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# **Study on Perspectives of Energy Production Systems and Climate Change Risks in Nigeria**

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Additional information is available at the end of the chapter

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## **1. Introduction**

In recent times, energy has been the hottest globally discussed subject. On the other hand, environment is the most resilient victim of the energy debate. Consequently, energy and environment are the world's most unlikely allies. Energy extraction, distribution or consumption constitutes a major cause of environmental pollution. The environmental pollutants from energy related activities are greenhouse gases. Although, cement manufacturing, construction or transportation activities do contribute to environmental pollution, the greenhouse gas emission from energy activities is two-fold: the emission from exploration and that from consumption. The combustion of energy fuels generate nitrogen oxides- a group of highly reactive and acidifying gases unlike suspended particles produced from cement manufacturing. In a photochemical process, nitrogen oxides are oxidized to nitric acid and it contributes to acid rain formation. Also, there is a consensus that fossil fuel based energy production and use are the main sources of carbon dioxide and other greenhouse gas emissions as shown in figure 1. These substances have many consequences for the health of human being, plants and estate property [1, 2]. The foregoing facts present energy production and utilization as high risk factors to the environment despite their huge benefits to the society.

The generic factors that cause the emissions are classified in two ways: anthropogenic and natural occurrences. The main anthropogenic contributors are identified as follows:

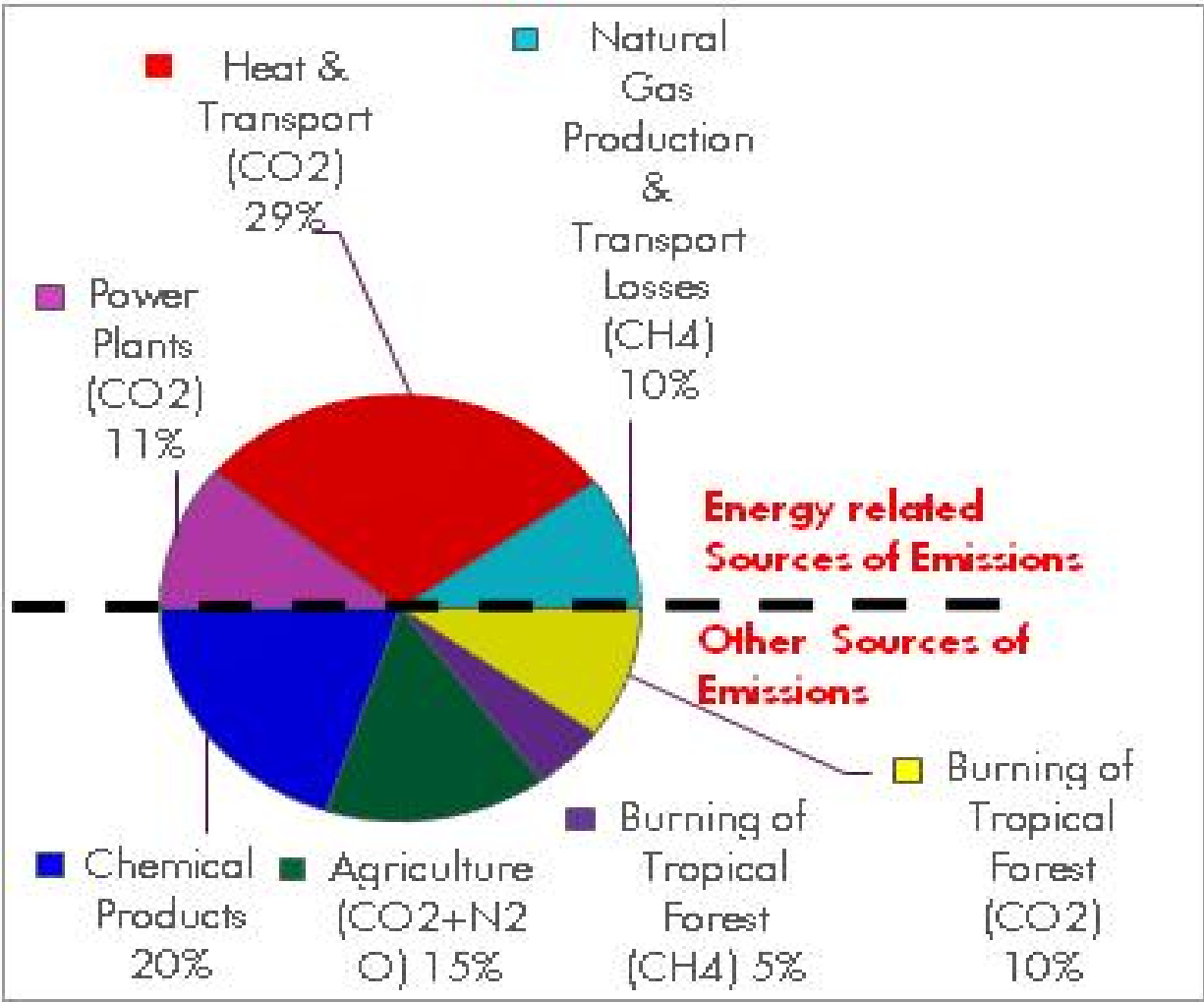
- carbon emissions from industrial processes
- agriculture (methane emissions from livestock and manure, and nitrous oxide emissions from chemical fertilisers)
- carbon emissions from transport (driving a car, air travel)
- use of fuel to generate energy (excluding transport)
- energy use in the home (the main use is heating)

- deforestation

On the other hand, the natural contributors to greenhouse gas emission are:

- Volcanic eruptions
- Ocean current
- Earth orbital changes
- Solar variability
- Tectonic processes

The CO<sub>2</sub> emissions have through a complex relationship formed with other anthropogenic gases reduced the capacity of the atmosphere to filter out the sun's harmful ultraviolet radiations, thus causing climate change [3].



**Figure 1.** Major sources of the greenhouse gases.

Given the aforementioned causative factors, understanding the complex climate change, its concept or solution requires a trans-disciplinarity interpretation. Trans-disciplinarity, is the principle of integrating forms of research comprising a family of methods for relating scientific knowledge and extra-scientific experience and practice in problem-solving. It is a

form of joint problem solving among science, technology and society [4]. The United Nations Framework Convention on Climate Change (UNFCCC) 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 [5]. Different authors have attempted to define climate change according to varied disciplines to reflect region or country-specific effects.

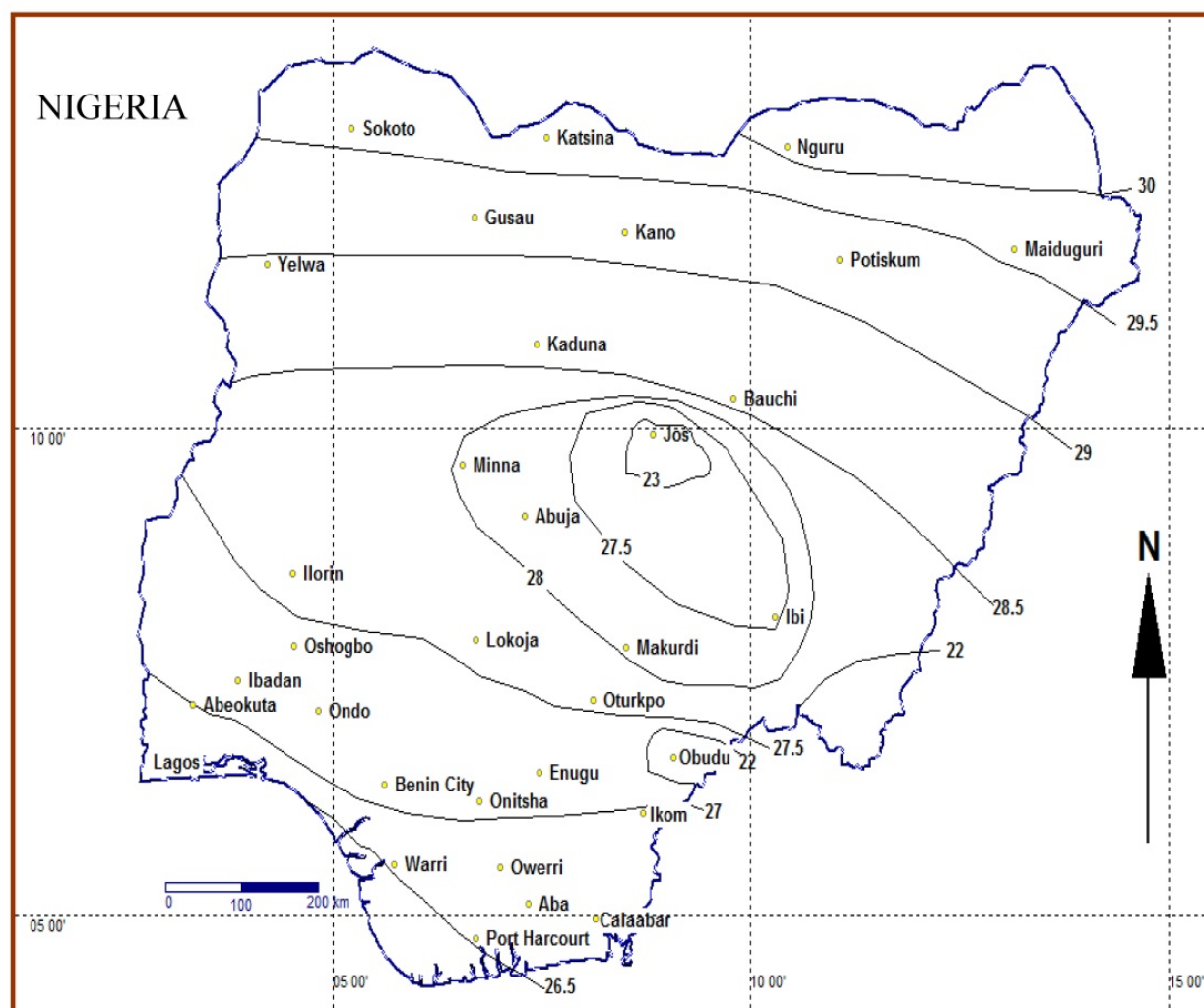
However, the common denominator of the definitions is that climate change is an extreme effect of climatic conditions triggered off by certain actions that are either naturally occurring or having human origin. Though, climate change is a global phenomenon, country-specific effects or adversities vary over time. The impacts vary by type of causative agent and geographical location of the vulnerable country.

Developing countries like Nigeria constitute the major hotspots of the climate change. Their fast growing population, crude agricultural practices (for nitrous oxide source), spiralling energy demand and lack of care for the environment are responsible for the peculiar situation. Definitely there are implications of these to energy producing and exporting countries like Nigeria, where there are multiple sources of emissions of greenhouse gases. According to Iloeje [6], Nigeria's energy reserves constitute both an opportunity and a risk. The former relates to benefits such as huge revenue generation while the later is associated with the burden on the ecosystem such as climate change.

This study focuses on Nigeria because of rising evidences and claims about prolonged changes in the climatic conditions. Various studies have identified impacts on the environment that are linked to climate change and are mostly caused by anthropogenic factors [7, 8]. Specifically, Nworah [9] has shown evidence of climate change impacts on the environment due to increase fossil energy production and consumption in Nigeria. Also, in the energy sector gas flare is a major contributor to the air pollution [10], which results in climate change. Figures 2, 3, and 4 showed evidence of ambient temperature rise in the last 100 years in Nigeria. Therefore, climate change poses great risks to health, built-up environment and social well-being.

However, the above studies have not done significant work on the adaptation and mitigation strategies to curb the effects of climate change. Developing high capacity for climate change adaptation and CO<sub>2</sub> emissions mitigation strategies is a necessity and priceless tool to overcome lasting effects of the change. Dearth of these strategies has been observed more in developing countries, such as Nigeria, than the developed countries. It is for the aforementioned reason that developing countries are highly vulnerable to climate change hazards. Getting sustainable solutions for these hazardous impacts is the motivation of this study.

The premium objective of the study is to identify policy and technological innovations and best practices required to advance climate change resilience for the environment as well as to promote low carbon development in Nigeria. It is believed that by domesticating adaptation strategies Nigeria will be well of it.



Source: [11]

**Figure 2.** Spatial pattern of air temperature rise in Nigeria (1901 – 1935)

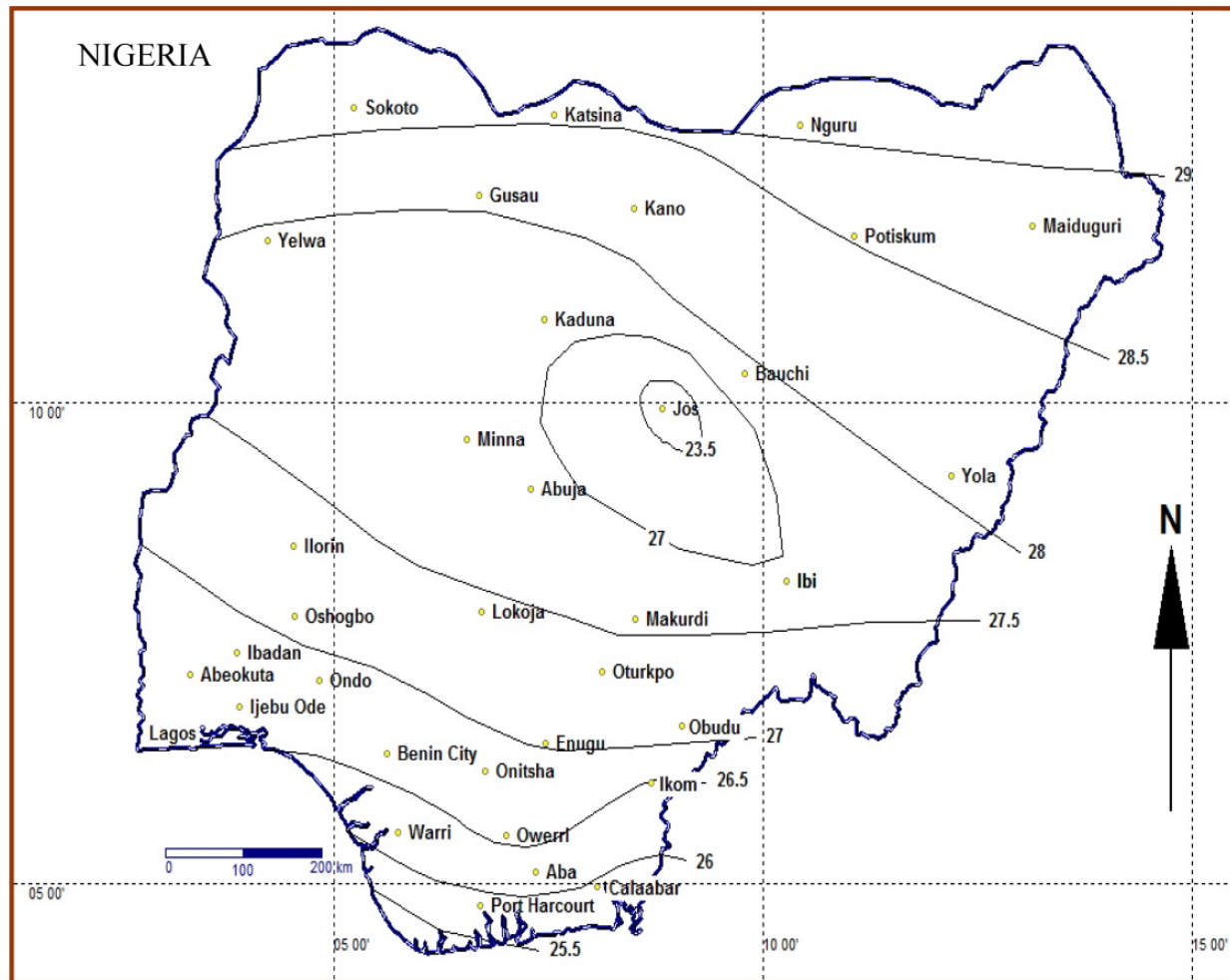
## 2. An overview of the Nigerian energy production system in relation to climate change

The choice of Nigeria for this study is on account of the following:

Population (2006 census): 140 million (there is one Nigerian in every three Africans)

Size: 923,770 square kilometres (With density of 152 person per square kilometre climate change problem could be worse than first thought)

Location: Lies between latitudes 4° and 14° N and longitudes 3° and 15° E. The location is characterised by a variety of climatic regimes such as tropical rainforest along the coasts, humid and Sahel regions in the south and north, respectively.



Source: [11]

**Figure 3.** Spatial pattern of air temperature rise in Nigeria (1936 – 1970).

Coastal risks: one –third of the 36 states – Lagos, Rivers, Ogun, Cross River, Bayelsa, Akwa Ibom, Abia, Imo, Ondo, Delta and Edo live within 10 to 80 Km of the Atlantic Ocean, a low lying region and are at risk from increased storm intensity and flooding.

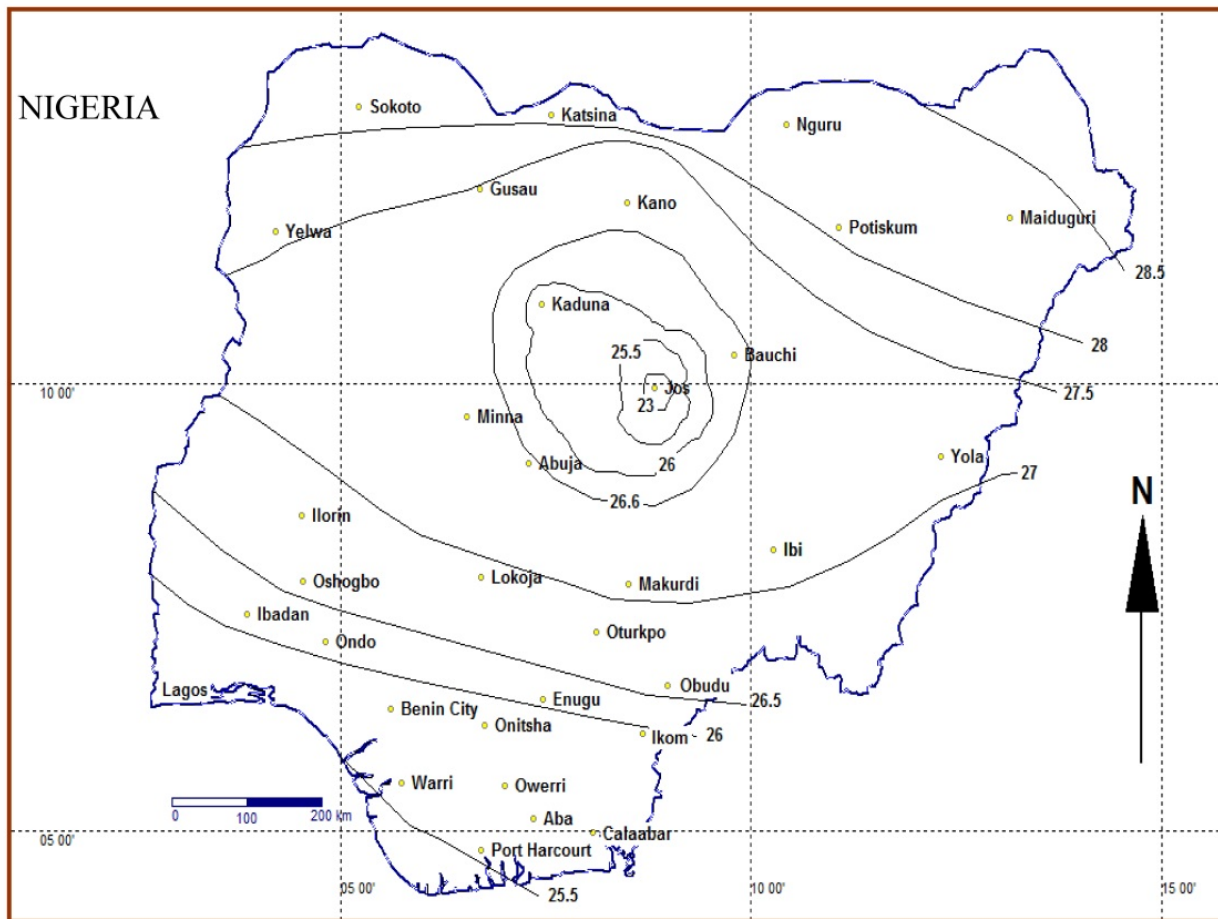
Fossil reserves: 5.1 MMtcm ( $10^6$  Trillion  $m^3$ ) of proven natural gas, oil

Total energy consumption (2002E): 275 billion kWh (0.2 % world total energy consumption)

Fuel share of energy consumption: Oil (58%), Natural gas (34%), Hydroelectric (7.9%), Coal (0.1%).

Energy related carbon dioxide emissions (2002E): 91.94 million metric tons (0.4% of world record).





Source:[11]

**Figure 4.** Ambient temperature rise in Nigeria (1971- 2005)

Per capita energy consumption (2002E): 1,964.3 kWh (vs U.S. value of 99,356.3 kWh)

Per capita CO<sub>2</sub> emissions (2002E): 0.8 metric tons (vs U. S. value of 19.97 metric tons)

Energy intensity (2002E): 2.712 kWh/\$ nominal-PPP (vs U. S. value of 2.738 kWh /\$ Nom.-PPP) [12].

Emissions in 1998 from (million metric tons): Solid fuels (172), liquid (25,410), gaseous (11,325), gas flaring (40,203) cement (1,345)

Carbon dioxide emission due to gas flaring: 3.3456kg of carbon dioxide per kWh per capita (relative to Nigerian population). The CO<sub>2</sub> emissions from energy sector are expected to grow by 2.2 % annually [13].

Thus, from the foregoing climatic characteristics and energy consumption mix in Nigeria, it is evident that the major generic causes of climate change are energy related activities.

### 3. Current status of Climate Change Convention in Nigeria

Nigeria submitted her first national communication under the United Nations Framework Convention on Climate Change (UNFCCC) in November 2003. The bold step to reduce hazardous emissions also set out / indicated the options/alternative for reducing emissions in the energy sector. These alternatives include:

- a. Energy use efficiency improvement options in the industrial , residential and commercial sectors
- b. Increased use of renewable resources, by introducing small scale hydropower plants and solar-electric options
- c. Supply-side options, especially rehabilitation of some existing oil refineries and power plants, and the introduction of newer combined-cycle technologies and cogeneration at industrial and rural areas
- d. Increased domestic use of associated natural gas to reduce gas flaring

Much of these lofty pathways to emission reduction are yet to be objectively implemented. Under the current status climate change problem in Nigeria could be worse than first thought. This implies that strong legislative enactment should be in place to regulate whatever adaptation policies being adopted.

#### 3.1. Climate change risks of energy production and emissions inventory

Energy production and consumption is known to be associated with some hazards to the ecosystem. The hazardous effects results in environmental degradation. The consequences, which are more prominent in the destruction of surrounding vegetation and marine life, could cause enormous devastation of the surrounding environment generally. For example, in Nigeria, the impact of oil operations on the environment has produced a technological shock of unexpected dimensions [ 14].

The climate change risks associated with energy exploration and exploitation activities can be categorized according to stages involved in the energy activities. These stages are encountered during discovery, harnessing, processing, storage, transportation and final utilization of energy. With adequate knowledge of the risks through the aforementioned stages then the deleterious effects can be grouped as follows:

Harm to living organisms,  
Hazard to human health,  
Hindrance to marine lives,  
Impairment to water and air qualities through pollution, and  
Impairment to profitable agricultural production, etc.

Figure 5 shows pictorially climate risks associated with energy extraction and use as expressed in a climate change tree.

These risks are not one time events, but are likely to increase in frequency and intensity. Hence, adaptation mechanisms are needed for their resilience by beneficiaries.



However, effective emission inventory is critical to cost-effective adaptation strategy. The purpose of an emission inventory is to locate the air pollution sources for a given location and to define the types and magnitude of pollutants that these sources are likely to produce. It projects pollutants and their frequency, duration and relative contribution from each source. Thus, climate change adaptation and carbon dioxide emissions mitigation can significantly be achieved if pollutant inventory level is known with certainty.

#### **4. Strategies for curbing climate change risks**

In Nigeria, increase in the total energy production and consumption and the resulting impact of climate change will continue for a long time, because of the following:

- Energy resources keep the economy running
- 90 % of government revenue is derived from energy royalty
- Substitute for transport, heavy industrial and domestic energy needs with renewable is implausible in the distant future.

The strategies available to Nigeria are to develop trans-disciplinarity skills to adapt to climate change consequences. That is, a form of collaborative problem solving expertise involving science, technology and society (the ultimate beneficiary) in varying priorities as bulwark against climatic changes. The above necessitates the promotion of adaptation strategy as a trade-in strategy to balance climate change effects. Since the forcing agents of the change are expected to continue for reasons of more energy and human activities, domesticating the strategies through a combination of policy changes, technology innovations and best practices are necessary steps.

##### **4.1. Policy, technology innovations, and best practices for climate change adaptation**

The world cannot reverse climate change. The effects will continue for a long time. What ought to be done in the light of prevailing mindset on consequences of climate change is how to live with the changes. Thus, living with climate change implies that adaptation strategies are of utmost importance, in the short-run, though mitigation measures also are important for long term solutions and should be widely promoted. Let us examine, in this paper, innovative climate friendly policies and technologies for advancing of climate resilience and low-carbon development in Nigeria.

The climate friendly policies and technologies are broadly classified into educational policy and energy technology policy. On the energy policy strategy the highlights include:

- Cogeneration ( cost-effective waste energy utilization)
- Energy planning and management (developing low ambient energy; promoting less dependence on fossil fuels, nanotechnology, photovoltaics, forestry ).

The key points on focus for the educational strategies include:

- Capacity building (unifying the knowledge of the problem with sustainable solutions)
- Curriculum revision to incorporate learning of climate change (express in content the problem, learning objectives and feasible outcomes).

## 4.2. Energy technology policy

### 4.2.1. Waste energy utilization - Cogeneration

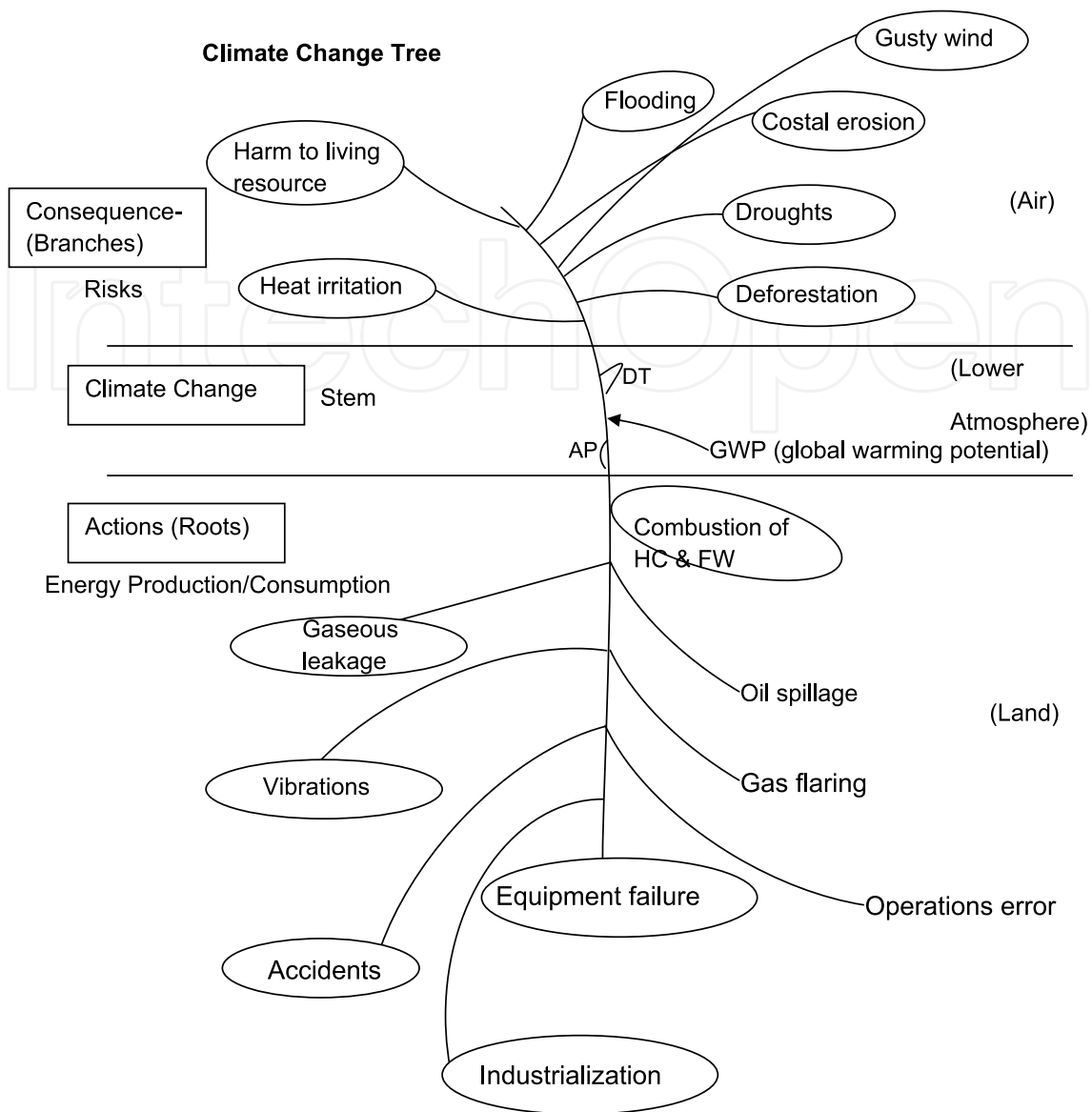
The key societal needs linked to energy utilization include:

- Residential and commercial buildings
- Air-conditioning and refrigeration
- Automotive propulsion
- Cement manufacturing
- Steel production
- Agriculture, fertilizer and processing
- Energy exploration and gas flaring
- Power generation

In these tasks, there are currently enormous energy wastes and opportunities for improvement. The wastes can be reduced, recycled and reused (3R) in further utility applications. For example, the on-going power sector reforms in Nigeria provide an opportunity to transform the sector in two ways: integration of cogeneration in the existing structure and scale-up renewable energy usage in the energy mix. What are the benefits and cost implications of the suggested transformation methods? These are common questions posed by sceptics of the aforementioned reform process.

Integrating cogeneration technology can achieve savings in cost monetarily and environmentally [15]. For now, we focus on the environmental savings. The choice of cogeneration technology is also influenced by its compatibility with available energy infrastructure in Nigeria [16].

The cogeneration concept describes the production of both electricity and thermal energy from same facility. In cogeneration, also called combined heat and power (CHP), the energy in the combusted fuel is used twice. The advantage of CHP results from capturing the waste heat created in the process of producing electric or thermal energy traditionally exhausted through the stack [17]. The secondary advantage of cogeneration is less fuel consumption that translates to less polluting of the environment. High level consumption of fossil fuels is responsible for greenhouse gas emissions that cause global warming. Reduced emission of greenhouse gases (nitrous oxide, carbon dioxide, methane, and water vapour) is possible with cogeneration technology. Taking full advantage of these potentials would lead to better economy of resources and friendly environment. Some characteristics of prime movers used for the cogeneration system as reported by Wu and Wang [18] are shown in table 1. However, application of cogeneration in Nigeria has ethical limitations.



Keys: AP = acidification potential; DT = differential temperature; HC = hydrocarbon; FW= fuelwood.

**Figure 5.** Climate change tree illustrating the risks associated with energy production

In Nigeria, there is acute shortage of generated grid electricity. Under the circumstance, it is difficult to operate cogeneration effectively without a reliable supply end. Secondly, self-autogeneration is the second best option that is relied upon to supply energy to all facets of activity due to unreliable grid system. Operating cogeneration under this situation is counter productive. Self-autogeneration is known for its high emission of GHGs more than the grid system. Nevertheless, these are ethical and management issues (sabotage, lack of integrity, poverty related) and there are rooms for improvement [10].

#### 4.2.2. Renewable energy and alternative fuels sources

These energy resources offer environmental benefits ranging from low carbon and sulphur emissions to non-emissions of greenhouse gases. The renewable solutions include wind

	Steam turbine	Spark ignition engines	Gas turbines	Micro-turbines	Stirling engines	Fuel cells
Capacity range	50kW–500MW	3kW – 6MW	250kW – 50MW	15kW – 300kW	1kW – 1.5MW	5kW – 2MW
Fuel used	Any	Gas, biogas, liquid fuels, propane	Gas, propane, distillate oils, biogas	Gas, propane, distillate oils, biogas	Any (gas, alcohol, butane, biogas)	Hydrogen and fuels containing hydrocarbons
Efficiency electrical (%)	7 – 40	25 – 43	25 – 42	15 – 30	~40	37 – 60
Efficiency overall (%)	60 – 80	70 – 92	65 – 87	60 – 85	65 – 85	85 – 90
Power to heat ratio	0.1– 0.5	0.5 – 0.7	0.2 – 0.8	1.2 – 1.7	1.2 – 1.7	0.8 – 1.1
CO <sub>2</sub> emissions (kg/MWh)	c	500 – 620	580 – 680	720	672 <sup>d</sup>	430 – 490
NO <sub>x</sub> emissions (kg/MWh)	c	0.2 – 1.0	0.3 – 0.5	0.1	0.23 <sup>d</sup>	0.005 – 0.01
Availability (%)	90 – 95	95	96 – 98	98	N/A	90 – 95
Part load Performance	Poor	Good	Fair	Fair	Good	Good
Life cycle (year)	25 – 35	20	20	10	10	10 – 20
Average cost Investment (\$/kW)	1000 – 2000	800 – 1600	450 – 950	900 – 1500	1300 – 2000	2500 – 3500
Operating and Maintenances cost (\$/kWh)	0.004	0.0075–0.015	0.0045 – 0.0105	0.01 – 0.02	N/A	0.007 – 0.05

**Table 1.** Characteristics and parameters of prime movers used in cogeneration system

energy, solar energy, geothermal systems, nuclear energy and biofuel / biomass. These sources have the capability to renew themselves, although the nuclear option is usually marred by public outcry as a result of the use of plutonium-239 in fast breeders. In biomass, fuelwood consumption is an aberration in standard energy mix due to poverty and deficient in conventional energy infrastructure. Fuelwood problem is solvable.

The alternative fuels such as biofuels are categorized as follows:

- First-generation biofuel (edible plants materials)
- Second-generation biofuels (non-edible plant materials)
- Third-generation biofuel (algae)

The use of biofuels does not contribute to global warming, as the CO<sub>2</sub> they release when burnt is equal to the amount that the plants absorb out of the atmosphere [19]. Why we

cannot depend so much on renewable energies for climate change adaptation is because the technology is alien to most vulnerable developing countries. Their initial cost of acquisition is prohibitive.

#### *4.2.3. Calculating greenhouse gas emission impacts*

To calculate the value of CO<sub>2</sub> and other greenhouse gas emissions reduction achieved by renewable and alternative energy, the information on the amount of kWh or MWh produced is required for a given utility. Each energy utility is required to produce specific grams of greenhouse gases while delivering 1 kWh at given conditions of operation. To associate the calculated value with renewable system, we make assumption that it would emit an equivalent amount for 1 kWh generation.

A general guideline in the assumption is to use as much local data as is possible. The data maybe observed or derived from literature. The following things are important in greenhouse estimation:

- to calculate greenhouse gas emissions for assigned lifetimes of facility or project
- to convert greenhouse gas impacts to metric tons of carbon dioxide equivalent
- to obtain carbon dioxide equivalent intensity of fuel or energy under consideration
- to treat carbon dioxide equivalent reductions as cumulative reduction

The above mentioned guide will help to accurately estimate the amount of emission reductions generated from energy project.

### **4.3. Changes proposed in educational policies**

#### *4.3.1. Institutional curriculum review to fit in climate change knowledge*

Revision of curricula of studies at all levels for inclusion of climate change adaptation is a necessity in developing countries. Curriculum can be defined as a document, plan or blue print for instructional guide used for teaching and learning to bring about positive and desirable learner behaviour change [20]. In this context, it is an institutional policy tool for bringing about or directing a desired change in a learning activity. The levels of the institution where the curricula changes are expected include primary, secondary and the tertiary with varying degree of climate science knowledge.

The process of integration involves the following approaches:

- Situational analysis (using questionnaire, interview techniques)
- Formulation of objectives (philosophy/rationale/motivation)
- Identification of resources(human, materials, intangible)
- Organization of the curriculum (sequence, scope)
- Evaluation of outcome(statistical, pictorial, reporting) [21]

Climate change integration into curricula of studies is critical to raising awareness and getting human reactions about the changing in weather conditions. This is a boost because lack of awareness is the main obstacle to vulnerability to climate change effects.

#### 4.3.2. *Capacity building in climate change*

There is increasingly difficulty to get talents in developing countries that understand and can interpret the science of climate variability. Climate change science is a complex phenomenon. The ability to understand and effectively communicate potential future climate scenario to decision makers are thus critical success factors for adaptation strategies [21]. This capacity resides with human resources. It is impossible to adapt to climate change without linking the process up with people who take the decision that impairs or makes the environment.

Before getting ready to train the required capability, human resource audit should be conducted in the critical areas of need. The audit will look at a variety of human resource management functions: staffing, training, appraisal and development, and overall effectiveness [22]. Essentially, it will help to identify local content of manpower requirements for capacity building process and domestication of those competencies.

To train people for climate change adaptation is critical to the success of the campaign on environmental sustainability with climate change. Although the training should be goal-driven, the output is largely determined by the input of the trainee. Awareness and educational capacity reflect on the expected input of the trainee. Therefore, he should be exposed to challenges and allowed a robust level of latitude to contribute towards dealing with the problems. The robustness makes for creativity. However, the capacity building approach to climate change adaptation has a long gestation period as a setback.

Yet legislation alone cannot offer all the solutions of climate change adaptation. There is need to focus on the attitude and commitment of people who operate the policies. The future challenge for the educational and energy technology policies perhaps is implementation. The more the implementation is devoid of corrupt tendency the farther the project of advancing climate change resilience will be on its road to success.

To attain best practices in this policy changes:

- complete plan for data collection must be defined before the collection process is began
- integrity of the strategies should be guaranteed through transparency
- capacity building should not end with tackling climate change, but should open up windows of opportunities for job creation
- energy policy strategy should promote energy efficiency
- in-situ use and compression of gas are adequate for managing gas flaring
- massive tree planting programme

With these practices and full implementation of the suggested policies low-carbon development is guaranteed in Nigeria.

## 5. Conclusion

The study presents the climate change risks associated with energy production and utilization as well as the possibility of achieving low carbon development in Nigeria. It also



describes that the climate change is a global phenomenon, but the adversity of its impacts depends on the types of causative agents and geographical locations of the beneficiary. Thus, following conclusions are drawn:

The major generic causes of climate change are energy related activities as energy consumption in Nigeria are found with mix ratio of 58 % oil, 34 % natural gas, 8% hydroelectricity, where in production 50% natural gas is flared.

The potent climate forcing agents are found from greenhouse gas emissions ( such as:  $\text{CO}_2$ ,  $\text{CO}$ ,  $\text{SO}_2$ ,  $\text{CH}_4$ , and  $\text{NO}_x$  ) and is from energy related resources.

The proposed changes in educational policies and application of cogeneration are found cost effective. If climate change adaptation strategies coupled with technological innovation, it will promote low-carbon development in Nigeria.

The best measures practices for realization of low carbon society are proposed to be adopted such as: transparency, capacity building and economic empowerment opportunities in energy sector.

The study also recommends that some ethical challenges are to be identified which affect the success in the framework of suggested policy e.g., sabotage and lack of integrity in policy implementation.

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