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Energy Utilization and Renewable Energy Sources in Nigeria

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Abstract: In this study, current and future perspectives of energy utilization and renewable energy options in Nigeria are examined and discussed from the standpoint of sustainable development. It is a well known fact that oil is Nigeria's major source of revenue and the mainstay of her economy hence, it is susceptible to global energy dynamics due to the country's unstable policies. The escalating demand in energy arising from economic activities and an ever increasing population has not been matched by investment in the provision of infrastructure required to meet the energy needs. The over dependence on oil as a major source of energy has put the country at a risk in view of the fast diminishing oil reserves, inadequate refining capacity to meet domestic consumption and serious cases of energy insecurity such as that of the Niger Delta. The electricity production capacity based largely on fossil fuel sources is at present below 3149 MW in a country with an approximate population of 150 million people. And yet her vast renewable energy resources comprising mainly hydro, solar, biomass and wind is very enormous and remain largely untapped. Energy projection based on four different growth scenarios shows a geometric increase in total energy demand by the year 2030. In this regard, full exploitation and promotion of renewable energy resources will provide a most efficient and effective means of achieving sustainable energy development in Nigeria.

Key words: Energy utilization, renewable energy, sustainable development hydropower, solar energy biomass, wind energy

INTRODUCTION

Energy is considered to be a very important ingredient for development and has always been a vital and indispensable input to the economic needs of the present civilization. It is undoubtedly, the driving force of industrialization (Onyegegbu, 2003). It is a powerful engine of economic and social opportunity such that no country has managed to develop much beyond a subsistence economy without ensuring at least minimum access to energy services for a broad section of its population (Steer *et al*., 2000). Energy is fundamental to the provision of the basic needs of the poor and the rural of which are, jobs, food, health services, education, housing, clean water and good sanitation.

Nigeria has a high population growth rate. The fact of her heavy dependence on oil and gas as the main source of revenue coupled with policy instability exposes the economy unduly to global energy dynamics thereby making the industry one of the most inefficient in meeting needs of populace globally. According to (Iwayemi, 2008), persistence of energy crisis has weakened the industrialization process and significantly undermined efforts to achieve sustained economic growth, increased competitiveness of indigenous industries in domestic, regional and global markets as well as employment generation. Most firms complain that infrastructures have proved more challenging than finance: an estimated 20% allocations in industrial projects is invested rather in the provision of an alternative energy supply.

These difficulties led the country to embark on power sector reforms. Prior to 1999, most operations in the country had been based on a mixed-economy. However, since the inception of the democratic dispensation in 1999, the economy has become largely private sector-oriented with a number of policy frameworks being put in place to improve infrastructure for energy supply. The policy change became imperative due to the increasing population and its effect on energy and socio-economic development of the nation. Among the policies approved was the overall National Energy Policy (NEP) which is designed to improve the energy security of the country through the development of all energy resources, provide adequate, sustainable and reliable energy at reasonable costs, promote a cost effective energy consumption pattern, promote technology and managerial acquisitions and their applications in the energy sector.

Other reforms include the liberalization of the power sector in 2005 with the passage of the Electric Power Sector Reform Act (EPSR) which removed the government's complete control of power generation and distribution, paving the way for the establishment of the Nigerian Electricity Regulatory Commission (NERC) which

serves to control the activities of all stakeholders and the issuance of operating licence to various parties in the power sector. A Biofuel policy framework was also endorsed in 2007 alongside the establishment of the Oil and Gas Implementation Committee (OGIC) for the reform of the oil and gas sector.

ENERGY PERSPECTIVE OF NIGERIA

According to (Sambo *et al*., 2006), population is a major driver of energy demand while its most important determinant is the level of economic activity and its structure measured by the total Gross Domestic Product (GDP) alongside with its shares by the various sectors and sub-sectors of the economy. Population projection of Nigeria was expected to grow from 115.22 million in 2000 to 268.81 million by 2030 at an average annual rate of 2.86% between 2000 and 2030.

Based on the models developed by Energy Commission of Nigeria (ECN) to analyze the country's energy sector for the period from 2000-2030 with the use of Model for Analysis of Energy Demand (MAED) and Wien Automatic System Planning (WASP) package (Table 1), it can be said that the energy demand of Nigeria will be approximately 2.5, 3, 3.5 and 4.5 folds between the years 2000 and 2015 and approximately 8, 13, 17 and 22.5 folds between the years 2000 and 2030 based on 7% (reference), 10% (high growth), 11.5% (optimistic) and 13% (optimistic) GDP growth rate per annum, respectively. This increase in demand for energy is due to the high level of economic activities expected in Nigeria as measured by the total GDP.

The trends are shown in Fig. 1. In 2005, the total energy demand based on 10% GDP growth rate revealed that household segment had the largest share of all the sectors. The sectoral energy demands in the 2030 plan period however, showed the highest growth rates for the industrial, followed by the services, household and transport sectors in that order (Table 2). The electricity demand extracted from the total energy demand, shows an increasing trend from the base year 2005-2030 on the four adopted growth scenarios respectively as shown in Fig. 2, indicating a high economic growth rate leading to a substantial increase in electricity demand. The energy consumed over the years shows a decreasing trend with increasing population, necessitating a corresponding increase in energy output. Hence, the country's large energy efficiency potential needs to be exploited (Table 3). In 2007, the total primary energy consumed was 11.4 million tonnes of oil equivalent (mtoe) with petroleum products having the largest share of 67.3% of the total consumption amounting to a total average consumption of 78.7% between 2002 and 2007. This level of consumption was followed by that of hydropower at 23.9%, natural gas at 8.7% and coal at 0.05% with their respective total average consumption standing at 16.08, 5.17 and 0.04% for the 2002-2007 periods as shown in Table 4. Flaring, adversely reduced the maximum contribution of natural gas to the total energy consumption mix in spite of its huge deposit in the country because most of the oil fields lack appropriate infrastructure for gas production and the general Niger Delta security issue (bunkering, sabotage etc.) have also weakened most of the oil and gas projects.

Department, Coal which generates 40% of the world's electricity has however been neglected for a long time in Nigeria because the existing coal power production facilities degrade the environment through pollution.

It may be observed that electricity, the highest grade of energy, is essential for economic growth, national development, improved standard of living and in meeting the Millennium Development Goals (MDGs) (Sambo, 2009). According to Power Holding Company of Nigeria (PHCN), the existing generation in 2007 was put at a total installed capacity of 7876 MW (75.9% thermal and 24.1% hydro), available capacity of 4914 MW (67.8% thermal and 32.2% hydro) and an operational capacity of 3149 MW (68.2% thermal and 31.8% hydro).

Table 1: Total projected energy demand (mtoe)

Scenario	2000	2010	2015	2020	2025	2030
Reference (7%)	32.01	51.40	79.36	118.14	169.18	245.19
High growth (10%)	32.01	56.18	94.18	190.73	259.19	414.52
Optimistic (11.5%)	32.01	56.18	108.57	245.97	331.32	553.26
Optimistic (13%)	32.01	72.81	148.97	312.61	429.11	715.70

Energy Commission of Nigeria (2006)

Table 2: Total energy demand based on 10% GDP growth rate (mtoe)

Item	2005	2010	2015	2020	2025	2030	Average growth rate (%)
Industry	8.08	12.59	26.03	39.47	92.34	145.21	16.2
Transport	11.70	13.48	16.59	19.70	26.53	33.36	4.7
Household	18.82	22.42	28.01	33.60	33.94	34.27	2.6
Services	6.43	8.38	12.14	15.89	26.95	38.00	8.7
Total	45.01	56.87	82.77	108.66	179.75	250.84	8.3

Energy Commission of Nigeria (2008)

Table 3: Per capita primary energy consumption in Nigeria

Year	Energy consumed (Mtoe)	Population (million)	Per ccapita energy consumption (toe/capita)
2002	18.783	122.365	0.153
2003	19.106	126.153	0.151
2004	16.267	129.927	0.125
2005	17.707	133.702	0.132
2006	12.421	140.003	0.089
2007	11.387	144.203	0.097

CBN (2006, 2007), NBS (2007)

Table 4: Commercial primary energy consumption by type (average % of total)

Type	2002	2003	2004	2005	2006	2007	Average
Coal	0.03	0.03	0.03	0.03	0.05	0.05	0.04
Hydro	11.93	14.20	17.39	12.04	17.03	23.90	16.08
Natural Gas	2.84	1.9	4.54	5.5	7.52	8.73	5.17
Petroleum Products	85.20	83.87	78.04	82.45	75.44	67.32	78.71

CBN Annual Report (2005, 2007)

Table 5: Electric power capacity in Nigeria (supply by fuel mix and demand for 7 and 13% GDP growth)

	Electric power demand											
	2010				2020				2030			
	Demand (MW%)		Supply (MW%)		Demand (MW%)		Supply (MW%)		Demand (MW%)		Supply (MW%)	
Fuel type	7	13	7	13	7	13	7	13	7	13	7	13
Coal	-	-	0	0	-	-	6.515	16.913	-	-	15.815	63.896
Gas	-	-	13.555	31.935	-	-	37.733	78.717	-	-	85.585	192.895
Hydro	-	-	3.702	3.902	-	-	6.479	6.479	-	-	11.479	11.479
Nuclear	-	-	0	0	-	-	3.530	11.005	-	-	11.872	36.891
Small hydro	-	-	40	208	-	-	140	1.000	-		701	2.353
Solar	-	-	5	30	-	-	34	750	-	-	302	4.610
Wind	-	-	0	500	-	-	1.471	3.971	-	-	5.369	15.567
Total	15.730	33.250	17.303	36.576	50.820	107.600	55.903	118.836	119.200	297.900	131.122	327.690

Energy Commission of Nigeria (2006, 2008)

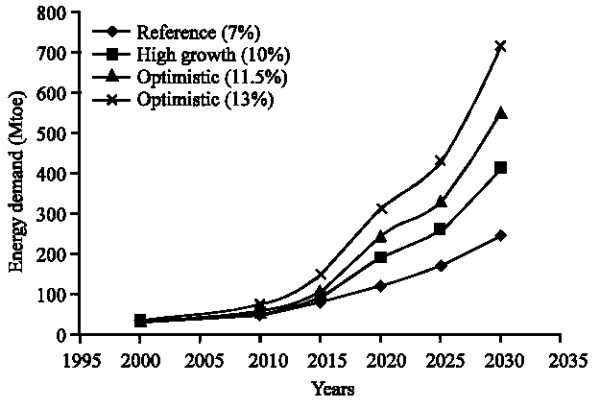

Fig. 1: Graph showing the projeted energy demand between 2000-2030

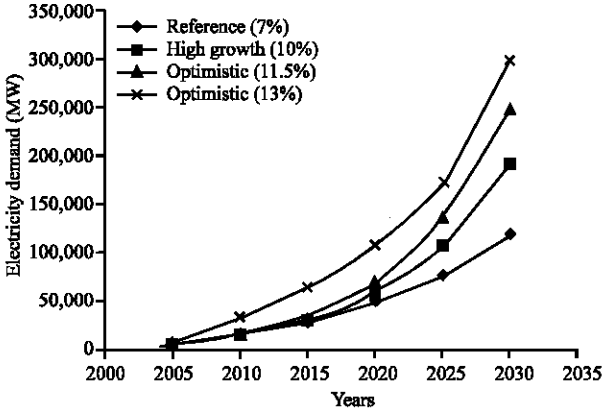

Fig. 2: Graph showing the projeted electricity demand between 2005-2030

However, the electric power capacity demand by projection in Nigeria would be approximately three-half fold between 2010 and 2020 and seven-half fold between 2010 and 2030, respectively at 7% growth rate while the projected supply by fuel mix shows a similar trend with the demand at both the 7 and 13% growth rates (Table 5). The earlier discussion shows a wide disparity in the energy demand to supply in the country both in the present and the future, necessitating an urgent need for alternative energy source in order to avert looming energy crises.

RENEWABLE ENERGY SOURCES

Renewable energy constitutes about 90% of the energy used by the rural population (Sambo, 2009).

Nigeria has abundant reserves of renewable energy sources ranging from solar, hydro, wind to biomass, etc. It is derived from non-fossil and non-nuclear sources in ways that can be replenished while its harvesting, conversion and use occur in a way that helps to avoid negative impacts on the viability and rights of local communities and natural ecosystems (Ikuponisi, 2004). Apart from the non-replenishment of the abundant fossil fuels that are present in the country, there is also the great threat to global climate through the release of carbon dioxide, heavy metals and particulates. Waste disposal, accident and the release of waste heat into the environment are also associated with nuclear energy, even though the latter poses no threat of climate modification.

There is today increased awareness on the need to consider renewable energy sources in Nigeria, going by the low level of socio-economic development attained through over reliance on fossil fuels in which oil and gas still contribute approximately 95% of the revenue and energy needs. The major sources of contribution to the total energy mix for the projected demand are fossil fuels such as oil and natural gas, coal, nuclear energy and renewable energy which is made up of solar, hydro power (large hydro and small hydro) and wind and biomass (Table 5). It is useful to observe here that, government plans to discourage increased consumption of fuel wood and other combustibles especially among the rural dwellers in the near future in an attempt to preserve the forest and natural ecosystem and thus avert climate threat. Each of the renewable energy resources is briefly considered in the following section.

Hydropower: Nigeria has high hydropower potentials because she is naturally endowed with large rivers, dams and waterfalls. Considering the share of energy option in Nigeria, hydropower can be regarded as a major source of electric power in the country. Contrary to fossil fuels, hydropower is renewable and can provide permanent fuel which is ever available for tapping, though the question of water levels remains.

The gross exploitable hydro potential in Nigeria is put at approximately 14,750 MW. However, only 1,930 MW representing 14% of the gross is currently being generated at Kainji, Jebba and Shiroro constituting about 30% of total installed grid connected electricity generation capacity of the country (ECN, 2005). This assessment is for large hydropower which was the type in use sequel to the oil crises in 1973 (Table 6). It is very likely that this capacity will be drastically reduced in the near future as the dam proposed for construction by Niger Republic on the Niger River will reduce water inflow into the Kainji lake which feeds Kainji and Jebba power stations.

Table 6: NEPA estimate of current exploitable hydro power sites in Nigeria

Location	River	Potential capacity (MW)
Zungeru II	Kaduna	225
Zungeru I	Kaduna	450
Zurubu	Kaduna	500
Gwaram	Jamaare	20
Izom	Gurara	10
Gudi	Mada	40
Kafanchan	Kongum	5
Kurra II	Sanga	25
Kurra I	Sanga	15
Richa II	Daffo	25
Richa I	Mosari	35
Mistakuku	Kurra	20
Korubo	Gongola	35
Kiri	Gongola	40
Yola	Benue	360
Karamti	Kam	115
Beli	Taraba	240
Garin Dali	Taraba	135
Sarkin Danko	Suntai	45
Gembu	Dongu	130
Kasimbila	Katsina Ala	30
Katsina Ala	Katsina Ala	260
Makurdi	Benue	1,060
Lokoja	Niger	1,950
Onitsha	Niger	1,050
Ifon	Osse	30
Ikom	Cross	730
Afokpo	Cross	180
Atan	Cross	180
Gurara	Gurara	300
Mambilla	Danga	3,960
Total		12,220
Jebba	Niger	570
Kainji	Niger	760
Shiroro	Kaduna	600
Grand total		14,750

REMP (2005)

In spite of this hydropower capacity in Nigeria still remains underexploited. It must be observed here that Small HydroPower (SHP) has gained rapid consideration in both the developed and developing economies of the world because of its inherent advantages like in-excessive topography problems, reduced environmental impact, minimal civil works and the possibility for power generation alongside with irrigation, flood prevention, navigation and fishery. As shown in Table 7, about 734 MW of SHP can be harnessed from 277 sites (based on a 1980 survey of 12 of the old states in the federation). The Inter-Ministerial committee on available energy resources however estimated a total SHP potential of 3,500 MW representing 23% (approximately) of the country's total hydro potential, if the rest of the country is surveyed (ECN, 2005).

Three of the states surveyed, Plateau, Sokoto and Kano have a total of 30 MW of SHP installed capacity in operation, 21 MW being generated by the Nigerian Electricity Supply Corporation Limited (NESCO) from 6 sites in Plateau State (Table 8). Currently, about 5% of the available SHP capacity is being exploited while the remaining is earmarked for future development.

Table 7: Small hydro potential in surveyed states of Nigeria

State (Pre 1980)	River basin	Total sites	Total capacity (MW)
Sokoto	Sokoto-Rima	22	30.6
Katsina	Sokoto-Rima	11	8.0
Niger	Niger	30	117.6
Kaduna	Niger	19	59.2
Kwara	Niger	12	38.8
Kano	Hadeija-Jamaare	28	46.2
Borno	Chad	28	20.8
Bauchi	Upper Benue	20	42.6
Gongola	Upper Benue	38	162.7
Plateau	Lower Benue	32	110.4
Benue	Lower Benue	19	69.2
Rivers	Cross River	18	258.1
Total		277	734.2

REMP (2005)

Table 8: Small hydro scheme in existence in Nigeria

River	State	Installed capacity (MW)
Bagel I	Plateau	1
Bagel II	Plateau	2
Ouree	Plateau	2
Kurra	Plateau	8
Lere	Plateau	4
Lere	Plateau	4
Bakalori	Sokoto	3
Tiga	Kano	6
Total		30

REMP (2005)

Hydropower is subject to seasonal drought because the actual hydro capacity is largely dependent on the levels of annual rainfall with its distribution and the river systems. With Nigeria's global location, total annual rainfall decreases generally from about 3,400 mm depth in the south with a total precipitation lasting over 8 months in a year to 500 mm at the northern boundaries with a precipitation that may be <3 months in a year.

Biomass: There is considerable uncertainty in the magnitude of total biomass energy available in Nigeria. However, the biomass resource base of some natural forests and plantations has been made from wood volume and oven dry specific data (Onyegegbu, 2003). The biomass resources available include fuelwood, agricultural waste and crop residue, sawdust and wood shavings, animal dung, poultry droppings, industrial effluents and municipal solid waste (Sambo, 2009). Biomass is important because of its high share of the total primary energy consumption. The total bioenergy capacity based on the recoverable energy potential from fuelwood, agro-waste, saw dust and municipal solid waste is estimated at over 710.1333 MJ. Estimated quantities of biomass resources are shown in Table 9.

Fuelwood is the most widely used domestic renewable energy re source in rural Nigeria and especially by low-income groups in the urban areas. Over the 1989-2000 period, fuelwood and charcoal constituted

Table 9: Biomass resources and the estimated quantities in Nigeria

Resource	Quantity (million tonnes)	Energy value ('000MJ)
Fuelwood	39.1000	531.0000
Agro-waste	11.2444	147.7000
Saw dust	1.8000	31.4333
Municipal solid waste	4.0750	-

Sambo (2009)

between 32 and 40% of the total primary energy consumption with 39 million tonnes estimate in national demand in 2000 (Sambo, 2009). It forms the largest percentage of the non-commercial energy (about 37.4% of the total energy demand) and will continue to dominate the non-electricity energy needs for the majority of the people in the country.

Presently, about 43.4×10^9 kg of fuelwood with an average daily consumption ranging from 0.5-1.0 kg of dry fuelwood per person is being consumed in the country annually (Ikuponisi, 2004).

Sawdust and wood chips are other biomass energy resources of high potential in the country. It is estimated that about 42 t of sawdust is generated for every 100 t of timber produced with an average of about 4.39×10^6 m^3 of log splits and plywood processed annually (Onyegegbu, 2003). The potential for sawdust generation can therefore be estimated at 1.8 million tonnes annually. This form of bioenergy is presently not exploited and yet constitutes an environmental pollution problem. Some other common sources of fuel prominent in the rural areas of the country are the agricultural based residues like cornstalks, rice husk, cassava peels, palm kernel shells, coconut shells and bagasse from sugarcane. As Nigeria is an agricultural nation, her annual production of biomass will continue to be enormous.

Wind energy: Nigeria falls into the poor/moderate wind regime with a generally weak wind speed in the South except for the coastal regions and offshore, which are windy (ECN, 2005). Wind speed ranges from 1.0-5.1 m s^{-1} at 10 m altitude (classified as >4.0 , 3.1-4.0, 2.1-3.0 and 1.0-2.0 m s^{-1}). The most attractive sites are the coastal areas, the offshore states, namely Lagos, Ondo, Delta, Rivers, Bayelsa, Akwa -Ibom, the inland hilly regions of the North, the mountain terrains in the middle belt and the northern part of the country. Peak wind speeds are experienced between April and August for most sites except in the offshore which have strong winds throughout the year. Total actual exploitable wind energy reserve may range from 8 Mwh $year^{-1}$ in Yola to 51 MWh $year^{-1}$ on Jos Plateau and 97 MWh $year^{-1}$ in Sokoto (ECN, 2005). Contribution of wind energy to the total energy consumption has been very insignificant. The first wind farm is to be built in Katsina and will be commissioned in 2011 with a capacity of 10 MW. Prior to

this project, the two pilot wind electricity projects in existence have been the 5 kWp Sayya Gidan Dada and a 0.75 kWp wind electricity project at Sokoto and Danjawa village, respectively. The Nigeria Meteorological agency (NIMET) performs wind measurements and collection of wind data at 42 Synoptic stations to evaluate wind energy potential over the country.

Solar energy: Nigeria is situated in the equatorial region that positions her for abundant solar radiation. With an annual average of 15 MJ m^{-2} day^{-1} of insolation, 1500×10^9 MWh of solar energy per year will be impacted on Nigeria's surface of total land area 923,768 km^2. In (Agbo and Oparaku, 2006), the annual average solar radiation is about 3.7 Kwm^2 day^{-1} along the coastal areas and 7.0 Kwm^2 day^{-1} along the semi arid zone of the country, giving the mathematical average as 5.4 Kwm^2 day^{-1}. An average of 6,372,613 PJ $year^{-1}$ (approximately $1,770\times10^3$ TWh $year^{-1}$) of solar energy is received on the entire land area of the country, hence, full exploitation of solar energy is capable of producing about 120,000 times the total NEPA electricity generation of 14.68 TWh for 2002. Provided a 100% efficient solar conversion device is adopted, 7.66 km^2 of land area will be needed for an average solar intensity of 1934.5 KWh m^{-2} (approximately 6898.5 MJ/m^2/year), the strength required to produce the same NEPA capacity for 2002. The solar potential in Nigeria is very high.

According to Onyegegbu (2003), the lowest and highest mean irradiations are of the values 12 and 30 MJ/m^2/day and occur in the forest regions of the South and the semi arid North, respectively. Minimum insolation is experienced for 5 months during the rainy season between May and October, while the maximum level of insolation exists for 6 months from November to April in the dry season.

Solar technologies have been a proved to be reliable for many decades in developed countries. An IEA study estimated over 100 million m^2 of collector area installed worldwide for water heating with about a tenth in the European Union countries (ECN, 2005). In Nigeria, the contribution of solar energy to the national energy need is very negligible compared to its high local potential. The industry is yet to be developed for full utilization because there is no awareness on the use of solar energy, (especially the photovoltaic system), no trained manpower, lack of commercial activity and political motivation for the different applications of the energy source are also serious challenges.

However, extensive work has been carried out on some solar applications involving the solar crop dryers, solar water heaters, solar water distillation, solar refrigerations, solar cookers, solar chick brooders at the National Centre for Energy and Research Development (NCERD), University of Nigeria , Nsukka and the Sokoto Energy Research Centre (SERC), usmanu danfodiyo university, Sokoto. Solar furnaces with temperature reaching 800°C have been produced in some tertiary institutions while solar Photovoltaic (PV) refrigerators have been manufactured by solar electric system, jos. Components like solar modules, batteries, inverters, converters, charge controllers, bulbs/tubes, lighting systems, solar lanterns, solar pumps and junction boxes are only being marketed in the country. According to Onyegegbu (2003), it is believed that there are over 500 installations of PV applications in the country with capacities ranging from 35-7.2 KWp. Most are government-owned while the rest are installed by private companies, NGOs and individuals.

In wind energy applications, the required equipment is imported, costly to acquire and difficult to maintain but local capacity in solar energy production exists, in fact, the technology for the manufacture of affordable solar collectors on a commercial basis is possible enabling the opportunity of being harnessed on a commercial scale. Solar radiation data and other climatic information in the country are archived in the Nigeria Meteorological agency (NIMET), International Institute for Tropical Agriculture (IITA), Nigerian Building and Road Research Institute (NBRRI) and various energy research centres established in some universities.

CONCLUSION

Four economic growth scenarios were considered in the review of the energy requirements. These are the Reference scenarios of 7% total GDP growth rate that will ensure the Millennium Development Goals' (MDG) objective of reducing poverty by 50% of the 2000 value by 2015. The high growth scenario of 10% GDP growth rate in the attempt to eradicate poverty by 2030 and the optimistic scenarios of 11.5 and 13% GDP growth rates that will further increase the rate of economic development.

From the energy outlook of Nigeria, it is very clear that energy demand is very high and is increasing geometrically while the supply remains inadequate, insecure, irregular and is decreasing with the years; the mix has hitherto been dominated by fossil sources which are fast being depleted apart from being environmentally non-friendly. The energy supply mix must thus be diversified through installing appropriate infrastructure

and creating full awareness to promote and develop the abundant renewable energy resources present in the country as well as to enhance the security of supply. About 40% of the annual natural gas produced in Nigeria is flared; appropriate infrastructure must be put in place to stop the flaring for effective power generation. Clean coal technologies must be adopted for coal exploitation in the country. Coal as it is well known has high carbon content contributes significantly to increasing CO_2 emission which leads to destructive climate effects. Its utilization for energy generation must therefore be carefully harnessed but in such a way that the huge benefits that could accrue from the vast deposits in the country are not neglected.

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