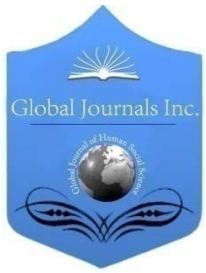
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Renewable Energy Deployment as Climate Change Mitigation in Nigeria

Olotu Yahaya [α] & Oyati Edith Nwabuogo [σ]

Abstract- The scientific evidence of climate change as a result of greenhouse gas emissions which causes ozone layer depletion is becoming increasingly obvious and clear. Findings revealed that energy from the fossil fuel is the major source of greenhouse emission which destroys the environment and makes it unhealthy for living beings. In Nigeria, conventional energy (oil and gas) with gas flaring has the highest percentage of 52% and liquid fuel of 32% of carbon dioxide (CO_2) respectively. This sector contributes revenue of over 70% to Nigeria's economy and generates an average total 21.8% of greenhouse gas emission. In Nigeria, there is a much more potential for share renewables with 15.4% of total energy production and 8.6 % of energy consumption. In reality with global environmental concern, Nigeria's carbon dioxide emissions have increased with energy production and consumption. The Integrated Renewable Energy Master Plan of 2008 projects a 26.7% renewable energy contribution to the Nigeria's energy use and this is expected to reduce CO_2 and greenhouse gas emissions at 38% by2025. Nigeria has not been playing significant role by reducing emissions of greenhouse gases. This paper highlights Nigeria's climate change situation and penetration requirements for various renewable energy deployments as mitigating instrument for climate change towards healthy and productive environment.

Keywords: greenhouse gas emission, mitigation, nigeria, climate change, renewable energy, resources, conventional energy, environment.

I. Introduction

Climate change is a serious global concern and widely acknowledged as a strong challenge being faced by the twenty first century. The impacts of greenhouse gases (GHGs) emissions and the resulting climate change have serious impact on global economy; therefore the need to control atmospheric emission of greenhouse and other associated gases will increasingly be based on efficiency of energy production, transmission, distribution and consumption in any nation [1]. It has been alarming that the global warming is increasing due to the burning of fossil fuel [2]. In Nigeria, convectional energy (oil and gas) contributes more than 75% s of country's economy and generates an average total of 21.8% of greenhouse gas emission [2].

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Nigeria's population is increasing geometrically and this further puts pressure on energy demand for socio-economic growth and development. If the growing population continues to depend on convectional energy; this will lead to overdependence on the non-renewable and depleting energy source which will not meet the demand and consequently increase the CO_2 emission and makes the environment highly unhealthy [2]. The linkage of the concepts of climate change mitigation and matching energy demand-supply is very important in addressing the well-being, economic growth and sustainability of any nation. Meeting growing energy demand and provide sustainable future energy needs; moving towards the deployment of renewable energy resource is a strong alternative mean to convection energy. If the abundant renewable energy resources in Nigeria are well harnessed; this will serve a strong instrument to creating friendly environment by lowering Co_2 emission and other associated greenhouse gases [3].

Theoretical and technical potentials of renewable energy resources (solar radiation, biogas, wind, and hydropower energy) indicated that Nigeria has strong potential of meeting energy demand for agricultural, domestic and industrial without relying on fossil fuel [4]. An average daily solar radiation (Rs) and wind energy of 12.MJ/m^2 to 28.5 MJ/m^2, 3.3 m/s to 7.0 m/s in the coastal to the northern part of the country could generate 427,000MW, hydropower, biogas and wind energy were estimated to have energy potentials of 11,000MW and 6.6 million (m^3) of biogas daily[4].

Climate change mitigation generally involves reductions in human (anthropogenic) emissions of greenhouse gases (GHGs)[5]. One of the major contributors to climate change mitigation is the adaptation of energy technologies. These include renewable energy sources such as solar power, tidal, ocean energy, geothermal power, and wind power; nuclear power, the use of carbon sinks, and carbon capture and storage [5]. Renewable energy is the key to solving country's energy-related inadequacy and also mitigating climate change effects. In Nigeria, it is important to control carbon dioxide (CO_2) emission and other associated greenhouse gases by moving towards to renewable energy development and application of energy efficiency mechanism. This paper provides a holistic overview of the renewable energy development and application for climate change mitigation, energy

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supply and sustainability for the growing population in Nigeria.

II. Global Energy Consumption

Global energy consumption has doubled in the last three decades of the past century [6]. In 2004, about 77.8% of the primary energy consumption is from fossil fuels (32.8% oil, 21.1% natural gas, 24.1% coal), 5.4% from nuclear fuels, 16.5% from renewable resources, of which the main one is hydroelectric, 5.5%, whereas the remaining 11% consists of non-commercial biomasses, such as wood, hay, and other types of fodder, that in rural-economies still constitute the main resource [7]. These 'rural' biomasses (mainly fodder) are usually ignored by statistical reviews of energy consumption proposed by oil companies, but for a correct global perspective they ought to be considered, because at least two thirds of human kind still lives in rural and artisanship economies not too different from the European Middle Age [7]. The fraction of energy demand covered by fossil fuels in 2004 appears to be 87.7%, a percentage often cited by various sources. Direct solar energy usage is about 11 Mtoe (millions, not billions of toe), less than 0.1% of the global consumption [7]. Fig.1.1 and 1.2 show the global energy consumption for two time slices.

a) Nigeria and energy consumption

Nigeria is endowed with convectional and renewable energy potentials. Despite the huge energy resources, the country is very far from meeting the energy demand of her populace. The sudden increase in population of Nigeria put high pressure on energy demand for socio-economic development. Population is a major driver of energy demand while its most important determinant is the level of economic activity and its structure measured by total Gross Domestic (GDP) alongside with its shares by various sectors and sub-sectors of the economy [8]. This increase in the energy demand is due to the high level of economic activities expected in Nigeria as measured by the total GDP [9]. At present, the nominal electricity generating capacity in Nigeria is less than 6000MW. The actual capacity is about half of the installed capacity [10]. Fig.1.4 and 1.5 shows the energy consumption and production in Nigeria in 2011. All renewables combined accounted for only 19% share of electricity production in the world, with hydroelectric power providing almost 90% of it as shown in fig.1.9 [10]. Therefore, substituting fossil fuels with renewables for electricity generation must be important part of any strategy of reducing CO_2 emissions into the atmosphere and combating global climate change [10]. One family using a typical solar home system can save yearly 290 litres of kerosene by using solar lighting technology and can prevent the emission of 0.76 ton CO_2 per year [11]. Fig.1.3a and 1.3b show the greenhouse gas emissions.

III. Renewable Energy and Climate Change

Demand for energy and associated services, to meet social and economic development and improve human welfare and health, is increasing [12]. The quality of energy is important to the development process [12; 14; 15]. Attaining sustainable development, delivery of energy services with low environmental effects is very important. However, energy services must be provided with low environmental implication considering the greenhouse gas emission.

The IPCC Fourth Assessment Report (AR4) reported that fossil fuels provided 85% of the total primary energy in 2004 [16]. Recent data confirm that consumption of fossil fuels accounts for the majority of global anthropogenic GHG emissions [16]. Emissions continue to grow and CO_2 concentrations had increased to over 390 ppm, or 39% above preindustrial levels, by the end of 2010. To maintain *both* a sustainable economy that is capable of providing essential goods and services to the citizens of both developed and developing countries, and to maintain a supportive global climate system, requires a major shift in how energy is produced and utilized [17]. However, renewable energy technologies, which release much lower amounts of CO_2 than fossil fuels are growing.

Renewable energy sources have contributed to Nigeria's energy mix for centuries now, albeit in a largely primitive way [21]. Fuel wood - or what is commonly referred to as woody biomass - is the longest standing primary energy source for rural Nigeria, and indeed, for much of the African continent [22]. Large hydropower has also featured substantially as an energy source, providing about 32 percent of Nigeria's national electric grid supply [23]. Nigeria's adoption of 'new' renewable energy sources solar photovoltaics, solar thermal, wind, small hydropower and efficient biomass is relatively recent [24]. The country is endowed with significant, even abundant quantities of each of these resources. Despite this huge potential, the existing renewable energy projects in Nigeria are very few and far between [22]. Fig. 1.9 shows the share of total world renewable energy.

A 10 MW pilot wind plant has been built in Katsina and is waiting commissioning, Zungeru hydropower plant of 700 MW installed plant capacity is under construction in Niger State [25]. A number of smaller hydropower plants are also being planned such as Gurara (30 MW) or Kashimbilla (40 MW)[26]. The 3,050 MW Mambilla hydropower plant project is currently being reviewed. In addition, the Nigerian Electricity Regulatory Commission (NERC) has issued licenses for 8 solar projects totaling a capacity of 868 MW and a 100 MW wind park [26]. Furthermore, investors are increasingly enthusiastic about developing large solar plants in the country. Table 1.1 shows the

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potential of the country's renewable energy which has been designed for clean energy generation purposes, while Table 1.2 reveals the energy balance in Nigeria in 2012.

The percentage of renewable energy consumption is majorly from hydropower as shown in fig 1.4. Energy resources from wind, geothermal, tidal, bio-power have not deployed in Nigeria [26]. In addition, the development of solar energy through the photovoltaic panel for converting the solar radiation to electricity is very nascent in the country [26]. Fig 1.3 shows electricity generated (Terawatt/hour) from non-hydro-renewable energy in United State of America [27]. The values of energy generated from renewable energy in US without considering hydropower shows that the country can sufficiently meet energy demand from every sector (agricultural, manufacturing, transportation e.t.c) without compromising the future demand. Without the deployment of renewable energy since 2005, green-house gas emissions in 2012 could have been 7% higher than actual emissions [27]. Renewable techno-logies also increase energy security [27]. Without the additional use of renewable energy since 2005, the EU's consumption of fossil fuels would have been about 7% higher in 2012. The most substituted fuel was coal, where consumption would have been 13% higher, while natural gas use would have been 7% higher, at a time when European gas reserves are dwindling [27]. Renewable energy has not been the only factor reducing Europe's greenhouse gas emissions. Policies and measures designed to reduce emissions, improve energy efficiency and stimulate the deployment of renewable energy have all played a role [27]. There were also other drivers for this reduction, including changing economic factors and shifts to less-polluting types of fuels [27].

IV. Renewable Energy in Nigeria

Renewable energy is energy that comes from resources which are naturally replenished on a human timescale such as sunlight, wind, rain, tides, waves, and geothermal heat [28]. Renewable energy replaces conventional fuels in four distinct areas: electricity generation, air and water heating/cooling, motor fuels, and rural (off-grid) energy services [28]. It is one of the means of tackling the global challenges of climate change [28]. Renewable energy supply in Nigeria is dominated by hydro-power and solar energy with 1% energy consumption from hydropower [28]. The total existing capacity for hydro power (small and large dams) in Nigeria is 1,930 MW [29]. The installed capacities of hydropower are estimated at with 14,750 MW [29]. The share of solar energy in the renewable energy share is expected to increase because of its strong potential across Nigeria and friendly technologies compared to other renewable energy sources such as tidal, wave, geothermal [30]. This level of solar radiation across the country can support huge deployment of solar power infrastructure designed to primarily feed in to the regional power distribution entities [30]. Fig 1.7 shows the estimates of renewable energy in Nigeria. Worldwide investments in renewable technologies amounted to more than US$214 billion in 2013, with countries like China and the United States heavily investing in wind, hydro, solar and biofuels."[30]. Deployment of renewable energy [RE] has been increasing rapidly in recent years. Under most conditions, increasing the share of RE in the energy mix will require policies to stimulate changes in the energy system [31]. Government policy, the declining cost of many RE technologies, changes in the prices of fossil fuels and other factors have supported the continuing increase in the use of RE[31]. In 2009, despite global financial challenges, RE capacity continued to grow rapidly, including wind power (32%, 38 GW added), hydropower (3%, 31 GW added), grid-connected photovoltaics (53%, 7.5 GW added), geothermal power (4%, 0.4 GW added), and solar hot water/heating (21%, 31 GWth added)[31]. Biofuels accounted for 2% of global road transport fuel demand in 2008 and nearly 3% in 2009[32]. The annual production of ethanol increased to 1.6 EJ (76 billion litres) by the end of 2009 and biodiesel production increased to 0.6 EJ (17 billion litres)[33]. In Nigeria there is need for the Federal government to look at existing policies on renewable energy and take full advantage of it to boost her power generating capacity"[30]. Investigations showed that the development of alternative energy sources is relatively young in the Nigeria [33]. In fact, a regulation to stimulate investments in 2,000 MW of electricity from renewable energy sources by 2020 was approved by the Nigerian Electricity Regulatory Commission [34].

V. Climate Change Mitigation

Nigeria as a country is highly vulnerable to the impact of climate change because its economy is mainly dependent on income generated from the production, processing, export and/or consumption of fossil fuels and associated energy-intensive products [35]. This sector contributes revenue of over 70% to Nigeria's economy and generates an average total 21.8% of greenhouse gas emission [35]. Nonetheless, carbon emissions from any country contribute equally to the pressure on the global climate [29]. The use of renewable energy sources is becoming increasingly necessary, if we are to achieve the changes required to address the impacts of global warming [35]. Apart from its benefits in GHG reduction, the use of solar energy can reduce the release of pollutants such as particulates and noxious gases from the older fossil fuel plants that it replaces [36]. Solar thermal and PV technologies do not generate any type of solid, liquid or gaseous by-

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products when producing electricity [36]. The future share of RE applications will heavily depend on climate change mitigation goals, the level of requested energy services and resulting energy needs as well as their relative merit within the portfolio of zero- or low-carbon technologies [37]. A comprehensive evaluation of any portfolio of mitigation options would involve an evaluation of their respective mitigation potential as well as all associated risks, costs and their contribution to sustainable development [37]. Setting a climate protection goal in terms of the admissible change in global mean temperature broadly defines a corresponding GHG concentration limit with an associated CO_2 budget and subsequent time-dependent emission trajectory, which then defines the admissible amount of freely emitting fossil fuels. The complementary contribution of zero- or low-carbon energies to the primary energy supply is influenced by the 'scale' of the requested energy services. [37].

a) Energy efficiency and GHG emission mitigation

Industry and manufacturing sector use almost 40% of worldwide energy [38]. It contributes almost 37% of global GHG emissions [38]. In most countries, CO_2 accounts for more than 90% of CO2-eq GHG emissions from the industrial sector [39; 40]. These CO_2 emissions arise from three sources: (1) the use of fossil fuels for energy, either directly by industry for heat and power generation or indirectly in the generation of purchased electricity and steam, (2) non-energy uses of fossil fuels in chemical processing and metal smelting, and (3) non-fossil fuel sources, for example cement and lime manufacture[40].The energy intensity of most industrial processes is at least 50% higher than the theoretical minimum [40].This provides a significant opportunity for reducing energy use and its associated CO_2 emissions [41]. A wide range of technologies have the potential for reducing industrial GHG emissions, of which energy efficiency is one of the most important, especially in the short- to mid-term [40]. Other opportunities include fuel switching, material efficiency, renewables, and reduction of non-CO_2 GHG emissions [41].

VI. Conclusions

Climate change is one of the most difficult challenges facing Nigeria and world. The cause can be natural or anthropogenic in nature. Climate change from anthropogenic causes due to the human activities on earth can be mitigated using technologies and formulation of environmental policies and laws. Convectional energy (oil and gas) which is the main economic stream of Nigeria generates high value of Co_2 emissions and other associated greenhouse gases into the atmosphere, leads to ozone layer depletion, global warming and consequently climate change. Therefore, moving towards renewable energy resources will play an important role in mitigation Co_2 emissions and GHGs. The large potential of renewable energy resources in the country is an advantageous factor for deploying RES for greenhouse mitigation measures, create clean and environment- friendly technologies and energy use mechanism. Actual energy-cost production is higher than the theoretical cost by 22% in Nigeria and such lead to high production cost in the country, demand for more energy, increase in Co_2 emissions and GHGs and increased cost of living. In turn, existence of enabling Energy policies (ECN) of Nigeria should be designed to support renewable energy sources and installed power plant efficiently.

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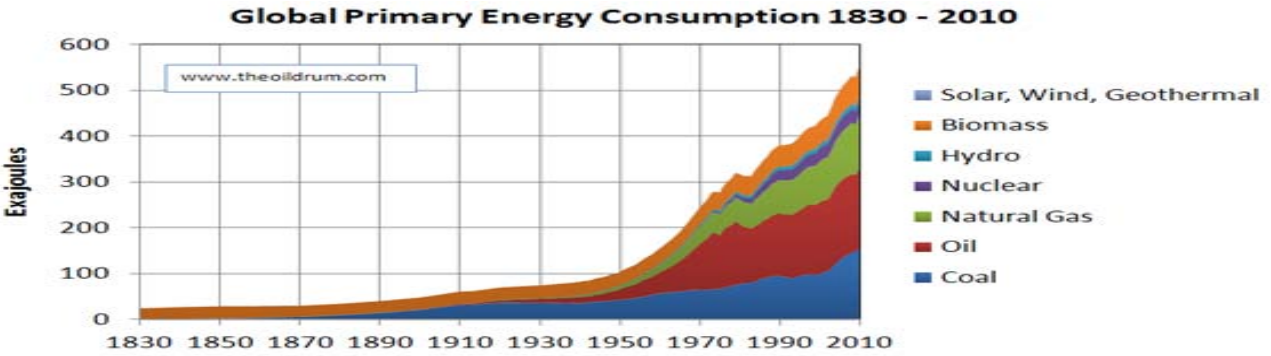


Fig. 1.1 : Global primary energy consumption (1830-2010)

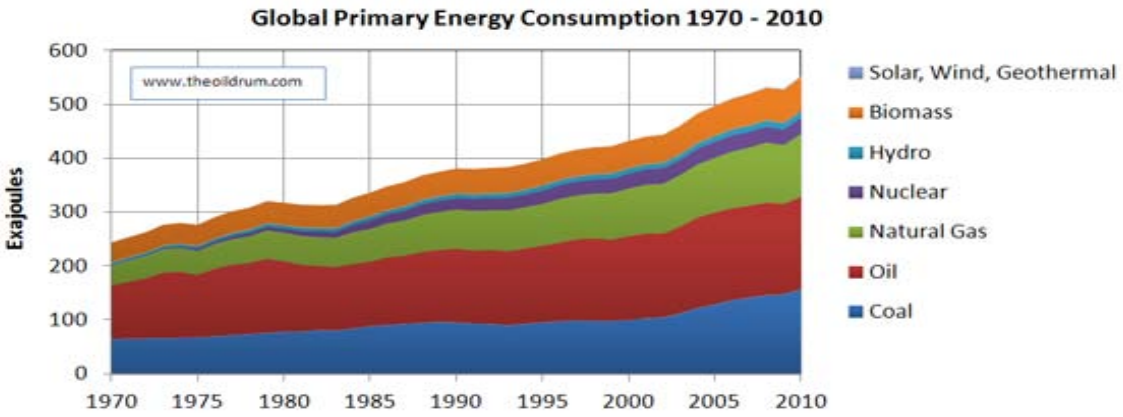


Fig. 1.2 : Global primary energy consumption (1970-2010)

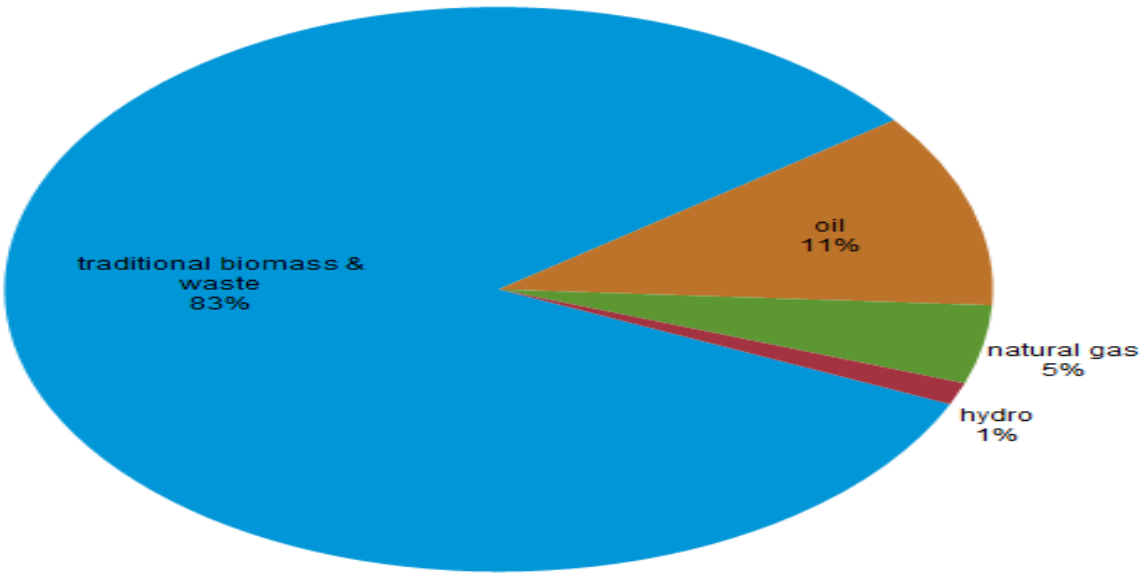


Fig. 1.5 : Total primary energy consumption in Nigeria, 2011 [23]

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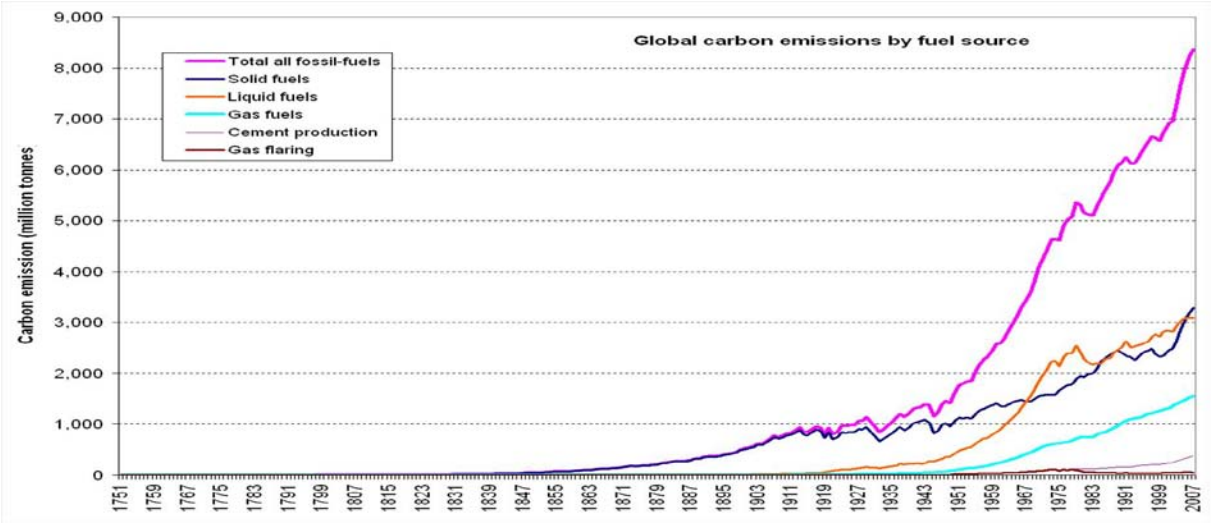


Fig. 1.3a : Global carbon emission from fossil-fuel [20]

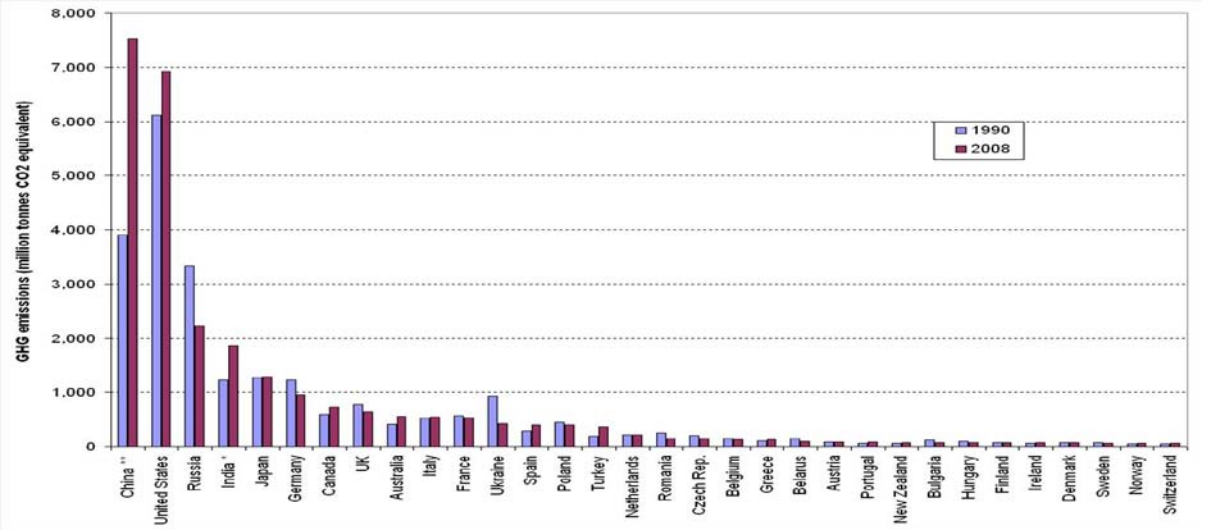


Fig. 1.3b : Global carbon emission from fossil-fuel on country level [20]

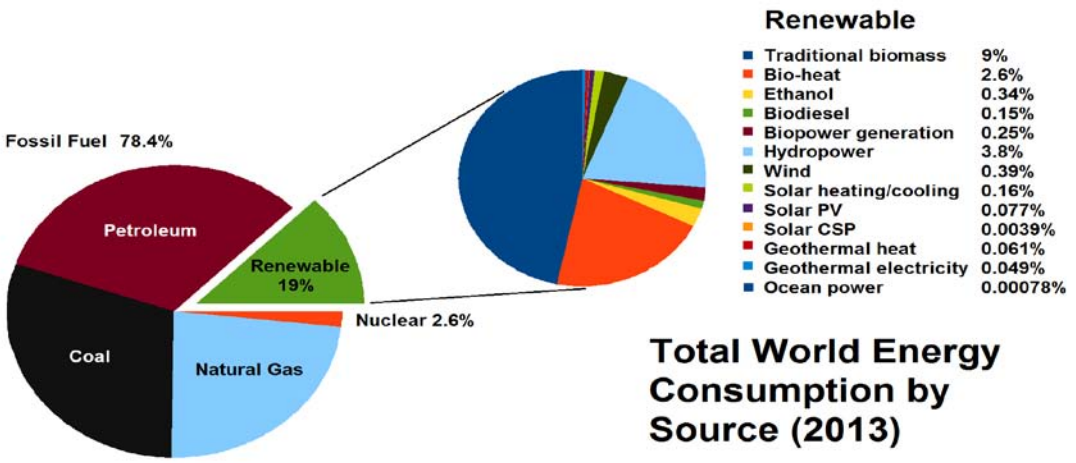


Fig. 1.9 : Share of total world renewable energy [30]

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Table 1.1 : Renewable energy potential in Nigeria [23]

Energy Resources	Estimated Reserve
Large Hydropower	11,250 MW
Small Hydropower (<30 MW)	3500 MW
Fuel Wood	11 million hectares of forest and woodland
Municipal Waste	30 million tonnes/year
Animal Wastes	245 million assorted animals in 2001
Energy Crops and Agricultural Residue	72 million hectares of agricultural land
Solar Radiation	3.5-7.0 kW h/m^2/day
Wind	2-4 m/s at 10 m height Wind speeds in Nigeria range from a low 1.4 to 3.0m/s in the Southern areas, except for coastal line and 4.0 to 5.1m/s in the North. The Plateau area particularly interesting.

Table 1.2 : Energy balances for Nigeria in 2012 kilotonne of oil equivalent (ktoe)[6]

	Coal and peat	Crude oil	Oil prod-ucts	Natural Gas	Hydro	Biofuels and waste	Total
Production	30	129,409	0	33,645	487	108,142	271,712
Imports	0	0	8,440	0	0	0	8440
Exports	0	-126,413	-755	-21,032	0	0	-148,201
International marine bunkers	0	0	-397	0	0	0	-397
International aviation bunkers	0	0	-186	0	0	0	-186
Stock changes	0	1830	538	0	0	0	2368
TPES* Total Primary Energy Supply	**30**	**4,825**	**7,640**	**12,613**	**487**	**108,142**	**133,736**
TPES (%)	**0.02%**	**3.61%**	**5.71%**	**9.43%**	**0.36%**	**80.86%**	**100.00%**

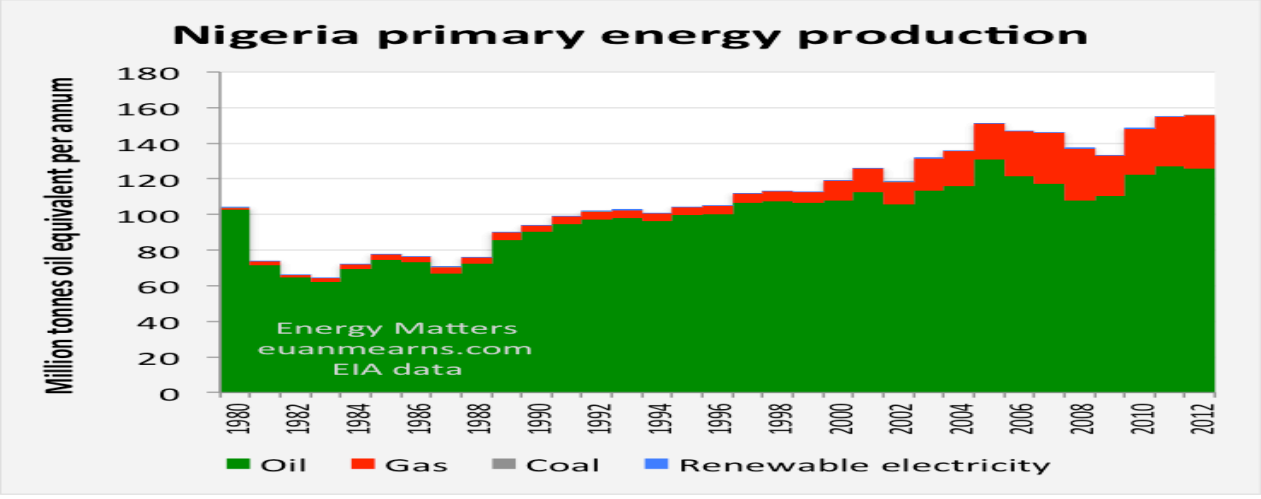


Fig. 1.5 : Nigeria primary energy production [16]

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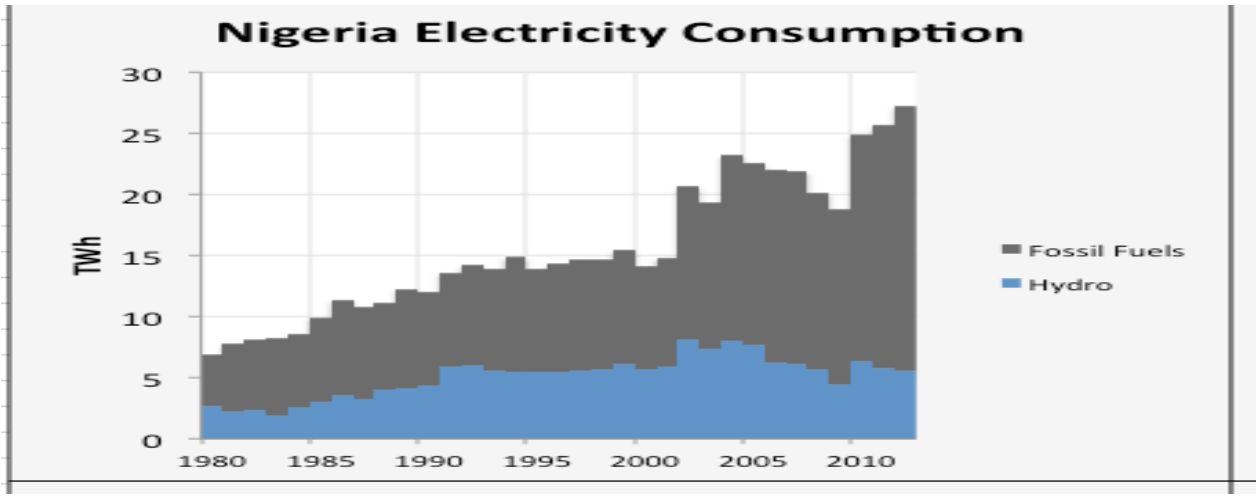


Fig. 1.4 : Nigeria electricity consumption [16]

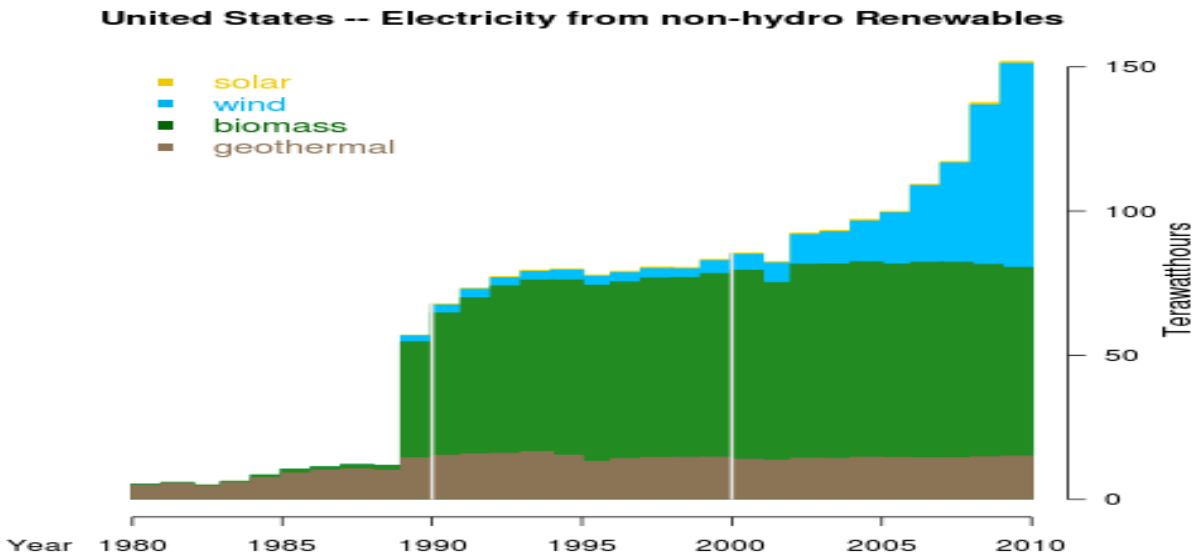


Fig. 1.6 : United States- Electricity from non-hydro-renewables

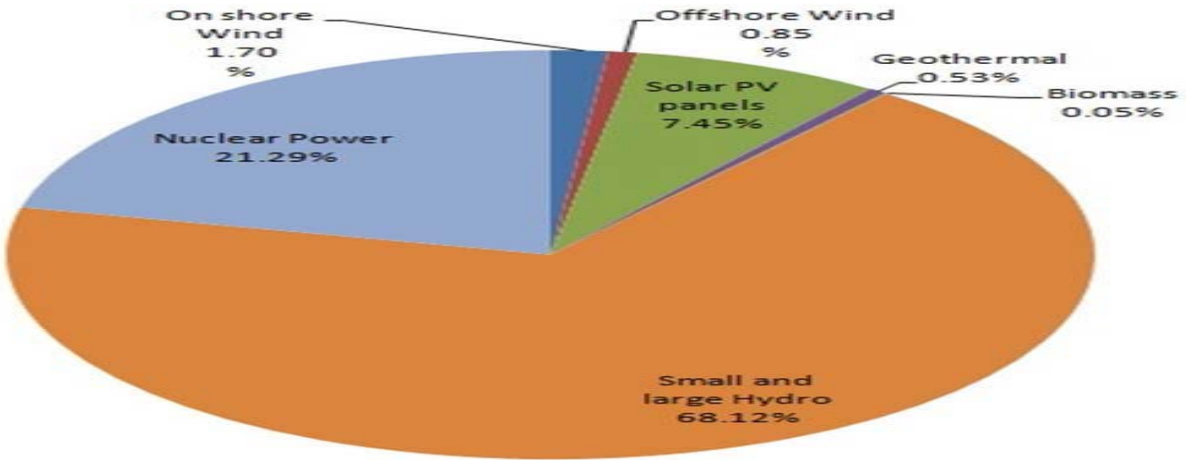


Fig. 1.7 : Estimates of renewable energy potential in Nigeria [23]

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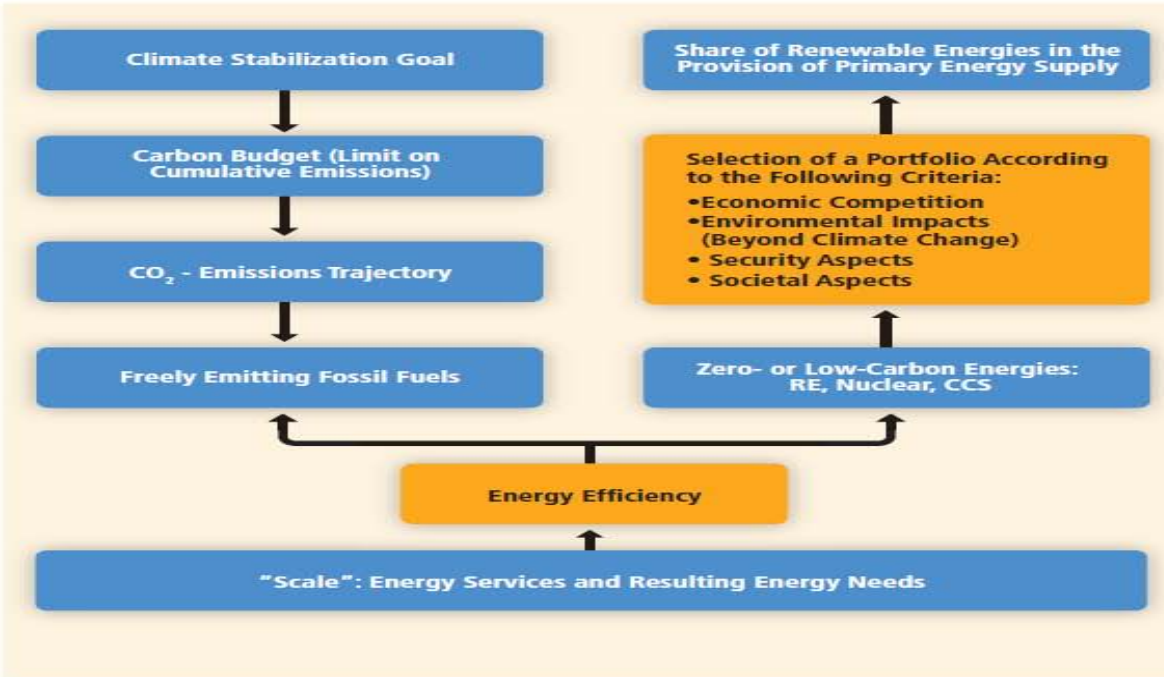


Fig. 1.8 : The role of renewable energies within the portfolio of zero- or low-carbon mitigation options (qualitative description). [33]

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