Clean technologies as mitigating strategies against the potential impacts of climate change in 21st century Nigeria

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Abstract: Even though it is not yet certain how climate change will affect Nigeria, the recent changes in rainfall regime could be an indication of some of the challenges that we may face as we move into the 21st century. At present, the Nigerian economy is largely dependent on fossil fuel, which is one of the biggest contributors of CO_2 to the atmosphere. This paper discusses the potential impacts of climate change in Nigeria in the 21st century and how renewable energy can be harnessed to mitigate or adapt to its effects. Various obstacles to achieving sustainable renewable energy in terms of policy, technical and financial barriers are enumerated and the strategies that could be adopted to overcome them are also discussed. The paper concludes that adopting clean technologies should be of utmost importance in domestic energy strategies and these should be supported by governments and other stakeholders.

1 Introduction

The term 'climate change' is now frequently used by scientists instead of 'global warming'. According to the National Academy of Sciences in the USA, this is probably to draw attention to the fact that there are other changes besides the rise in global temperatures. According to the US Environmental Protection Agency, 'climate change' refers to any significant change in measures of climate lasting for decades or more. These changes could be due to natural factors and processes, as well as human activities that change the atmosphere's composition (*e.g.*, through the burning of fossil fuels, deforestation, reforestation, urbanisation, desertification, *etc*.) (Keeling, 1998; IPCC, 2001; Akinbami *et al*., 2003). On the other hand, global warming has been described as an average increase in the temperature of the atmosphere near the Earth's surface and in the troposphere, which can contribute to changes in global climate patterns. It could be induced by both natural and human activities. It then becomes clear that global warming is subsumed in climate change.

Perhaps the complexities in the science and politics of climate change are some of the reasons that make it an issue of global discourse but more importantly, its observed and potential global impacts on the ecological systems. These impacts are not only felt by technologically developed regions, but also by the so-called less developed countries, albeit with different intensities. Weaver *et al.* (2006) corroborated this by observing that the danger inherent in climate change and the vulnerability to its potential impacts vary across space and the affected parties and systems, infrastructures and activities. For instance, on the global scene, there is now strong evidence that an increase in temperature has affected many natural systems and that both physical and biological systems are also affected by anthropogenic warming (IPCC, 2007d).

There are mounting evidences that human activities which have brought about an increase in the level of greenhouse gases during the industrial revolution may be responsible for climate change. To make matters worse, the natural levels of these gases are being fuelled by emissions of CO_2 from the burning of fossil fuels and flaring of natural gas. Furthermore, the addition of methane and nitrous oxide from farming activities has also added to the enhanced greenhouse effect.

One of the international bodies that assess scientific, technical and socio-economic information concerning climate change, its potential effects and options for adaptation and mitigation is the United Nations Intergovernmental Panel on Climate Change (IPCC). Some of the following explanations in the paper on the potential impacts of climate change of the three working groups in the IPCC reports are based on the fifth IPCC report (IPCC, 2007d). The IPCC Working Group 1 (IPCC, 2007c), in its latest report, has estimated the 'low scenario' (B1, the most optimistic scenario family) average temperature for the 21st century to be within the range of 1.1°C and 2.9°C, while that of the 'high scenario' (A1FI, the most pessimistic scenario family) is estimated to be within the range of 2.4°C and 6.4°C. They also reported that the average global temperature would rise by 1.8°C to 4.0°C by 2100 and that a warming of about 0.2°C per decade is projected under the 'business as usual scenario' by the Special Report on Emission Scenario (SRES). The group also reported that the model projection for the rise in the sea level is within the range of 18 and 13 cm for the 'low scenario', while that of the 'high scenario' is put between 26 and 59 cm in the 21st century.

All these projections are not without their consequent impacts. For instance, the IPCC Working Group 2 (IPCC, 2007a) projected that there is a high probability that the dry regions would get drier and the wet regions would get wetter. Furthermore, they also stated that by mid-century, the annual average river runoff and water availability are projected to increase by 10%–40% at high latitudes and in some wet tropical areas and decrease by 10%–30% over some dry regions at mid-latitudes and in the dry tropics. Global precipitation is projected to increase and the risk of flooding is high.

In the assessment of the IPCC Working Group 3 (IPCC, 2007b) on the issue of climate change mitigation, it is believed that it is possible to stabilise greenhouse gas concentrations at a reasonable cost by 2050. Stabilisation between 445 and 535 ppm is estimated to cost less than 3% of the global Gross Domestic Product (GDP). One of the strategies suggested for dealing with the impact of climate change is that of carbon pricing, which would serve as an incentive for both consumers and producers to patronise and produce more environmentally friendly products and services. Other measures which were also suggested were mitigating technologies with economic potentials. Some of them are more fuel-efficient vehicles, efficient lightning and end-use electrical equipment, afforestation, reforestation, forest management and reduced deforestation.

This paper intends to examine the potential impacts of climate change in Nigeria in the 21st century and how renewable energy can be harnessed to mitigate or adapt to its effects. Various obstacles to achieving sustainable renewable energy in terms of policy, technical and financial barriers will be investigated and strategies that could be adopted to overcome them will be explored.

2 Background information on Nigeria

Nigeria lies between 4°N and 14°N and between 3°E and 15°E and according to the country's National Population Commission, she had an estimated population of over 140 million in 2007. It is often said that for every six black people in the world, there would always be a Nigerian. The average life expectancy at birth is 54 years (Poverty Reduction Strategy Paper, 2005). She is bordered in the north, east, west and south by Niger, the Cameroon, Benin Republic and Atlantic Ocean, respectively. The country spans an area of 924 000 sq km. The country could be divided into five ecological zones: Forest, Southern Savanna, Northern Guinea Savanna, Sudan Savanna and Sahel. Deforestation is one of the country's environmental problems and this has reduced Nigeria's forest area by 50% in the past 15 years.

Agriculture provides jobs as a means to livelihood. Roughly 60% of Nigeria's population still engages in agricultural activities. Nigeria enjoys a tropical climate by the virtue of her location. Nigeria has a mean average temperature of 27°C with average maximum temperatures of between 32°C along the coast to 41°C in the far north, while the mean minimum temperatures range from 21°C in the coast to under 13°C in the north (Federal Ministry of Environment, 2003). The precipitation varies from the coast (where there is over 3500 mm of rainfall) to Sahel, where there is little under 600 mm. Recent studies and model projections have indicated an increase in the amount of rainfall, especially in the northern part of the country (Adejuwon and Omotayo, 2006; Odekunle *et al.*, 2007).

The nation's known oil and natural gas reserves are estimated at 32 billion barrels and 174 trillion cu. ft., respectively. Most of them are located in the south-eastern and southern coastal area and she is the sixth largest producer in the Organisation of Petroleum Exporting Countries (Poverty Reduction Strategy Paper, 2005). More than 70% of the natural gas produced is currently being flared, even though there is an ultimatum to stop it by 2008. The inability of the oil-producing companies to implement this ultimatum is not unconnected with the fact that gas gathering is capital-intensive. However, this does not justify putting the environment in peril from climate change impacts. Nigeria's rivers are the main source of close to half of the electricity in the country. According to the National Economic Empowerment Development Strategies document, capacity utilisation in the industry is about 50% and it is estimated that if appropriate policies are put in place, the country could reap an estimated $2–$3 billion a year in return from foreign direct investment.

3 Potential impacts of climate change in 21st century Nigeria

Nigeria was among the first set of 154 countries that signed the United Nations Framework Convention on Climate Change, which entered into force on 21 March 1994. Nigeria ratified the convention in August 1994 (Adejuwon, 2004). The climate change in the country in the 21st century is expected to depend primarily on the global climate change which will, in turn, depend on the concentrations of greenhouse gases like carbon dioxide, methane and nitrous oxide (Adejuwon and Omotayo, 2006). According to the Federal Ministry of Environment (2003) and David and Ewah (2004), the main activities leading to the emission of greenhouse gases in Nigeria are gas flaring and transportation and electricity generation, while the energy, agriculture and land use change and waste management sectors are also the major contributors of CO_2 and CH_4 emissions. The net carbon emission in the country is estimated at 192 Tg CO_2, 17.0 Tg CO, 5.9 Tg CH_4 and 660 Gg of NOx and 12 Gg of N_2O. There is a meagre amount of literature on the issues concerning contemporary climate change in Nigeria. Nonetheless, there are studies on the observed and potential impacts of climate change and policy implications (Federal Ministry of Environment, 2003; Adejuwon *et al.*, 2006; David and Ewah, 2004).

Adejuwon and Omotayo (2006) used the output of the Hadley M2 General Circulation Model based on a 1% per annum compound increase in CO_2 using a simple interpolation technique to project Nigeria's climate in the 21st century. Their analyses were based on the meteorological stations in each of the five ecological zones in Nigeria. Climate parameters like cloud cover, precipitation, minimum and maximum temperatures and vapour pressure were considered.

From their results, cloud cover is projected to decrease generally in the Forest and Sahel zones towards the 21st century in Nigeria. The projection of rainfall in the Forest zone indicates that there is a high probability that the rainy season will become wetter while the dry season will become drier in the 21st century. Although an increase in rainfall was projected for June, July and August up to 1969 in Sahel, this amount of rainfall will decrease for the rest of the century. In the Forest zone, the mean monthly minimum temperature for January is projected to increase from 21.4°C to 26.4°C. It is lower in Northern Guinea than in Southern Guinea. Increases of between 4°C and 5°C are projected for all the months in Sahel.

According to the model projections, the pattern of the seasonal distribution of maximum temperatures will be maintained, *i.e.*, there will be high mean monthly maximum temperatures during the dry season and low mean monthly maximum temperatures during the raining season. However, an increase of between 3°C to 4°C in the mean monthly maximum temperatures is projected for the Forest zone in Nigeria during the 21st century. The model also projected that between 2070 and 2099, the mean maximum temperatures for Sahel will be higher than the normal body temperatures and that the difference between the April temperature of this period and that of the normal body temperature is 8°C. Regarding vapour pressure, an increase of 27.5 h*Pa in 1990 to 33.4 h*Pa during 2070 and 2099 is projected for the January vapour pressure in the Forest zone in Nigeria. In general, the increases in Sahel are about 4 h*Pa for January to April and 6 h*Pa from May to December as we move through the 21st century in Nigeria.

It is noteworthy that these projections are not without some key uncertainties. For instance, given the fact that the inputs to the model are products of human activities and that the knowledge of feedback processes in a climate system (especially those involving clouds, water vapour and aerosols) is not fully understood, there is bound to be uncertainties in the projected climate change. Nonetheless, the knowledge of climate change science is getting better everyday and model projections are being improved upon everyday as well. Besides, some of the model projections are currently being validated (Odekunle *et al.*, 2007).

4 Clean energy technologies as mitigating strategies for climate change impacts

Clean technologies rest within the domain of renewable energies. In general, renewable energies are derived from nonfossil and non-nuclear sources in ways that enable these to be replenished, sustained and have no harmful side effects (Francis, 2004). Renewable energy can be broadly placed into six categories: hydro, biomass, geothermal, solar, wind and tidal power. The strength of renewable energy lies in its ability to be renewed, as well as the sustainability of its harvesting, conversion and use. In addition to these environmental benefits, renewable energies also have economic gains. In fact, this is one of the reasons why the adoption of renewable energies is referred to as a win-win strategy for climate change mitigation. Some of the economic gains are:

- reduction in the dependence on fossil fuel and energy security
- creation of a new market for efficient energy technologies
- reduction in the economic cost of climate change impacts and creation of jobs
- reduction in the health problems related to greenhouse emissions.

The International Energy Agency (2003) also added that since they use primarily indigenous resources, most of the energy dollars can be kept at home.

What further strengthens the argument for renewable energy as a viable option, especially for developing countries like Nigeria, is the fact that while fossil fuels and other energy sources could be depleted (see Table 1), renewable energy can be replenished. Akinbami (2001) estimated that in the total energy consumption of Nigeria in 1995, the share of natural gas was 5.22%, hydroelectricity took 3.05%, fuelwood had the majority share of 50.45% and petroleum products had a 41.28% share. Oladosu and Adegbulugbe (1994) reported that the household sector is the highest consumer of energy in the country, making it one of the most important energy policy targets in the country.

Table 1 Nigeria's energy potential*

	Reserve	*Production*	*Depletion time*
Crude oil	20 billion barrels	2.5 million barrels per day	25–30 years
Natural gas	106 trillion cu ft (1989) to 60 trillion cu ft (2010)	2200 to 2500 million cu ft per day	180 years
Coal	Over 2.75 billion tonnes, of which about 639 million tonnes is proven	500 000 tonnes per annum	1278 years
Fuelwood	43.3 million tonnes (Chendo, 2001)	Rural area per capital consumption is 393.43 kg/annum, while urban households consume 255.75 kg/annum Note: Consumption is estimated to be higher than the rate of regeneration.	Demand is expected to grow at an annual rate of 1.2% (Aruofor, 2001) and it is expected to decrease within the next 50 years if the present rate of deforestation continues (Akinbami, 1997)

Note: *Based on 1989 reserves, assuming that production continues at the stated rate and there is no increase in the reserves.

Source: Adapted from Akinbami (1997)

5 Hydro power potential

Nigeria is blessed with abundant rivers and natural falls which could be harnessed to generate electricity (Aliyu and Elegba, 1990) and the gross hydro potential is estimated at 14 750 MW with the capability to generate 36 000 GWh (ECN, 2003). The most important drainage basin in Nigeria with a high potential for power generation is that of the Niger and Benue rivers. However, there are still some other rivers which could be used as a source of hydro power. According to the information in The Renewable Energy Master Plan (REMP), 227 of such sites have been reported to be viable for hydro power. Aliyu and Elegba (1990) have advocated the use of these sites for power generation for the country's rural areas. At present, hydro power generation is put at 14% of the nation's hydro power potential and represents some 30% of the total installed grid-connected electricity generation capacity (ECN, 2005). This source of energy produces very clean energy although, high initial capital cost, site specificity, weather and climate dependency are some of its disadvantages. However, cleaner energy, the long life span of its facilities and low maintenance costs are its own strong points.

6 Solar energy potential

By virtue of its location, Nigeria enjoys a high intensity of sunlight. The average annual solar energy intensity has been estimated to be around 1934.5 kWh/m2 per year and, by implication, an average of 6 372 613 PJ/year of solar energy (ECN, 2005). This amount

of energy is more than 1.082 Million Tonnes of Oil Equivalent (MTOE) per day (Francis, 2004). As large as this energy is, it is only available for just 26% of the day. Nonetheless, estimates show that the country does not need more than 3.7% of the land area to collect the needed energy, which is equivalent to the energy in the nation's reserve (Francis, 2004). If well harnessed, it could generate 120 thousand times the total annual average electricity produced by the Power Holding Company of Nigeria (ECN, 2005). Solar energy conversion is usually of two categories. Those that are used for solar heating, cooling, drying and thermal power plants fall into the category of solar-thermal technologies, while those that are used for crop drying, house heating and heating of process water for industries, hospitals, *etc*., airconditioning, the preservation of foods and drugs and power generation are called photovoltaic technologies (ECN, 2003). Besides the dusty winds which deflect solar radiation intensity around November to February (Bala *et al.*, 2000), solar energy is available, replenishable and environmentally friendly when compared with other forms of energy. It is particularly useful for low- to medium-power applications (ECN, 2003).

7 Biomass potential

Biomass has been defined as organic, nonfossil material of biological origin (ECN, 2003). There are so many methods involved in the conversion of biomass to biogas. Some of these methods are physical, biological, pyrolysis, gasification, burning, anaerobic digestion or biodegradation processes (ECN, 2005). Nigeria has abundant biomass resources which include wood, forage grasses and shrubs, animal waste and other wastes from forestry, agriculture, municipal and industrial activities as well as aquatic biomass. These resources have been estimated to be about 8×10^2 MJ (Francis, 2004). According to Akinbami *et al.* (2003), biomass such as feedstock substrate, water lettuce, water hyacinth, dung, cassava leave, urban refuse, solid (including industrial) waste, agricultural residues and sewage are economically viable for the country. Furthermore, given the increase in population, the amount of solid waste would increase and these could be converted to biogas for the generation of energy. Akinbami *et al.* (2003) also estimated that within a suitable environment, a 6.0 m^3 family-sized biogas digester will generate 2.7 m^3 of biogas, which is equivalent to about 79.11 MJ.

8 Obstacles to the adoption of renewable energy technology

As laudable as renewable energy is, not much of it has been deployed in Nigeria. As a matter of fact, Akinbami (2001) stated that besides hydro power and biomass, other sources of renewable energies have not been fully exploited. The current contribution of renewable energy is 0.6% of the total generating capacity in Nigeria (ECN, 2006). However, this is about to change with the implementation of the REMP. In recent times, attention has been paid to solar energy, especially in the rural electricity.

According to Akinbami (2001), there are five major barriers to the deployment of renewable energy technologies. These barriers are:

1 lack of technological capability

2 high cost of investment of renewable energy

3 financial constraints

4 low level of public awareness

5 lack of a comprehensive national energy policy.

Another major problem is that of the absence of a strong linkage between the key sectors which are supposed to drive the market for renewable energy technologies. Such sectors are composed of small and medium enterprises, research and development, the ministries of environment and housing, the federal ministries of water resources, aviation, energy, transportation, information and communication and the integrated rural development agency. Renewable energy alliances between these sectors will increase the market share value of renewable energy technologies in Nigeria. Furthermore, the lack of human and manufacturing capabilities could bring about the production of substandard renewable energy technologies. This means that a quality assurance agency that would protect the interests of consumers should be established. In other words, agencies such as the Consumer Protection Agency and Standards Organisation of Nigeria should be strengthened to look into the activities and productions of the organisations involved in the manufacturing of renewable energy technologies. Another barrier is that of the regular supply of resources needed for the smooth running of the renewable energy programme. This problem has been known to affect the cost of production of renewable energies.

9 Policy response to the development of renewable energy technologies

Nigeria has never been found wanting in the development of policies, but it is rather the implementation that is usually difficult. But with the entrenchment of democracy and the rule of law, the actualisation of policies should be a bit easier. Renewable energy is not an exception to this rule. Some of the policy instruments targeted at promoting affordable and efficient electricity which eventually should lead to the deployment of renewable energy technologies in the country are:

- the 1999 Constitution of the Federal Republic of Nigeria
- the National Electric Power Policy (ECN, 2001)
- the National Energy Policy (ECN, 2003)
- the Renewable Energy Master Plan (ECN, 2005)
- the draft Rural Electrification Policy
- the National Economic Empowerment and Development Strategy 1&2 (NEEDS)
- Renewable Electricity Policy Guidelines (ECN, 2006)
- the Seven-point Agenda
- the Vision 20:2020.

The REMP identified and addressed the barriers to the deployment of renewable energies. This document sets out a 20-year vision and roadmap for renewable energy development in the Nigerian economy and it is in tune with the Millennium Development Goals and the objectives of the Kyoto Protocol. This is believed to be possible with the abundance of renewable resources such as hydro power, solar radiation, biomass and wind. This policy document is also structured to benefit from the expanding market opportunities for future renewable energy technologies, as well as reduce greenhouse gases' concentration. It intends to develop and test the delivery of business models for renewable energy services. The document also tries to create the knowledge and capacity necessary for a systematic and cost-effective deployment of renewable energies in the country. Moreover, it creates synergies between all the stakeholders in the production, usage and maintenance of renewable energy technologies. To achieve its goals and objectives, REMP has a built-in programme called the Framework Programme for Renewable Energy Promotion. This programme is set up to look into the issues of R&D, databases, markets, pricing, product standards, public awareness as well as capacity building both within the context of human resources and technical development. Another effort by the government in making renewable energy technologies more attractive to private investors is the adoption of fiscal incentives to the manufacturers of such technologies. These fiscal incentives could be in the form of exemption of custom duties, tax holidays, capital incentives and loans. REMP also advocates the set-up of a renewable energy fund, renewable energy leadership and national research and development policy to facilitate and sustain the deployment of renewable energy technologies.

Another policy directed at the effective and efficient supply of electricity across the country is that of the National Electricity Power Policy (NEPP) supported by the Electric Power Sector Reform Act. This policy puts emphasis on the use of nonthermal and renewable energy. Another policy which depicts the desires and aspirations of the Nigerian citizens with a focus on growth and poverty reduction is that of NEEDS. One of the main agendas of the policy is the development of renewable energy technologies as a means to accelerate energy sector growth and development and eventual privatisation of energy-related operations. This policy document also stresses the importance of private sector participation in the development of renewable energies as a way of not only generating employment, but also reducing poverty among the populace.

10 Conclusion

Climate change poses a great deal of challenges to the growth and development of a habitable environment, infrastructures and economy of Nigeria in terms of its observed and potential impacts. These threats are in undoubtedly surmountable. The adoption and deployment of renewable energy technologies is capable of mitigating the threats. Given the abundant renewable energy resources in the country, the potentials and future of the renewable energies market is bright. However, the problems of a comprehensive legal framework, affordability, public awareness, human and manufacturing competence, financial constraints and competition with fossil fuel are the major obstacles to the acceptance of clean technologies in Nigeria.

The Nigerian government has taken a bold step in not only addressing these challenges, but also developing policies which are designed to add renewable energies to the total energy mix in the country. These policies are entrenched in NEEDS, the

Millennium Development Goals as well as the objectives of international conventions such as that of the United Nations Framework Convention for Climate Change. Renewable energies would not only free Nigeria from fossil fuel dependence, but also cut down greenhouse gas emission, create new markets and generate employment for the populace. Although these policies are adequate, this study proposes the establishment of an independent body outside REMP to monitor the full implementation of the policy. Also, there is the need to sensitise private investors that renewable energy technologies are the energies of the future; however, the economic benefits may not be immediate. A conducive atmosphere for renewable energy technologies' transfer and appropriate fiscal protection is pivotal to the successful implementation of renewable energy technologies. If these renewable energy technologies are properly developed, they could serve as an impetus for the development of other sources of renewable energies such as wind, tidal, geothermal, ocean and hydrogen power. With all these policies in place and at full implementation, one could envision a Nigeria whose sources of energy will depend solely on renewable energies.

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