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THE ROLE OF ENERGY MIX IN SUSTAINABLE DEVELOPMENT OF NIGERIA

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ABSTRACT
No single energy resource can sustainably meet the energy demands of any country. Integrating all exploitable energy sources is a viable way of achieving stability in energy supply for Nigeria. Hence, the paper focuses on the role of energy mix in sustainable development of Nigeria. Secondary data was analyzed using linear regression (Ordinary Least Square) estimation procedure to measure the impact of existing energy mix (crude oil, coal and electricity) on sustainable development of Nigeria. Granger causality test was also used to ascertain whether growth in per capita energy consumption influenced growth in per capita carbon emissions in Nigeria. Empirical results indicate that existing energy mix has not significantly influenced sustainable development given that electricity generation is inadequate and coal is no longer in use. Results also show that per capita increase in oil consumption resulted in per capita increase in carbon emission and global warming. Exploitable energy sources were however identified in anticipation that an integrated energy plan with emphasis on renewable energy sources for off-grid areas would promote stability in energy supply and sustainable development.

KEYWORDS: Energy mix, Sustainable development, per capita growth, Nigeria

INTRODUCTION

Energy availability, economic growth and sustainable development are grossly inseparable. Generating adequate power has been a major challenge for successive Nigerian governments. Hydro-powers and thermal plants were established between 1960 and 1979. No other successful attempt was made to increase the energy generating capacity till 1999 when President Olusegun Obasanjo commenced the power sector reform. The highpoint of the reform was a deregulation policy to promote independent power generation. Licenses were issued to some private companies and states to establish power projects to achieve energy targets of 10,000 MW by 2010. Subsequently, few IPPs (independent power plants) were built by some state governments and major oil and gas companies, particularly in the Niger Delta (Chukwudi, 2008). Notwithstanding, electricity supply by the end of 2010 was far below the projection leaving most Nigerians still without electricity for domestic or industrial use.

Energy is vital to every aspect of the socio-economic life. Most developed countries have achieved remarkable degrees of stability and efficiency in energy supply and management. Increasing energy sources ensures energy security, which also enhances sustained growth in all sectors of the economy including small-medium scale enterprises (SMEs). Equally necessary is improvement in energy utilization by way of efficiency in conversion of energy resources into useful energy and innovation in energy conservation and management systems. Stability in energy supply sustains growth in agriculture and industry, leading to increase in per capita income. This, added with constant improvement in transport systems, educational opportunities, health care delivery and other social services translates to sustainable development. It is economically needful that energy sources should be diversified, because no single source is capable of providing all the energy requirements for sustainable development in the wake of steady increase in population, urbanization and industrialization (Droege 2004).

Nigeria since independence has witnessed increases in the rate of urbanization and growth in the transport sector and industry mainly propelled by fossil fuel (coal – oil). As energy demand assuredly increased, supply became grossly inadequate. The challenge of meeting present energy demand in Nigeria is colossal in the sense that while seeking for sustainable energy supply and making energy choices, the environmental problems of fossil fuels need to be considered. Hence, in solving our energy supply constraints, options in a prospective energy mix should equally be environmentally friendly, sustainable and efficient (conserving energy for more work). The objectives of the study are: (a) to identify the exploitable energy resources in Nigeria (b) to ascertain the effect of current energy mix on gross domestic product (GDP) and (c) to ascertain ways of enhancing efficient energy supply through a need-based integrated energy system.

SOME ENERGY SOURCES IN NIGERIA

Non Renewable Energy Sources

Coal

According to the Federal Government of Nigeria (FGN, 2003) coal mining in Nigeria started in 1906 and recorded an output of 24,500 tons in 1916. Production peaked at 905,000 tons in 1958-1959 making over 70% of commercial energy consumption of the country. The Nigerian Railway Corporation was the major consumer of coal, although this demand dwindled following the discovery of oil and replacement of coal-burning trains with diesel-powered engines. Following the discovery of oil, emphasis on coal began to diminish and coal production declined to 52,700 tons by 1983 and 14,390 by 2000. A year later in 2001, coal made up just 0.02% of commercial energy consumption in Nigeria (Sambo, 2010). Tables 1 to 3 represent data on Nigeria's coal reserves and production capacities.

Table 1: Coal Reserves in Nigeria	
Proven coal reserves	About 639 million metric tones
Inferred reserves	2.75 billion metric tones

Table2: Coal Production Potential in Nigeria	
Underground production potential	200,000 to 600,000 metric tones per year
Surface production potential	400,000 to 800,000 metric tonnes per year (World Bank, 1983)

Table 3: Coal fields in Nigeria	Location
22 Coalfields	Spread in over 13 States
Consist of approximately: 49% sub-bituminous coal, 39% bituminous coal and 12% Lignite Coals.	

Adapted from data from the National Energy Policy, 2003 & the Nigerian Coal Corp., not dated.

Crude Oil

Following its discovery at Oloibiri, Delta State in 1956 (MBendi, 2011) oil would eventually become dominant in Nigeria's energy scenario as the economic mainstay. Presently, oil accounts for over 95% of export earnings and over 65% of government revenue according to the International Monetary Fund- IMF (EIA, 2010). However, according to Odularu (2007) petroleum production and export, which play a dominant role in Nigeria's economy accounts for about 90% of gross domestic earnings making Nigeria the "13th oil producer in the world" (Nation Master, 2008). Nigeria has an estimated 37.2 billion barrels of proven oil reserve situated along the Niger River Delta and offshore in Bight of Benin, Gulf of Guinea and Bight of Bonny. Production capacity as at 2009 was over 2.2 million b/d making Nigeria the largest oil producer in Africa (EIA, 2010). An oil boom in the early 1970s drew the country's attention away from agriculture, which hitherto was the mainstay and contributed an average of 72% of GDP between 1955 and 1969 (Folawewo & Olakojo, 2010). Since then, oil has been dominant in the energy scene of the country at all levels of economic activities.

Natural Gas

Gas discoveries in Nigeria were incidental to oil extraction activities. Proven reserves are estimated at about 163 trillion standard cubic feet, which is enormously larger than oil resources in energy terms (FGN, 2003). Nigeria also has the largest natural gas reserves in Africa, but the sector is still underdeveloped as most of the gas (about 80%) is presently flared, despite a fine per 1000cf of gas flared imposed by the Nigerian Government in the 1980s. It was simply an inducement to the oil moguls to flare more gas (Chukwudi, 2008). About 19.2 trillion cubic feet of gas was flared between 1960 and 2004 and some 2bn cf annually with a daily flare of 2.5 million cf since 2005. Nigeria has therefore accounted for 19 % of total gas flared globally each year for decades making all efforts to end gas flaring since 1984 futile (Ibid, 2008). Natural gas is a cleaner and environmentally safer source of energy than oil; it is potentially exploitable and will contribute significantly to socio-economic development of Nigeria.

Tar Sand

According to the Energy Commission of Nigeria (ECN) in the FGN (2003) tar sand deposits in Nigeria are estimated at about 30 billion barrels of oil equivalent. Bitumen, used for road construction and other industries is a major tar sand derivable. The Kaduna refinery has been refining imported heavy crude; so refining heavy crude from tar sand will not be difficult. Thus, integrating tar sand into the country's energy base will contribute significantly to its energy demands for sustainable economic growth and development.

Nuclear Energy

Availability of nuclear minerals such as uranium and thorium is crucial to any nuclear programme. According to the FGN (2003) uranium has been found in large deposits on the Jos Plateau and environs since 1947. By 1979, about 617,000 km^2 of land area had been covered by aerial radiometric surveys and another 90,000 km^2 by other surveys. Nigeria should not however jump into the nuclear technologies without carefully weighing the merits against its hazards.

Renewable Energy Sources in Nigeria

Apart from the conventional and finite energy sources mentioned above, Nigeria is also endowed with abundant alternative and renewable energy potentials in solar, hydro, wind, biomass, wave/tidal, geo-thermal etc. No nation can claim immunity to the global threat of climate change. Thus, the need for alternative and environmentally friendly energy sources has become a recurring global issue (Guardian News, 2009 & Ethical CORPORATION, 2010). Hence, a vigorous exploitation of Nigeria's vast renewable energy deposits is a step in the right direction to reduce the energy crisis in the country. Renewable energy sources are particularly ideal for Nigeria where most of the population resides in rural areas with geographical limitations to the national energy grid.

Hydropower

The Niger and Benue Rivers and their tributaries form the core of the Nigerian river system with potential for large-scale (greater than 100MW) hydropower development. Several small rivers and streams also provide opportunities for small-scale (less than 10MW) hydropower projects. Estimate of total exploitable large-scale hydropower potential in Nigeria is over 10,000MW, capable of producing 36,000GWh of electricity annually only about one fifth had been developed as at 2001. Likewise, estimate of exploitable small-scale hydropower potential is at 734MW. Small hydropower plants for electricity provision are suitable in remote areas. By 1999, hydropower represented about 32% of the installed grid-connected electricity generation capacity (FGN, 2003).

Solar Energy

The annual average total solar radiation in Nigeria is from about 12.6 MJ/m^2-day in the coastal latitudes to about 25.2 MJ/m^2-day in the far North. Overall, Nigeria receives 5.08 * 1012 kWh of energy per day from the sun and if solar energy appliances with just 5% efficiency are used to cover only 1% of the country's surface area, then 2.54 * 106 MWh of electrical energy can be obtained from the sun; equivalent to 4.66 million barrels of oil per day (Sambo, 2005). The two main forms of solar energy technologies are: solar thermal for heating, cooking, drying etc. and solar photovoltaic (direct conversion of sunlight to electricity). Solar energy technologies are environmentally friendly and thus vital for agriculture, industrial growth and rural development. It is also possible to generate PV power and feed into the national grid (FGN, 2003). Solar energy is the most promising of the renewable energy sources, because of its limitless potential and capability to be installed at the very point of load or load centre; this makes it highly recommendable for remote locations of the country (Scienceray, 2009). A lot of technical skills are however needed for an efficient and a sustainable solar energy development in Nigeria.

Biomass Energy

Identified biomass materials in Nigeria include: wood, forage grasses and shrubs, animal waste, agricultural and forestry residue, municipal and industrial waste, as well as aquatic biomass (FGN, 2003). Biomass materials can be transformed into fuel briquettes, a cleaner source of fuel than direct combustion for both domestic and industrial uses. They can also be converted into cooking gas (which is a completely clean energy) in biogas digesters. Energy plants like Jatropha, sugarcane and maize are proven sources of clean bio-fuel. Nigeria has abundant biomass resources for full-scale exploitation. About 80 million cubic metres (43.4 * 109 kg) of fuel wood is consumed annually in Nigeria for cooking and other domestic purposes (Sambo, 2005). In addition, intense demand for wood by construction and furniture industries are aiding the depletion of Nigeria's biomass. Forage grasses and shrubs produce 200 million tons of dry biomass, which give up to 2.28 * 106MJ of energy.

Similarly, crop residues and waste produce estimates of 6.1 million tons of dry biomass with energy content approximate to 5.3 * 1011MJ. Nigeria's forestland is about 9,041,000 ha, which is 9.9% of its total landmass (Environmental News, 2010). Meanwhile, 1985 estimates suggested that animals and poultry produced 227,500 tons of waste with energy content of 2.2 * 109MJ" when converted to biogas.

Altogether, the International Energy Agency (IEA) cited in EIA (2010) asserts that biomass, especially fuel wood accounts for over 80% of Nigeria's total energy consumption mainly for off-grid heating and cooking needs in the rural areas where nearly 81 million people live without electricity. Although Nigeria has abundance of fuel wood from its huge forestry, firewood consumption has its own serious consequences for the environment and climate due to inefficient burning of fuel wood and lack of effective forestry management and maintenance policies.

Wind Energy

According to Climate Institute (2010), studies have been done on wind energy potentials in Nigeria. For instance, Oriaku et al. (2007) observed a 98 percent probability of having 2.0 meter per second/hourly wind speed available between 1994 and 2003 in Umudike, Abia State with a maximum extractable speed estimated at 11.3 kilowatts. Similarly, Ngala et al. (2007) found that there was enough wind speed to generate power for Maiduguri, Borno State and its environs where the estimated energy densities at 25 meters in height were between 4.712 and 27.449-megawatt hours per month. Furthermore, Sambo (2005) found that wind energy potential in Nigeria ranges from 2.32 m/s in the coastal city of Port Harcourt to 3.89 m/s in the arid region around Sokoto with a maximum extractable power per unit area for the two sites estimated at 4.51 and 21.97 watts per square metre of blade area, respectively.

Overview of Policy Framework

Since independence Nigeria lacked a coherent and comprehensive energy policy thrust. Independent energy policies existed however in individual sub-sectors in the energy industry (electricity, oil & gas and solid minerals), which generated conflicts at the expense of the national economy. The Energy Commission of Nigeria (ECN) developed a Draft National Energy Policy for the first time in 1993, which was reviewed in 1996 and adopted in 2003. This provided a platform for the development and exploitation of all the country's energy resources to promote sustainable energy supply. It also covered key energy utilization sectors, energy related issues such as environment, energy efficiency, energy financing and energy policy implementation. In addition, the instrument stipulated strategies for systematic exploitation of the energy resources, the development and effective use of energy manpower, supply of rural energy needs, energy security and private sector participation. These strategies were harmonized and grouped into short-medium and long - term measures for easy implementation. It was hoped that the document would provide the framework for the development of the energy sector, to contribute effectively to the national economy (FGN, 2003).

The 2003 National Energy Policy Plan identified various potentially exploitable energy sources in Nigeria that need to be highlighted in this paper, especially to underscore their potential input to the envisaged energy mix for sustainable development in Nigeria.

Energy Consumption in Nigeria by Type

The main areas of energy utilization are transportation and conversion of energy resources to electricity for household and industry. Electricity, which is the most popular form of energy, was first produced in Lagos in 1896- a 60KW of electricity, higher than the maximum demand as at then. Electricity generation officially commenced in 1946 when the colonial government mandated the Public Works Department to supply electricity to Lagos State. The Electricity Corporation of Nigeria (ECN) was established in 1950, charged with electricity development and supply (Obadote, 2009). Then the Niger Dams Authority was established by an Act of Parliament to generate electricity from water power along the Niger River and elsewhere. On April 1, 1972, the ECN and NDA were merged into the National Electric Power Authority (NEPA) responsible for electricity generation and distribution throughout the country. NEPA renamed Power Holding Company of Nigeria (PHCN) in 2004 struggled to meet increasing demands and today, majority of Nigerians have no electricity or inadequate supply. In the prevailing energy crisis Nigeria's energy consumption mix is dominated by over-dependence on biomass, particularly fuel wood as depicted in figure 1: below. Combustible renewable firewood inclusive has a record 80.2%, followed by natural gas 9.9% and oil 9.4%. Hydroelectricity has only 0.5%. In spite of the fact that oil is the mainstay of the economy, its contribution to the energy consumption mix is however appalling. The reason is not far fetched: less than 40% of Nigeria's about 150 million people are

connected to grid electricity and without power over 60% of the time (Obadote, 2009). The use of coal is now extinct having since been jettisoned in the wake of oil discovery and the 1970s' boom. The global popularity of RE technologies has not instigated tangible political thrust and will either locally.

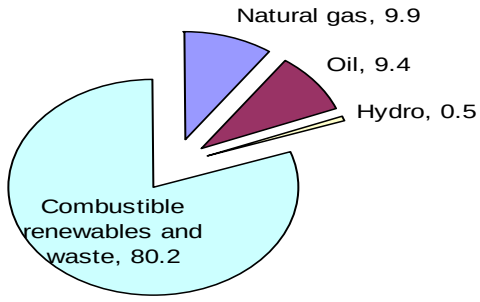

Fig. 1: Total energy consumption by type, in 2008 (IEA; cited in EIA, 2011).

METHODOLOGY

Data Source

The study is based on analysis of secondary data over the period 1970-2005, sourced mainly from the statistical bulletin of the Central Bank of Nigeria (2007 & 2008), World Development Indicators (World Bank, 2007), Energy Information Administration (EIA) and International Energy Agency (IEA). Descriptive statistics (correlation measures and graphical illustrations) are used in the data analysis. However, to measure the impact of existing energy mix on economic growth and sustainable development in Nigeria, statistical regression is employed.

Estimation procedure

Linear regression (Ordinary Least Square) estimation procedure is utilized in analyzing the impact of three main energy sources (crude oil, {Cro}, coal and electricity consumption {Ec}) on economic growth (GDP) in Nigeria. Similarly, Granger causality test is employed to ascertain if growth in per capita energy consumption (GEnergy) influenced growth in per capita carbon emissions ($GCO_{2)}$ in Nigeria. The study applied the logarithmic values of energy sources for the analysis. Moreover, Unit root test is utilized to investigate the characteristics of the time series data used for the estimation of the model in order to avoid spurious regression, which results from the regression of two or more non-stationary series (Dickey and Fuller 1979, 1981).

RESULTS AND DISCUSSION

Results of Unit Root Test

Table 1: Results of ADF Test for Unit Roots

Variables	Level	First Difference	1% Critical value
Ec	2.9273	-3.0540**	-2.639
GDP	1.4592	-4.0325**	,,
COAL	-0.89446	-5.8777**	,,
CrO	0.12000	-5.2480**	,,
Genergy	-3.5428**	-	-2.757
GCO_2	-4.3779**	-	,,

** indicates significant at 1 percent level

The results of the Augmented Dickey-fuller (ADF) Unit root tests are presented in Table 1.The test was applied to the data in level and first differences. The null hypothesis of non-stationarity of all the variables used was tested against the alternative hypothesis of stationarity. The results indicate that the data set of all the variables except GEnergy and GCO_2 were not stationary in their levels. However, after first differencing, the variables

were found to be stationary. Therefore, for efficient and unbiased estimate, we shall introduce each variable in its stationary form into our model.

Results of Ordinary Least Square (OLS) regression

Table 2 Results of modeling DLGDP by OLS

Variable	Coefficient	Std.error	t-value
Constant	0.21296	0.06462	3.295**
DLEc	0.64970	0.41628	1.561
DLCrO	0.92058	0.40992	2.246*
DLCoal	0.02812	0.0849	0.331
$R^2 = 0.585$ F(3, 31) = 4.6659 [0.0150]**			

* and ** indicates significant at the 5% and 1% levels respectively.
(DLGDP: Differenced Log of GDP)

Table 2 depicts the impact of three main energy sources on economic growth in Nigeria. The result indicates that the overall performance of the regression is quite satisfactory with an R2 of 0.58 and a computed F- value of 4.66 which is significant at the 1% level. The results indicate that increases in energy sources have a positive relationship with economic growth (GDP). However, only crude oil has a significant impact on GDP at the 5% level.

Electricity consumption has not impacted significantly on economic growth in Nigeria owing to the irregular power supply that has paralyzed economic activities over the years. On the other hand, coal consumption is not significant because it is no longer utilized as a source of energy for economic activities in the country.

Results of Correlation measures and Granger Causality Tests

Table 3 Paired Samples Correlations

Variables	N	Correlation	P-value
GCO_2 & Genergy	18	.583	.011

Table 4 Results of Causality Tests

Null Hypothesis	F-Statistics	Probability
Genergy does not Cause GCO_2	4.63175	0.04344*
GCO_2 does not Cause Genergy	1.34885	0.29929

* Denotes the rejection of the null hypothesis at 5% level of significance

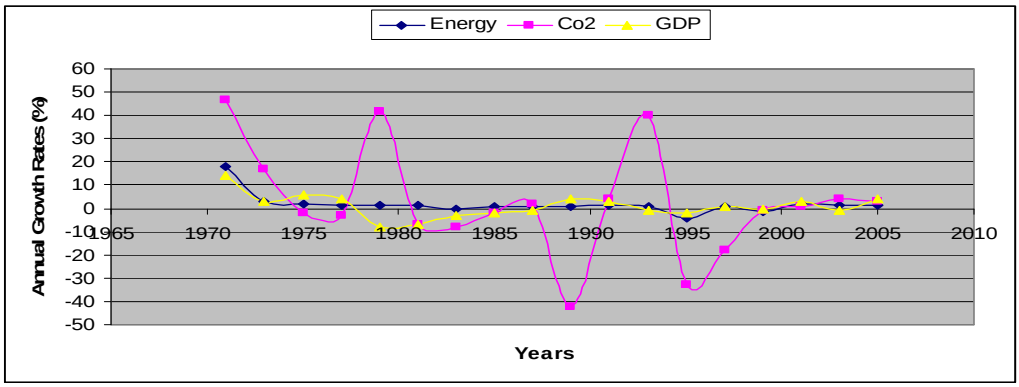

Fig.2: Per Capita Annual Growth Rates of Energy Consumption, Carbon Emissions and Economic Growth in Nigeria (1971-2005).
Source: World Development Indicators (World Bank, 2007).

Table 3 shows the correlation measures between growth in per capita energy consumption and per capita carbon emissions in Nigeria. The value of .583 indicates a positive relationship between them implying that an increase in one increases the other. A causality test was carried out in Table 4 to ascertain the direction of influence. Since the P-value of 0.043 is less than the test value of 0.05 or 5%, we therefore conclude that unidirectional causality is found to run from growth in per capita energy consumption to growth in per capita carbon emissions. But the reverse does not exist since 0.399 is greater than 0.05.This implies that energy consumption of which crude oil is a major component has influenced the emission of carbon to the atmosphere thereby endangering the environment. Fig. 2 depicts a clearer picture of carbon emission scenario in Nigeria. It shows that changes in the growth of per capita carbon emissions outweigh the changes in per capita energy consumption growth implying a serious negative effect on the environment.

RECOMMENDATIONS AND CONCLUSION

Recommendations

In the light of the findings of the study, the paper recommends the following:

First, that energy sources should be diversified. Since power failure is a regular occurrence in Nigeria with attendant negative impact on the quality of living and business productivity, a new approach to electricity generation in which a mix of several energy sources including renewable sources is optimally utilized should be vigorously pursued and adopted.

Second, the utilization of renewable energy technologies especially solar energy to provide off-grid electricity to remote communities should be intensified. The scenario whereby combustible renewable and waste accounted for 80.2 percent of total energy consumption in Nigeria (fig.1) and mainly utilized by the rural areas to meet off-grid heating and cooking needs is not sustainable as it does not only contribute to green house gas but also portends a threat to health, woodlands and the economy.

Third, it is imperative to intensify research and development in the energy sector, especially renewable energy to increase energy sources and improve energy management systems that will promote sustainable development.

Last, there should be increased funding in energy sector, which is capital intensive and requires huge amount of investment. The public and private sector could form a partnership to tackle this investment problem. Government should also increase the budgetary allocation to the energy sector and release these funds duly.

CONCLUSION

Integrating energy sources is a viable way to address the energy problems of Nigeria, which include irregular power supply and rising costs / scarcity of conventional or traditional energy sources. The paper discussed the roles of diverse energy sources in meeting the energy challenges. Positive impacts of existing energy sources on economic growth were highlighted, while energy consumption pattern was found to influence carbon emissions in Nigeria. Utilization of the country's abundant renewable energy resources combined with efficient use of fossil fuels facilitated by technological innovations can improve their environmental impact and economic conditions. Moreover, efficient management of energy resources is imperative for economic growth, environmental protection and energy systems sustainability.

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