**Scientific Papers** (www.scientificpapers.org)
Journal of Knowledge Management, Economics and Information Technology

Issue 6
October 2011

# Potential Impacts of Global Climate Change on Power and Energy Generation

**Authors:** **Christian Ifeanyi ENETE**, Nnamdi Azikiwe University, Awka, Nigeria, ugwuenete@yahoo.co.uk, **Michael Oloyede ALABI**, Kogi State University, Anyibga, Kogi State, Nigeria, alabimoo6@yahoo.com

Climate change and climate variability is receiving much attention recently because it has significant effects on our power and energy sector and therefore on the socio-economic activities of the society especially in a developing country such as Nigeria. Approach: The aim of the study is to examine the influence of climate change on power generation. Literatures were identified for review through a comprehensive search by using electronic and non-electronic databases. Related published literature and documents were searched in a systematic way using a range of key words relating to climate change impacts and energy. Results: The literature review indicates that climate change undermine power and energy production by increasingly depleting renewable and non-renewable sources, creating resources scarcity as well as damage to infrastructure. The review also indicate that climate change undermine environmental dimensions by increasing sea-level rise, extreme weather events and land degradation and pollution. Conclusion: In reducing climate-induced threats on power sector, efforts should be geared towards ensuring that our energy sector withstand the changes to our climate that are already underway by optimizing energy mix, developing low carbon and renewable energy, formulating relevant law and regulations and promoting technology advancement and economic engineering.

***Keywords:*** *Climatic change, alternative energy, mitigating policy, renewable energy, coal-bed methane, united nations framework, power generation, mitigating policies, global climate models, Nigeria energy scene, Global warming*

## Introduction

Climate change is a major global issue of common concern to the International Community. It is an issue involving both environment and development, but it is ultimately an issue of development. Climate change will have wide-ranging impacts on society and the infrastructure that supports civilization. Global warming could impact not only on agriculture and human health but also patterns of human settlement, energy use, transportation, industry, environmental quality and other aspects of infrastructure that affect our quality of life (IPCC, 1990).

Numerous examples from history illustrate how the success of civilization and human welfare is intimately linked to climate (Gore, 1993). Fossil-fuel use will affect future climate. Fossil fuels, currently the mainstay of economically developed countries, supply energy either directly as fuel or indirectly as generated electricity, for manufacturing, agriculture, transportation and space heating. Future Green House Gas (GHG) emissions and resultant climate change will depend largely on future rates of fossil-fuel consumption.

Many complex and interacting factors determine the consumption rate of fossil fuels. Demand is a result of population growth rate, availability of fossil fuel, energy efficiency, conservation measures and use of non-fossil energy sources, general industrial productivity, energy policy and future climate (Hardy, 2003. All these factors will affect fossil-fuel utilization rates and future climate.

This study examines how climate change influences power and energy generation in general, with emphasis on the Nigeria Case. Specifically, it will examine the concept, causes and effects of climate change; world energy scene, Nigeria energy scene, effects of energy use on

climate, key areas for GHG, mitigation, alternative energy sources and Nigeria's efforts in mitigating climate change.

**Climate change: An overview:** Climate change refers to any change in climate over time, whether due to natural variability or as a result of human activity. The United Nations Framework Convention on Climate Change (UNFECC) defines climate change as a change of climate which is attributable directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over a comparable time periods (IPCC, 2001).The Earth's climate is driven by a continuous flow of energy from the sun. Heat energy from the sun passes through the earth's atmosphere and warms the earth's surface. As the temperature increases, the earth's sends heat energy (infrared radiation) back into the atmosphere. Some of this heat is absorbed by gases in the atmosphere, such as carbon dioxide (C02) (the major contributor to global warming), water vapor, methane, nitrous oxide, ozone and halo carbons.

These gases, which are all naturally occurring, act as a blanket, trapping in the heat and preventing it from being reflected too far from the earth. They keep the earth's average temperature at about 15°C warm enough to sustain life for humans, plants and animals. Without these gases, the average temperature would be about -18°C... too cold for most life forms. This natural warming effect is also sometimes called the greenhouse effect.

These rapid increases in the condition of these gases in the atmosphere due mainly to human activity, particularly the burning of fossil fuel and deforestation, have been affecting the surface climate of the earth. This alteration is achieved through altering the radiation balance of the earth, warming the surface and affecting atmospheric circulation. It is this global warming of climate, the enhanced greenhouse effect that has become the subject of concern at global, national and local level (Carter et al., 1994).

**Climate change: Causes and features:** The major causes of climate change are both anthropogenic and natural. The IPCC, fourth report released in 2007 stated that, multiple lines of evidence confirms that the post-industrial rise in greenhouse gases does not stem from natural mechanisms. In other words, this is anthropogenic climate change and the significant increases in

the atmosphere of these potent greenhouse gases are as a result of human activity (IPCC, 2007).The most potent of the greenhouse gases are carbon dioxide (Co2), methane ($CH_4$) and nitrous oxide ($N_2O$).

The natural causes are increases in the volume of gases, moisture and particulates in the lower atmosphere by volcanic eruptions, ocean turbulence, and desert winds. These forces combine with anthropogenic forces to create greenhouse conditions. A serious natural factor is the alteration in the intensity of solar radiation itself in the form of sunspots-representing the most well known expression of solar activity (Lozan, Hupfer and Global, 2000). Lozan et al. (2000) identified 27 greenhouse (CFC) gases in the atmosphere. A principal component of these gases is Co2, which contributes approximately 49% of the 3.3°C increase in warming due to these gases. This Co2 dominance is due to industrialization in America and Europe and Biomass burning and gas flaring in the tropics (FAO, 1997).So far, Global Climate Models (GCMs) have projected three generalized impact of climate change arising from global warming which are of immediate relevance to Africa in general and Nigeria in particular (IPCC, 1999).These are summarized as follows:

- Desserts are likely to become extreme - becoming hotter but not significantly wetter. The Sahara desert which borders West Africa to the north has been noted to be making almost persistent “incursion” into the Sahel resulting in drier conditions during the summer monsoon.
- Global hydrology cycle will be intensified with changes in precipitation, its total amount, frequency and intensity. And this will certainly affect hydropower generation.
- Agricultural production (including forestry) will increase in some areas and decrease in others taking into account the beneficial effects of Co2 concentration.

World energy consumption and electricity generation: Coal has led the recent surge in global energy demand and is on a strong growth path. Statistics from the world coal institute show that coal provides 25% of global primary energy needs and generates 40% of the world’s electricity and production of coal has grown 78% over the last 25 years.

It is a truism that presently we are at a peak oil crisis and there is no doubt that oil stocks and reserves are dwindling. For each year in future, there will be less oil available than there had been in the past. To some extent, this forecast will force us to reconsider cleaner alternatives. If we are going to combat greenhouse gases and global warming, then we must consider alternative energy as a viable choice to traditional fossil fuel sources.

**Nigeria's energy scene:** The National energy is at present almost entirely dependent on fossil fuels and firewood (conventional energy sources) which are depleting fast. According to Chendo (2001), recent estimates indicated that the reserve for crude oil stood at about 23 billion barrels in 1998, natural gas 4293 billion m3 at the beginning of 1999, made up of 53% associated gas and 47% non associated gas. Coal and lignite stood at 2.7 billion tones, Tar sands at 31 billion barrels of oil equivalent and large-scale hydropower at 10,000 mv. Tables 1 and 2 show various conventional and non-conventional energy sources and their estimated reserves in Nigeria.

**Energy supply mix in Nigeria:** The 1995 distribution of energy consumption (Fig. 2) typifies the current energy supply mix in the country. It shows that of the total energy consumption, the share of natural gas was 5.22%, hydroelectricity 3.05%, fuel wood had the lion share of 50.45% and petroleum products had 41.28% share. This further confirms the fact that presently, renewable-energy use in the country is split essentially between hydroelectricity and traditional fuel wood (Akinbami, 2001).

**Table 1**: Nigeria's conventional energy resources *Source: Chendo (2001)*

| Resources | Reserve | Resources in energy units (billion tones) | % Total conventional energy |
|---|---|---|---|
| Crude oil | 23 billion barrels | 3.128 | 21.0 |
| Natural gas | 4293 billion $m^3$ | 3.679 | 24.8 |
| Coal and lignite | 2.7 billion tones | 1.882 | 12.7 |
| Tar sands | 31 billion barrels of oil equivalent | 4.216 | 28.4 |
| Hydropower | 10,000 mw | 1.954 (100 yrs) | 13.1 |
| Total | Conventional/ Commercial energy resources | 14.859 | 100% |

**Table 2**: Nigeria's non conventional energy resources *Source: Chendo (2001)*

| Resource | Reserves | Reserves (billion tones) |
|---|---|---|
| Fuel wood | 43.3 million tones | 1.6645 (over 100 years) |
| Animal wastes and crop residue | 144 million | 3.024 (over 100 years) |
| Small scale hydropower | 734.2 mw | 0.143 (over 100 years) |
| Solar radiation | 1.0 kw $m^{-3}$ land area (peak) | - |
| Wind | 2.0 - 4.0 m $s^{-1}$ | - |

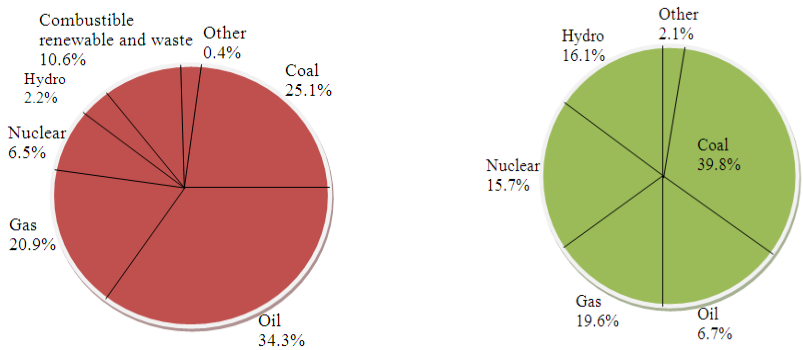


**Figure 1**: World Energy Consumption and Electricity Generation. (a): World Energy Consumption.(b): World Electricity Generation
*Source: http://www.global-greenhouse-warming.com*

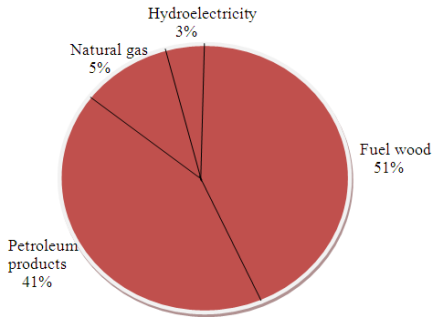


**Figure 2**: Typical energy supply mix in Nigeria
*Source: Akinbami, (2001)*

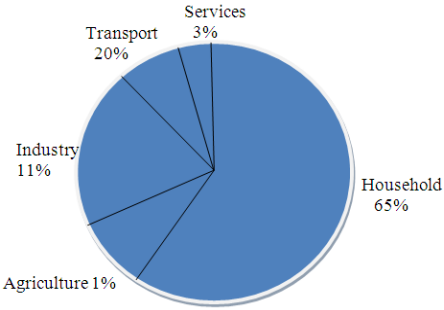


**Figure 3**: Sectoral distribution of national final energy consumption (PJ) in 1989
*Source: Oladosu and Adegbulugbe (1994)*

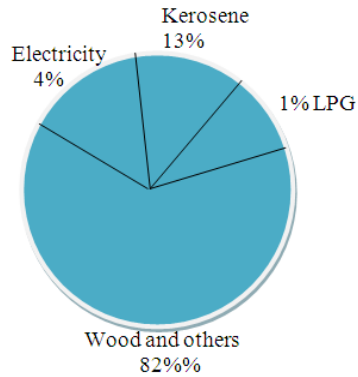


**Figure 4**: Distribution of household final energy consumption
*Source: Oladosu and Adegulugbe (1994).*

**Economic sectors and energy patterns:** From the energy point of view, the Nigeria economy can be disaggregated into industry, transport, commercial, household and agricultural sectors. However, the household sector presently dominated energy consumption in Nigeria. This makes it the most important energy sector of the Nigeria economy (Oladosu and Adegbulugbe, 1994). Figure 3 shows sectoral distribution of National Final Energy Consumption.

The household sector has consistently accounted for over half of Nigeria's total domestic energy consumption. In 1989 its share was about 65%. This alone is enough to highlight the importance of the sector in the

Nigeria energy system. However, an analysis of the final energy composition of this consumption is even more revealing.

According to Oladosu and Adegbulugbe (1994), the energy consuming activities in the sector are cooking, lighting and operation of electrical appliances (non-substitutable electricity). In 1989, the shares of these activities in final energy consumption were 91%, 6-3% respectively. Total final energy consumption was 487PJ. The major energy carriers are fuel wood, kerosene, Liquefied Petroleum Gas (LPG) and electricity. Small amounts of charcoal and coal are also used. Fuel wood is mainly consumed in this sector and accounted for over half of total natural energy consumption in 1989. A small amount is consumed in rural industries and the commercial sector. This means that fuel wood constitutes about 80% of total residential final energy consumption as illustrated in Figure 4.

## Discussion

**The effects of energy use on climate:** The United Nations Framework Convention on Climate Change (UNFCCC, 2002) calls for stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. The actual level at which atmospheric $C0_2$ stabilization is achieved will depend on the product of several factors, known together as the KAYA IDENTITY (Hoffert *et al*., 1998):

Where

| | | |
|---|---|---|
| Mc | = | N (GDP/N)(E/GDP)(C/E) |
| Mc | = | $C0_2$ emitted from fossil fuel combustion |
| N | = | Population |
| DP | = | Gross domestic product |
| E/GDP | = | Energy intensity in N year $\$^{-1}$ |
| C/E | = | Carbon intensity = the weighted average of the carbon-to- energy emission in kg factors of all energy sources$CN^{-1}$ year $^{-1}$ |

The level of atmospheric $C0_2$ stabilization that can be achieved in this century will depend on all these factors (Hoffert *et al*., 1998). In the developing world, because of the projected rapid growth rate in energy use, achievable increases in energy efficiency will have little impact in reducing total GHG

emissions (Pearson and Fouquet, 1996).Improvement in energy efficiency alone will not be sufficient to stabilize $C0_2$ at reasonable target values. Meeting $C0_2$ stabilization goals will require a simultaneous decrease in carbon fuels as a proportion of total energy. New carbon free sources of energy will be required to decrease carbon intensity (Hoffert *et al*., 1998).

**The effects of climate change on energy supply and demand:** The impacts of climate change on supply and demand will vary greatly by region. For example, in the United Kingdom and Russia a 2-2.2°C warming by 2050 will decrease winter space-heating needs, thus decreasing fossil-fuel demand by 5-10% and electricity demand by 1-3% (Moreno and Skea, 1996). In the North eastern United States, summer time decreases in stream flow will reduce hydropower generation during that season (Linder, 1990).

In Nigeria, a 2-2.2°C warming by 2050 will increase dry season air-conditioning demand by 3-6% and electricity demand by 4%. At the same time, dry season decreases in stream flow will reduce hydropower generation during that season.

Model studies, assuming a 3-5°C increase in temperature by 2055, suggest that electricity demand and fuel costs will increase significantly because of climate change (Linder, 1990). Annual electricity energy demands will increase slightly by 4-6% by the year 2055. As a result of climate change, peak national demand will increase 16-23% above base case values, that is, above the increased demand due largely to population growth without climate change.

The costs of increasing electrical capacity to meet the increased demand due to climate change will be large. By 2055, the annual costs for capital, fuel and climate-induced modifications in utility operations will be 7-15% greater than costs without climate change.

An increase in electrical demand (much of it generated by fossil-fuel combustion) would make policies that limit GHG emissions more difficult to achieve. And with increased demand, the need to import power could affect the balance of payments of Nigeria's foreign trade.

Following its effect on runoff and stream flows, climate change will also affect hydroelectricity power generation. Hydropower supplies 2.3% of the world's total energy and 3% of Nigeria's electricity. The African drought of 1991 - 1992 led to a significant decrease in hydropower.

**Nigeria's efforts in mitigating climate change:** As a developing country of responsibility, Nigeria adopted series of policies and measures taking into account its specific national circumstances, making positive contribution to the mitigation of climate change. They include:

- Restructuring the economy, promoting technology advancement and improving energy efficiency. Since 1999, the government of Nigeria has paid more attention to the change of the economic growth pattern and the restructuring of economy and integrated the reduction of energy and other resources consumption, the promotion of clean production and the prevention and control of industrial pollution into its national industrial policies.
- Optimizing Energy mix by developing low-carbon and renewable energy
- Under national policy guidance and with financial support, the share of high grade and clean energy was improved by strengthening the development and utilization of hydropower, oil, gas and supporting the development and utilization of new and renewable energy including biomass, solar, geothermal and wind power.
- Launching national wide tree-planting and forestation campaign
- Since 1990, tremendous achievement has been made in tree-planting and a forestation along with the implementation of key forest ecological projects in Nigeria
- Strengthening laws and regulations and policies and measures relevant to addressing climate change
- To address newly-emerging issues in recent years, the National Assemblies have passed a member of laws to further reinforce the policies and measures relevant to addressing climate change
- Attaching great importance to climate change research and capacity building
- The government of Nigeria values its capability and capacity to support scientific studies and researches on climate change and constantly enhance them. It has implemented a number of key research projects with some Nigeria Universities such as climate change programmer with FUT, Minna

**Alternative energy sources (renewable):** Renewable energy is considered to be one of the pivotal "Wedges" that can combat global warming and stabilize the climate, through the reduction of carbon dioxide emissions. Alternative energy or Renewable Energy (RE) sources are not destroyed when we use the energy harnessed. Renewable energies are alternatives to traditional sources. They are different to fossil fuels or nuclear power, which must be consumed (coal or gas burnt in power stations, oil in transport, uranium in nuclear power) to release energy.

To utilize renewable sources requires developing technologies that harvest this energy. For instance, specific technologies like those below, are needed to efficiently convert natural processes into energy to power our societies. They include: Sunlight (solar power), wind, waves, tides (tidal power), flowing water (hydropower), geothermal heat, biological processes (biomass) including: Ethanol, palm oil, biofuels and biodiesel from algae. Nigeria is currently under utilizing its renewable (alternative) energy sources.

**Key areas for GHG Mitigation:**

**Formulate and implement relevant laws and regulations:** Vigorously strengthen energy legislation to establish and improve energy legal system, promote the implementation of Nigeria's national energy development strategy, establish the legal status of medium and long term energy program, promote the optimization of energy mix, mitigate GHG emissions from energy production and transformation. Major policies and measures are as the following:

- Expedite the constitution and amendment of laws and regulations that are favorable to GHG mitigation;
- Strengthen research and formulate energy strategy program;
- Implement the Renewable Energy Law of Nigeria.

**Strengthen institutional innovation and mechanism construction:**

- Accelerate Nigeria's institutional reform in energy sector;
- Further promote mechanism construction for renewable energy development. Based on the principle of integrating government guidance, policy support and market force, stable mechanism for

investment will be established through government investment, government concession and other measures.

**Intensify relevant policies and measures in energy industry:**

- Properly develop hydropower on the precondition of protecting the ecosystem;
- Actively promote the development of nuclear power;
- Expedite technology advancement in thermal power generation;
- Vigorously develop Coal-Bed Methane (CBM) and Coal-Mine Methane (CMM) industry;
- Promote the development of bio-energy;
- Actively support the development and utilization of wind, solar, geothermal and tidal energy.

**Strengthen the development and dissemination of advanced and suitable technologies:**

- Technologies for the clean and efficient development and utilization of coal-as such, emphasize the research and development of highly-efficient coal mining technologies and supporting equipments, efficient power generation technologies and equipment such as heavy-duty gas turbines, Integrated Gasification Combined Cycle (IGCC), high-pressure, high-temperature ultra supercritical unit and large-scale supercritical circulation fluid bed boilers; vigorously develop coal liquefaction, gasification and coal-chemistry and other technologies for coal conversion, coal gasification based multi-generation systems technology and carbon dioxide capture, utilization and storage technologies;
- Exploration, exploitation and utilization technologies of oil and gas resources;
- Nuclear power generation technology-Research and master fast reactor design and its core technology, including nuclear fuel and structural material related technology;
- Renewable energy technology. Prioritize the development of low-cost and scale exploitation and utilization technologies, including the development of large scale wind-power generation equipments, high performance and low-cost photovoltaic battery technology,

solar thermal power generation, integrated solar energy building technology and biomass and geothermal energy development and utilization technologies;

- Power transmission and distribution and grid safety technologies. Prioritize the research and development of large-capacity.

## References

[1] Akinbami, J.F.K., 2001, *Renewable energy resources and technologies in Nigeria. Present situation, future prospects and policy framework,* Mitigation Adaptation Strategies Global Change, 6: 155-181

[2] Carter, T.R., M.L. Parry, H. Harasawa and S. Nishioka, 1994. IPCC, *Technical Report for Assessing Climate Change Impacts and Adaptations,* Department of Geography, University College, London, UK and Centre for Global Environment Research, National Institute for Environmental Studies, Japan

[3] Chendo, M.A.C., 2001, *Non-conventional energy source: development, diffusion and impact on human development index in Nigeria,* N. J. Renewable Energy, 9: 91-102.

[4] FAO, 1997, *Changes in the Tropical Forest Area,* UNO Geneva

[5] Gore, A. 1993, *Climate and Civilization, Earth in the Balance: Ecology and Human Spirit,* New York: Plume Publishing, pp: 56-80.

[6] Hardy, J.T., 2003, *Climate Change: Causes, Effects and Solution,* John Wiley and Sons Ltd, England

[7] Hoffert, M.I., K. Caldeira, A.K. Jain, E.F. Haites and L.D. Danny Harvey et al., 1998, *Energy Implications of Future Stabilization of Atmospheric Co2 Content,* Nature 395: 881-884. http://www.global-greenhouse-warming.com

[8] IEA, 1998, *Biomass energy: Data, analysis and trends, Paris: Inter. Energy Agency*, p: 339. http://www.iea.org/index.html

[9] IPCC, 1990, *Climate Change: The IPCC Scientific Assessment*, Houghton, J.T., G.J. Jonkins and J.J. Ephraim, (Eds.). Cambridge University Press, UK

[10] IPCC, 1999, *Aviation and the Global Atmosphere*, Penner, J.E., D.H. Lister, D.J Griggs, D.J. Dokken and M. Mcfarland, (Eds.), Cambridge University Press, United Kingdom

[11] IPCC, 2001, *IPCC 3rd Assessment Report*, McCarthy, J.J., O.F. Canziani, N. Leary, D.J. Kokke and K.S. White, (Eds.). Cambridge University Press, Cambridge

[12] IPCC, 2007, *Contributions of working Group III to the fourth Assessment Report of the Intergovernmental Panel on Climate Change*, Metz, B., Davitson, O.R. P.R. Bosch, R. Dave, L.A. Meyer (Eds.). Cambridge University Press, Cambridge, United Kingdom

[13] Linder, K.P., 1990, *National Impacts of Climate Change on Electric Utilities, In: The Potential Effects of Global Climate Change on the United States*, Smith, J.B and D.A. Tirpak, (Eds.). New York: Hemisphere Publishing Corporation, pp: 579-596

[14] Lozan, J.L., P. Hupder and H. Grabi, 2000. Climate of the 21st Century University of Hamburg, Hamburg

[15] Moreno, R.A. and J. Skea, 1996, *Industry, Energy and Transportation: In: Climate Change 1995: The Science of Climate Change, IPCC Impacts and Adaptation*, Houghton, J.T., L.G. Meira, B.A. Callander, N. Harris and A. Katternberg et al., (Eds.)., Cambridge, Cambridge University Press, pp: 365-398

[16] Oladosu, G.A. and A.O. Adegbulugbe, 1994, *Nigeria's Household Energy Sector: Issues and Supply/Demand Fronties. Energy Policy*, 22: 538-549

[17] Pearson, P.J.G. and R. Fouquet, 1996, *Energy Efficiency, Economic Efficiency and Future Co2 Emissions from the Developing World*, Energy J., 7: 135-159

[18] UNFCCC, 2002, Available from: http://unfccc.int