a kernel (endocarp) enclosed with pulp and mesocarp. The pulp is edible oil, while the kernel oil is used primarily for the production of soap. Both parts can be used in producing biodiesel. Oil palm is the fourth most produced commodity in Nigeria (Abila, 2010). It is grown predominantly in the south-eastern part of Nigeria on small-scale farming, and as semi-wild palms (Elbehri, 2013). Its 2013 production was about 960,000 t and market share 3% (Dukku, 2011). Oil palm accounts for about 10% of global biodiesel production, and is rapidly increasing particularly in Indonesia and Malaysia (Pahl, 2008). It is the most efficient source for biodiesel yield per unit of land compared to other oil crops such as soybeans, rapeseed or sunflowers. The

average oil yield from oil palm is about 3.74 t/ha/a while for soybean oil it is 0.38, sunflower 0.48, and rapeseed 0.67 (Elbehri, 2013). With the increasing demand and high potential for expanded trade opportunities in developing countries, new oil palm plantations for biodiesel production are emerging in Africa and in Latin America (Elbehri, 2013). However, Malaysia, Indonesia and Nigeria remain the top three producers of oil palm in the world (Abila, 2010). Nigeria is ranked 13th largest producer soybean in the world with average yield of 591,000 metric tonnes (Abila, 2012). It is estimated that Nigeria had the potential of producing 284.5 ML of biodiesel from 638,000 ha of soybeans cultivated in 2007. Soybean is a major feedstock for biodiesel production in the U.S and in Latin America (Elbehri, 2013). China is also a major producer of soybean; however, it does not use it as feedstock for biodiesel production because of its competition with food. Argentina and Brazil are expected to expand to soy oil for biodiesel production due to the availability of land and relatively lower production cost. Though under the current market forces, soybeans tend to be grown as a single crop in these countries, thus posing the challenge of sustainability.

Table 4: Shows Nigeria's Agro Ecological Zones

Zones description	Percentage of country area (%)	Annual rainfall (mm)	Monthly temperature (°C)			Major crops
			Min	Normal	Max	
Semi-arid	4	400–600	13	32–33	40	Sorghum, millet, wheat
Dry sub-humid	27	600–1000	12	21–31	49	Sorghum, taro, maize, cassava, rice, millet, yam
Sub-humid	26	1000–1300	14	23–30	37	Sorghum
Humid	21	1100–1400	18	26–30	37	Yam, cocoyam, cassava, rice, maize
Very humid	14	1120–2000	21	24–28	37	Cocoa, coffee, rubber, oil palm, ginger
Ultra humid (flood)	2	>2000	23	25–28	33	
Mountainous	4	1400–2000	5	14–29	32	Cotton, groundnut, tobacco
Plateau	2	1400–1500	14	20–24	36	

Source: Aqua stat (Food and Agricultural Organization, 2005), (Aregheore, 2005), (Food and Agricultural Organization and International Fund for Agricultural Development, 2005).

Table 5: Indicates Crops with Potential to Produce Biofuel and Nigeria Global Ranking in Biofuel

Crop	2007 average yield (MT)	Biofuel fuel type	Biofuel yield (L/Ha)	Nigeria Ranking (global)
Sesame	100,000	Biodiesel	696	7
Palm oil	1,300,000	Biodiesel	5950	3
Palm kernel	1,275,000	Biodiesel	5950	3
Groundnut	3,835,600	Biodiesel	1059	3
Soybean	604,000	Biodiesel	446	11
Coconut	225,500	Bioethanol	2689	17
Sugarcane	1,506,000	Bioethanol	6000	51
Cotton seed	212,000	Biodiesel	325	16
Cassava	34,410,000	Bioethanol	4000	1
Sweet corn	6724,000	Bioethanol	172	10

Source: Liebig (2008); Mobius LLC (2007); Food Agricultural Organization (2009)

1.7 Biofuel Potential in Nigeria

Following recurrent fuel scarcity issues in Nigeria, and increases in petrol and petroleum prices, Nigeria has started to diversify its fuel supply to use its natural resources more effectively. Biofuel is an attractive alternative to substitute for fossil fuel. Solid biofuels which are used mainly in developing countries, especially wood, account for about 69% of world renewable energy supply, while liquid biofuels account for 4% of transportation supply and 0.5% of global Total Primary Energy Supply (TPES)(Hanninen:2014). Biogas share is about 1.5% and has the highest annual growth rate of 15% since 1990 compared to other biofuels. Liquid biofuels have a significant annual growth rate of 11%, whereas solid biofuels have an annual growth rate of 1% (Hanninen, 2014).

Information Energy administration of U.S. (INTERNATIONAL ATOMIC ENERGY) Statistics revealed that since 1990, bioenergy share has been about 10% of global TPES with an average annual increase of 2% (Hanninen, 2014). Bioenergy supply has increased from 38 EJ in 1990 to 52 EJ in 2010 following the rising demand for energy by non-Organization for Economic Co-operation and Development Countries (OECD) and the new policies to increase the share of renewable and

domestic energy sources in both OECD and non-OECD-countries (Hanninen, 2004). Bioenergy is typically the major source of energy in developing non-OECD countries, but covers a minor share of TPES in OECD-countries. China and India were the largest bioenergy producers in 2010; producing 20% and 17%, respectively of the world's bioenergy (Hanninen, 2014).China's share of bioenergy was less than 10% of its TPES while India's share was nearly 25%. Nigeria and United States were the third and fourth largest bioenergy producers with shares of over 80% and below 4%respectively (Hanninen, 2014).

Given that the Clean Development Mechanism (CDM) of the Kyoto Protocol obligates 15 rich countries to invest in green energy in developing countries, the Nigerian National Petroleum Corporation (NNPC) renewable energy program

(Automotive Biomass Programme) is likely to attract investment grants. To date 70,000 Euros grants have been received by NNPC from Germany's Renewable Energy, Energy Efficiency Partnership (REEEP) (Nwokeji, 2007).

The programme is expected to improve the ability of the agricultural sector, create jobs in the rural areas, maximize the country's carbon credits in line with Kyoto protocol of which Nigeria is a signatory

(Nwokeji, 2007), and attract grants/funds to the NNPC, while creating opportunity for foreign exchange earnings in the country by exporting surplus products and freezing crude oil in the country that otherwise would be used. According to the former Group Managing Director of the NNPC, Kupolokun, Nigeria will earn about \$150 m annually from the biofuel initiative after take-off (Nwokeji, 2007).

NNPC has an intricate biofuel production program; effort should be directed towards its actualization, rather than on the importing of ethanol. The August 2005 Nigeria Automotive Biomass Programme was established to develop two major types of biofuels: ethanol from cassava and sugarcane, and diesel from oil palm, as well as integrate the downstream petroleum sector with the agricultural sector.

The renewable energy program is expected to expand the country’s energy base and create commercial opportunities for the corporation through partnerships with the private sector, in the form of Joint Ventures (JV’s) and agencies with the

requisite expertise, such as the various agricultural research institutes in the country. NNPC has MOUs in place with two Brazilian companies, Petrobras and Coimex to leverage on their experience and

marketing expertise. Talks with Venezuela’s PDVSA were also revived for technology transfer for converting cassava to ethanol (Nwokeji, 2007). Conversion of starchy feed stocks such as cassava, maize, rice, sweet potato, and yam into bio ethanol has been successfully commercialized in several countries. In the U.S., 13.9 billion gallons of bio ethanol was produced in 2011 (57.5% of global bio ethanol production), almost all of which was from maize (Simonyan and Fasina, 2011). Nigeria’s climatic conditions support the production of maize and other starchy feed stocks.

Currently, bio ethanol, biodiesel, and biogas are the major biofuels produced in Nigeria (Table (Ullah *et al.*, 2015) of which biogas is more feasible at industrial scale compared to biodiesel which is still under investigation. Biogas also has the advantage of reduced impact on the environment as its feedstock does not pose the threat of deforestation. Ethanol production in Nigeria has been in existence since 1973 with cassava as the main feedstock. One of the major biofuel companies in the country, the Nigeria Yeast and Alcohol Manufacturing Company plans to establish a 200 million USD ethanol plant, with a targeted production of 30 million litres annually (Dukku, 2011).

Table VI: Biofuel production status in Nigeria.

Biofuel	Potential raw material	Industrial feasibility in Nigeria	Proposed use	Main advantage	Land use	Water use
Bioethanol	Sugarcane, sweet sorghum, cassava	Developing	Transportation	Reduced pollution, diversification of fuel mix	Sizeable	Sizeable
Biodiesel	Jatropha, oil palm, soy beans	Under investigation	Transportation	diversification of fuel mix	Depends on crop	Depends on crop
Biogas	MSW, Manure, Sewage	Good	Indoor combustion	Reduced deforestation, improved indoor air quality	None	Limited

Source: (Ishola, 2013) MSW=Municipal Solid Waste.

1.8 Sustainability

Globally, countries are imposing blending of transport fuels with 10% biofuels in order to ensure energy security and reduce greenhouse gas emission (Bindraba, 2009). An expanding biofuels sector poses both opportunities and threats for sustainable development. The set of opportunities includes increased local use of biomass resources, which may induce rural development and facilitate the production of transportation biofuels, as well as create job opportunities, and improve air quality in cities, while the threats include food crisis, land use change and tenure security, climate change, and socio-economic implications (Amigun *et al.*, 2013). The continued volatility of fuel prices, the environmental issues associated with GHG emissions, and the combined effect on food and Global economics have incited a sense of resolution amongst stakeholders to source for sustainable and viable solutions in the production of biofuels.

Sustainable biofuel production involves the utilization of agricultural residues, forest residues, and solid waste. It excludes traditional uses of biomass as fuel-wood. Traditional biomass is not sustainable, and is used in most developing countries as a non-commercial source – usually for cooking. Most Nigerians use traditional biomass such as wood, and charcoal to meet their household energy needs – cooking and heating (United States Energy Information and Administration, 2015).

Solid waste management in Nigeria is one of the greatest challenges facing state and local government environmental protection agencies (Ogwuleka, 2009). The volume of solid waste generated increases faster than the ability of the waste management agencies to improve on the financial and technical resources needed to parallel this growth. This being stated, it is necessary to consider utilizing these wastes for biogas production for a country with urgent needs for waste management and with ample supply of solid waste across the country.

In recent years landfill areas have been a major source of biogas production (Ishola, 2013). Biogas production is a viable option with numerous

advantages. Besides being an effective waste management procedure, it is a means of reducing health hazards, indoor air pollution and deforestation. It is flexible in terms of feedstock, does not claim any land, produces fertilizer as a by-product, can be implemented relatively quickly at small scale and is suitable for decentralized use. The technology for biogas production can be implemented almost everywhere with household waste, sewage, industrial waste, agricultural residues and other organic material (Ishola, 2013).

Imposing a mandatory 10% blending ratio of biofuels in transportation fuel would, for example, take 85–176 million hectares of arable land, depending on the generation of biofuels – first or second (Bindraba, 2009). That is, the crop combination used as feedstock, fraction of residues, and the assumed crop yield. According to (Bindraba, 2009), these lands engaged for biofuels production could produce food enough to feed 320–460 million people. It is possible that the further use of land for biofuels production could contribute to loss of biodiversity, increase in GHG emissions and trigger food versus fuel competition.

A study carried out by the Centre for International Forestry Research (CIFOR) evaluated the impacts such plantations may have on sustainability and found out that biodiversity, soil fertility, and water availability as the major issues with utilizing short-rotation crops for biofuels production. However the impact on biodiversity depends considerably on the land use prior to the change. Though deforestation will normally bring about decrease in biodiversity, the usage of degraded land would improve biodiversity and add to species multiplication. Thus landscape conservation could ensure biofuel sustainability in Africa.

1.9 Environmental Impact

The growing global demand for clean energy, the concerns about climate change and the need for GHG emissions reduction have challenged most countries to source for alternative forms of energy. Nigeria is not an exception. Environmental sustainability of biofuels is primarily defined in terms of GHG (CO₂, methane, N₂O) emissions

reduction, and other emissions resulting from agricultural practices such as the use of fertilizers

and pesticides, irrigation, soil tillage, and harvesting (Elbehri, 2013). Additionally, land use prior to biofuel conversion is a critical factor in evaluating the environmental impact. GHG reduction potential suffers markedly if grasslands or forests are used for biofuels. If grasslands or forests are converted into agricultural land to produce biomass, the GHG reduction potential will be different than if biomass production is just started from agricultural land. So far, studies on biomass and GHG emissions assume that land use remains unchanged (Elbehri, 2013). Besides GHGs, energy and water resource preservation are other issues to consider when evaluating environmental sustainability. In some circumstances, the quantity of water used and its impact on local water quality and future availability may be the main constraint against biofuels. Linked to water is the problem of fertilizer runoff—especially near streams and rivers.

Nationally, increasing fuel wood consumption contributes to deforestation with consequent desertification and Soil erosion (Energy Commission of Nigeria, 2013) there is concern on the sustainability of sugarcane, in terms of land use change. This has been a particular issue in Brazil, the world’s leader in sugar cane ethanol, where sugar cane expansion into grazing areas can push livestock systems into the forest zones. Brazil, being sensitive to these concerns, has placed restrictions on sugar cane expansion areas to minimize the negative impacts (Elbehri, 2013).

However, oil palm plantations can also pose environmental problems when expansion takes place on sensitive lands (e.g. peat soils, forests). This is a particular concern in Malaysia and Indonesia where some oil palm is planted in drained peat lands, resulting in significant CO₂ emissions outweighing any carbon benefits arising from the new palm-oil plantations (Elbehri, 2013).

Moreover, expansion of corn for ethanol in the USA – which tends to reduce soybean acreage as corn–soybean rotation contracts – pushes up soybean

acreage expansion in Latin America (Elbehri, 2013). This, in turn, raises concerns over potential undesirable land expansion and even encroachment

into forested areas, with potentially negative environmental and GHG emission consequences. Consequently, rice husk constitutes one of the major environmental nuisances as it forms the major municipal solid waste heaps in the areas where it is disposed. Most rice husks generated during rice milling are burnt in the field. This kind of traditional disposal method has caused widespread environmental concerns since it causes air pollution. As a result of the health and environmental concerns, many countries have imposed new regulations to restrict field burning activities. Subsequently, methods to dispose and to use agricultural residues such as rice straw and rice husk have shifted towards the global “waste to resource” agenda (Ohimain, 2010).

Socio-Economic Implications

- Reduce tail pipe emission and climate change.

2.0 METHODOLOGY

This research is a review of the energy situation and related factors that explain the default on fossils fuel dependency and other sources of energy generation and the need for Nigeria to sustain, develop and adopt biofuels technology to help improve energy situation. It also stimulates the trend in the investments in the broader biofuels subsector ranging from feedstock production to biofuels refining. The research sourced data from basically secondary sources and through desk-reviews. This review work is limited by the inability to conduct primary survey and the attendant’s gaps in information. Secondary data are sourced from the internet, academic journals, CBN, PHCN and energy commission of Nigeria reports etc. Data sourced were analyzed using descriptive statistics.

2.1 Bioethanol Production

The conventional production of ethanol from grain goes through a number of stages to produce ethanol and other co-products. The key operations are starch hydrolysis, fermentation and ethanol recovery. Starch hydrolysis is a mature technology that utilizes

enzymatic liquefaction and saccharification to produce a relatively clean glucose stream, which is then fermented by yeast to produce ethanol the main by-products.

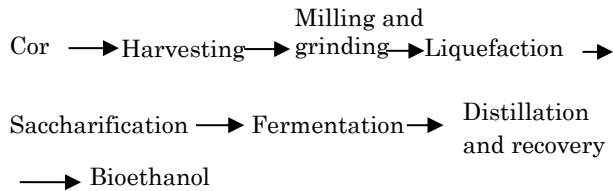


Figure 1: Process flow chart for bioethanol production

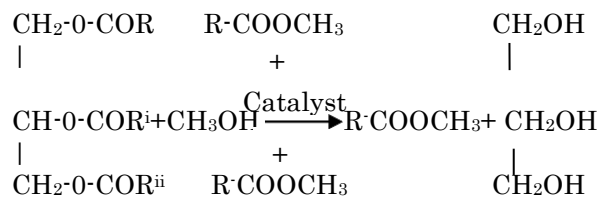
Source: (Dutta *et al.*, 2014)

2.2 Biodiesel Fuel Production From vegetable Oil

Biodiesel production is based on trans-esterification of vegetable oils through the addition of methanol (or other alcohols) and a catalyst, giving glycerol as a co-product. Feedstock includes soybean, rapeseed, sunflower, soyseeds, Jatropha and Palm oil seeds from which the oil is extracted chemically or

mechanically. Advanced process includes the replacement of methanol of fossil origin, by bioethanol to produce fatty acid ethyl ester instead of fatty acid methyl ether (the latter being the traditional biodiesel). In order to expand the relatively small resource base of biodiesel, new processes have been developed to use recycled cooking oil and animal fats though these are limited in volume.

2.2.1 Chemical Reaction (Trans-esterification)



Equation 1: (Hassan and Majeski, 2008)

Fig 2: The transesterification process for the production of biodiesel

Transesterification is a base-catalyzed chemical reaction process. Almost all the

Biodiesel is produced by using a base-catalyzed transesterification process, as it is the most economical process for it only requires low temperatures and pressures. In reaction, 100 parts of a fat or oil is reacted with 10 parts of methanol in the presence of a base catalyst to produce 10 parts of glycerine and 100 parts of methyl esters (biodiesel). Normally the methanol is charged in excess to assist in quick conversion and the excess is recovered for reuse. The catalyst is usually sodium or potassium hydroxide that has already been mixed with the methanol. A typical transesterification reaction is shown above as triglyceride reacts with methanol through a base catalyst to produce biodiesel methyl ester and glycerine

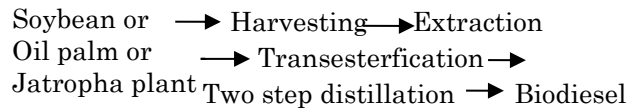


Fig. 3: Flow chart for the production of biodiesel fuel

3.0 CONCLUSION AND RECOMMENDATIONS

3.1 Conclusion

This review identifies the biomass resource available in Nigeria and the potential to use these resources to meet the country's biofuel demand and to achieve sustainable energy growth and development so as to enhance national Productivity. Biomass is obtainable from a wide variety of sources such as: energy crops, agricultural crop residues, forest resources, urban and other wastes, which are distributed throughout the country based on the climatic and vegetative zones. With rising demands for clean energy and recurrent fuel scarcity, Nigeria needs to diversify its fuel supply and maximize its use of natural resources. Biofuel is an attractive fuel in the world because of its sustainability and clean energy, and will help Nigeria address its erratic fuel and electricity supply.

3.2 Recommendations

In this study, it is established that biofuels are source of energy that will help achieve sustainable development in Nigeria. The need to integrate biofuels into the national grid is essential for sustainable development. Therefore, it is recommended that the country should do following:

1. The government should promote the development and adoption of biofuels through development of policies on energy efficiency and integrate them into the current energy policies. A comprehensive and coherent energy policy is essential in guiding the citizens towards an efficient usage of its energy resources.
2. The Nigeria government should take advantage of global partnership with countries like Brazil, United States of America and residential energy efficiency project initiative of UK among others to help the country in a creative integration of renewable energy systems.
3. The government should provide large acres of land and put the right machineries in place for the cultivation of cassava specifically for the production of ethanol fuels and Jatropha for the production of biodiesel crops.
4. Establish an agency to promote and advertise in print media, radio jingles, television adverts on the importance of biofuels
5. Carry out a resource survey and assessment to determine the total biofuels potentials in the country as well as identify the local conditions and priorities in ecological zones.
6. Establish a testing and standard laboratory for biofuels technology.
7. Establish biofuels funding/financing agency as a separate body from NNPC
8. Develop drivers and incentives for promotion of biofuels.

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