



ASSESSING THE IMPACT OF CLIMATE CHANGE ON RENEWABLE ENERGY SYSTEMS IN NIGERIA: A REVIEW

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ABSTRACT

Climate change poses significant environmental challenges, particularly in Nigeria, where the economy heavily relies on fossil fuels. This dependency has led to adverse effects, including increased wildfires, droughts, health impacts, and coastal flooding. The alteration in climate patterns is primarily attributed to both natural phenomena and human activities that change atmospheric compositions. The paper discusses the potential of renewable energy sources as a critical solution to mitigate climate change impacts. It reviews current energy sources in Nigeria and highlights the urgent need to transition towards renewable energy to reduce environmental harm and enhance energy security for sustainable development.

Keywords: Climate Change, Renewable Energy, Fossil Fuels

INTRODUCTION

Energy is an essential ingredient or tool for socioeconomic development and an index of prosperity in any nation (Akuru & Animalu, 2019). It is one of the basic requirements of human society and vital for human life and for technological advancement. In general, energy can contribute to widening opportunities and empower people to exercise choices. The place of energy and power in the sustenance of economic activities, and their contribution to the standard of living cannot be overemphasized for any nation. As a result, the demand for energy today is far greater than ever in our highly technological world.

In Nigeria, energy is the mainstay of growth and development because it serves as a tradable commodity for earning the national income, which is used to support government development programs (Sambo, 2022). Due to population growth, inevitable industrialization, more agricultural production and improving living standards, Nigeria needs more energy to meet the rising demand. It also serves as an input into the production of goods and services in the nation's industry, transport, agriculture, health and education sectors, as well as an instrument for politics, security and diplomacy. The energy chain to deliver these cited services begins with the collection or extraction of primary energy, which is then converted into energy carriers suitable for various end-uses (Patel, 2021).

There is the case that not everything, everything that happens is due to human intervention, while what does happen is destiny from the almighty, the almighty maker and the source of all our lives in this world. As in the topic of discussion this time, namely about climate change, in which long-term climate change is one of the big issues in environmental issues. If we look ahead to what is happening in our environment, both from the weather and temperature or the water we use and experience changes over a long period of time. These transformations, resulting in adverse effects on terrestrial organisms, encompass heightened temperatures, prolonged droughts, and escalated insect infestations, all of which are intricately linked to climate change and have led to an upsurge in wildfires (Akuru, & Okoro, 2020).

Additionally, diminishing water reservoirs, diminished agricultural outputs, urban health ramifications attributed to heatwaves, and amplified occurrences of flooding and coastal erosion serve as further areas of concern. Nonetheless, amidst these challenges, renewable energy stands out as a potential mitigator against the direst consequences of climate change. Renewable energy sources, including wind, solar, biomass, biogas, geothermal, hydroelectric, and various marine-based energy forms such as offshore wind, wave, and tidal energy, offer promise in alleviating the impacts of climate change (Chindo, & Nyelong, 2025).

However, it's worth noting that climate change also exerts an influence on the viability of these renewable energy sources. The positive impacts of clean energy, spanning wind, solar, geothermal, hydroelectric, and biomass sources, are manifold. In a recent study featured in Nature Climate Change, researchers have sought to quantify the effects of global warming on the availability of eight key renewable energy technologies (Darmstadter, 2024). The team did not present a very surprising result, and that is actually good news. The role of renewable energy in climate change is very influential and has many impacts, not only for the environment but also for living things. It does not erase all the negative impacts that occur as a result of this long-term climate change, but renewable energy aims to be able to reduce the impact of climate change that occurs on this earth. Because, with this renewable energy, the environment will have a chance to begin to heal.

Renewable energy also has the aim of repairing environmental damage caused by this long-term climate change. Renewable energy has a positive impact, some of which are reducing global warming emissions, where we know these gases act like a hot cloth that covers the earth and confines the earth to that hot temperature for a long time. So, with that, this is where the role of renewable energy is to reduce the heat that surrounds the earth for a long time which over time has damaged the earth, both the environment on earth and living things (IPCC, 2020).

The following questions have been developed to guide the process of this research:

- i. To what extent are fossil fuels being used in energy production and associated activities in Nigeria?
- ii. What are the indices used to measure the impact of climate change and to what extent has/could it affect Nigeria?
- iii. What proactive measure(s) need to be taken to address the possibility of a negative impact assessment?

Conceptual Clarification

The impacts of climate change in Nigeria in the coming years are expected to result from global changes in climate. This change will in turn be based on increases in the concentrations of the greenhouse gases including carbon dioxide, methane and nitrous oxide. Increasing concentrations of greenhouse gases in the atmosphere enhances the potential of the atmosphere to conserve heat and therefore bring about global warming (EIA, 2021). Thus, increases in the concentrations of the major greenhouse gas emissions within the country is a function of the emissions of these gases and will depend, in the main, on increases in the consumption of fossil fuels, among other factors. In other words, expected global climate change will depend basically on global population increases, global energy consumption, and global changes in land use pattern (Nigeria's First National Communication, 2023). Rich-income countries can be blamed elaborately for greenhouse gas emissions but not exclusively. This is because even if drastic efforts are made by the developed world to reduce greenhouse gas pollution, there is even a greater risk that greenhouse gas emissions in the developing world if unabated, would translate into worsening rates, caused by rapid industrial growth, in a not distant future (Odjugo, 2020). In an earlier paper (Akuru and Okoro, 2020), the statistics of energy and its contribution to Nigeria's GDP have been set forth, though these values could increase if over 90% of energy used by rural dwellers is accounted for. Currently a high proportion of Nigeria's total energy output is generated from fossil fuels such as oil and coal. In general, the quest for an option to conventional power schemes for extension to remote and rural locations of developing countries like Nigeria arises from the high costs associated with the extensions, as well as the maintenance, of the power grid system to rural areas. This has led to a considerable interest in the development and application of renewable energy resources. Interest in renewable energy has traditionally grown from the need to expand energy resources to reach remote and rural locations. However, the use of conventional

sources and fuelwood to generate energy has continued to generate dire environmental consequences. Renewable energy is that form of energy obtained from sources that are essentially inexhaustible, unlimited and rapidly replenished or naturally renewable such as wind, water, sun, wave, refuse, bio-fuels etc. Nigeria is endowed with sufficient renewable energy resources to meet its present and future development requirements as well as complement its current oil-dependent economy (Akuru and Okoro, 2020; Nigeria's First National Communication, 2023).

Greenhouse gas (GHG) emissions are produced when fossil fuels are produced and consumed and these emissions contribute to climate change. Climate change is caused by two basic factors (Odjugo, 2020), which include natural processes (biogeographical) and human activities (anthropogenic) summarized in Figure 1. 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 Nigeria's First National Communication, 2023). It is well established that the activities of developed nations are mostly accountable for climate change, but developing nations are those suffering more due to inability to cope as a result of poverty and low technological development (Odjugo, 2020).

Several studies have focused on climatic impacts in Nigeria and the results are appalling (Odjugo, 2020; Odjugo, 2021; Chindo and Nyelong, 2025; Adefolalu et al., 2017). Other independent studies have linked climate change with the economy (Yahaya et al., 2021) and global warming) of Nigeria (Odjugo, 2021). The spillover effects of climate changes are increasing temperature (global warming), sea level rise leading to population displacement as well as land disputes, draught and desertification, unpredictable rainfall with negative impacts on agriculture, human health problems, etc. On the other hand, the visible effects of climate change have resulted in setting up measures to address it. Such mitigation options include emission cuts, reduction in water pollution, afforestation and sustainable energy investments (Odjugo, 2020; Odjugo, 2021). Based on the comparative impacts of climate change at regional levels, this paper is an attempt to review the dire consequences of Nigeria's over-dependence on fossil fuel-based energy resources and its impact on climate change and propose a viable alternative into its energy mix.

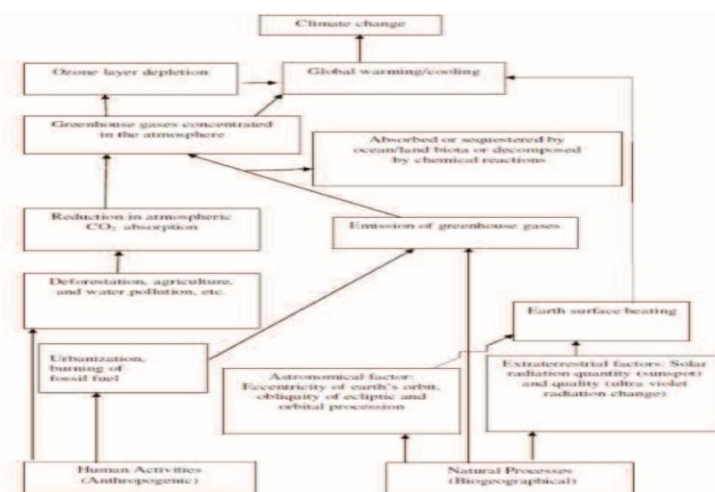


Figure 1: Causal Factors of Climate Change

Source: (Odjugo, (2020)

Renewable Energy

Renewable energy refers to energy derived from naturally replenishing sources, which include; sunlight, wind, the movement of water, and geothermal heat, renewable energy sources as seen as green, abundantly free, and with very little or no harmful effects on environment either from their usage or their process of production (Moya et al., 2018). Hence its importance in energy security and climate change mitigation. Renewable energy provides varieties of energy such as on-grid and off-grid electricity generation, air and water heating/cooling for various applications. It constitutes about 30% of global energy consumption with the projection of contributing more than 35% in 2025 (World Energy Council, 2023). With respect to the scope of this paper, the focus on renewable energy source with significant potentials in Nigeria.

Climate Change

Climate change is referred to as a long-term change in the average weather conditions including changes in temperature, rainfall, sea-level, and windiness. According to (Treat, 2025), climate change refers to the mean variability of temperature, precipitation and wind over a period of time, ranging from months to millions of years. Union of Concerned Scientist (2017) defined climate change as “a change of climate which is attributed directly or indirectly to human (anthropogenic) activity, leading to alterations in the composition of the global atmosphere which is in addition to natural climate variability observed over comparable time periods”.

The natural variability results from changes in the sun’s activity or large-scale volcanic eruption. The anthropogenic induced variability is generally due to burning of fossil fuels such as coal, oil, and gas which are major cause of greenhouse gas emission into the atmosphere. Quest for more energy to drive industrialization and urbanization is largely responsible for greenhouse gas emission with consequent impact on the atmosphere including rise in earth surface temperature (Krutakov, 2021).

According to United Nations, the average temperature of the earth surface is now about 1.10C warmer than it was in the

late 1800s before the industrial revolution, and warmer than any time in the last 100,000 years. The effects of climate change are felt in different ways including health, food production, heat waves, housing, and safety (on transport, at home and at work), with different severity of vulnerability especially among the people living in flood prone areas of developing countries such as along River Niger in Nigeria. Issues relating to climate change form one of the major reasons for increasing global support and adoption of renewable energy to achieve energy security (White, 2021).

MATERIALS AND METHODS

The methodology adopted here, though qualitative, relies heavily on secondary data consisting mainly of existing records and documentation in various forms including data both from the energy sector in Nigeria and the National Population Commission and other sources relevant to the study. The general approach was to reuse mostly the results of the available data that have been previously published and model them to suit the objectives of this research. The various data sets were then analysed and the results interpreted and resolved into presentable formats using tables, charts and graphs.

Data Collection

The rate of population growth in Nigeria is summarized in Figure 2. Energy Consumption by Source is the total amount of primary energy consumed from the usage of a specified fuel. Primary energy includes losses from transportation, friction, heat loss and other inefficiencies. Specifically, consumption equals indigenous production plus imports and stock changes, minus exports and international marine bunkers; the IEA calls this value Total Primary Energy Supply (TPES) (Wu et al., 2017). Table 1 provides details for the distribution of energy source and the amount consumed in metric tons equivalent of oil in Nigeria. All energy consumption values presented here are calculated and reported by the International Energy Agency (IEA) based on an energy balance methodology using metric tons of oil equivalent (toe) (Yoshino, et al., 2017).

Table 1: Nigeria’s Energy Consumption by Source, 1999 (in 1000 Metric Tons Oil Equivalent)

Source	Consumption Rate
Total fossil fuels	14,410
Coal and coal products	37
Crude oil and natural gas liquids	9,349
Natural gas	5,261
Nuclear	0
Hydroelectric	486
Renewables, excluding hydroelectric	72,390
Primary solid biomass(includes fuel wood)	72390
Biogas and liquid biomass	0
Biogas and liquid biomass	0
Geothermal	0
Solar	0
Wind	0
Tide, wave and ocean	0

Source: Earth Trends Country Profile, (2025)

Table 2: Structure of Nigeria's GHG Emissions, (2025)

Sector	%
Energy	54.9
Industrial	0.5
Agricultural	38.7
Others	5.9

Source: World Resources Institute's Climate Analysis Indicators Tool (CAIT), 2025

Table 3: GHG Emissions for Nigeria by sector in 2015

Sector	MtCO ₂	%
Energy	126.7	28.6
Electricity & Heat	12.5	2.8
Manufacturing & Construction	4.1	0.9
Transportation	20.5	4.6
Other Fuel Combustion	17.5	4.0
Fugitive Emissions	72.1	16.3
Industrial Processes	1.5	0.3
Agriculture	101.5	22.9
Waste	15.4	3.5
Land-use Change and Forestry	194.8	44.0
International Bunkers	2.6	0.6
Total	442.6	

Source: World Resources Institute's Climate Analysis Indicators Tool (CAIT), 2025

Since greenhouse gas (GHG) emission lead to climate change, data on key indicators of GHG emissions in Nigeria are shown in Table 2 and a further breakdown of the components of the energy sector is provided in Table 3.

The total amount of GHG emissions for Nigeria is further broken into its three major gas types which include methane (CH₄), Carbon dioxide (CO₂) and Nitrous oxide (N₂O), with the emission profile showing CO₂ having 33% from the total emission as at 2005, second to N₂O with 50.8% (Nigeria and Climate Change Road to COP15; CO₂ which contributes to the bulk of emissions from the energy sector, based on fuel combustion and other related processes, is expected to increase as Nigeria becomes more industrialised at the rate of over 3 Mton per year (Muhammad & Goheer 2021). The key drivers of CO₂ emissions have been linked to population, economic activity and the CO₂ intensity of the economy (Nigeria and Climate Change Road to COP15). Table 4 is therefore extracted to account for these dependencies.

Research Findings and Analysis

The link between population and energy has been reported in two phases (Darmstadter, 2024). The first link relates to levels and changes in economic development approximated by income or gross domestic product (GDP) per capita. In this case, as income per capita rises, so does per capita energy use. The second link on the other hand, stresses that even at comparable levels of per capita GDP, the volume of energy use will differ among countries and regions, depending on the structural characteristics of the economy, spatial features, climate, fuel prices, government policies, and others. Normally, a country's growth rate is a factor in determining how the infrastructural needs of its people are produced and

consumed. To this end, the pattern on Figure. 1 shows that Nigeria's population has risen steadily from an estimated 2.1% in 1960s to about 3% in recent times. Though there was steady decline in the 1990s, the rate is still very high.

Quantifying the linkage between changes in population and energy consumption, three broad factors go into the determination of changes in total energy use. These items are expressed in Equation 1 as percentage changes (Darmstadter, 2024).

$$\text{Population} + \text{GDP per capita} + \text{Energy per unit of GDP} = \text{Energy} \quad (1)$$

Using the data presented in Table 5, the energy consumed in Nigeria for 2021 is approximately 17.56%. This result shows that there is an active relationship between growth in population and energy use. To extend the result in Table 5, the extent which energy is used can also tell on the environmental impact. An increase in energy use will mean that the threat from climate change and other environmental degradation, especially from a fossil-fuel based economy, will become aggravated.

Table 4 shows explicitly that CO₂ emissions in Nigeria have increased over the years based on the current trend. The information provided has been used in Figure 3 to forecast what the trend would be by the turn of this century. Nigeria has its economy to be largely crude-oil based and with a teeming population growing at an average of 2.7%, it is anticipated that in the coming years, CO₂ emissions will significantly increase. In considering CO₂ emissions from combustion only, 158.42 million Nigerians were responsible for emitting a total of 54.90 Mt of CO₂ as at 2024 (2024 Key World Energy Statistics).

Table 4: Key Nigerian Trends and Global Ranking (for all GHG Emissions)

	Rank*	Units	2000	2025	Av. annual growth
Total GHG emissions	26	Mt CO ₂ eq.	182.7	299.2	3.30 %
Total GHG emissions incl. LUCF (2000 data)	20	Mt CO ₂ eq.	330.4	442.6	3.00 %
Population	10	People 2000 Intl	9445 000	141356000	2.70 %
Income Per Capita	144	Dollars/cap	1464	1731	1.10 %

	Rank*	Units	2000	2025	Av. annual growth
GHG Intensity of Economy	21	Tons eq./Million Intl Dollars	CO ₂ 1322.00	1223.10	-0.50 %

* Rank out of 186 nations or groups of nations in terms of absolute value of 2005 data

Source: World Resources Institute’s Climate Analysis Indicators Tool (CAIT), (2024)

Table 5: Structure of Nigeria’s GHG Emissions, (2025)

Population	3.0 %
GDP per capita	7.58 %
GDP per unit energy use	6.98%

Source: Online

CO₂ emissions by sources and sector for Nigeria are summarised in Figures 4 and 5. This shows the country’s huge reliance on conventional energy sources as a large part of the country’s emissions emanate from gas flares, which results from burning of gases released in the process of petroleum extraction. Similarly, the sector with the greatest amount of emission is the transportation sector, largely operated on processed fossils fuels. The content of renewable energy deployment in Nigeria is abysmal. Renewable energy is available in abundant potentials however; integration into the energy mix has been sluggish and disproportionate. From Table 1, it is evident that renewable forms of energy practically do not add to the country’s energy mix despite the fact that Figure 4 reveals its zero emission characteristics.

RESULTS AND DISCUSSION

The research undertaken in this paper has revealed that Nigeria relies heavily on fossil fuel. About 40% of its national GDP, over 80% of government’s revenue and over 90% of Nigeria’s foreign earnings come from crude oil related activities (Nigeria and Climate Change: Road to COP15). This submission is premised upon certain indices such as population and economic development which have been highlighted with high possibility to affect the way energy is consumed.

In estimates, the gross emissions of GHGs have been documented as the internationally accepted common framework to report emission inventories of GHG emissions (IPCC/OCED, 2024). The source-emission relations for any GHG are given by the equation: (2)

$E =$ is emission of pollutant I from the consumption/production of a product whose quantity is represented by an activity (A) index and F is the emission factor for the pollutant i (emissions per unit activity A). The total emission of pollutant i for each process is then added over the total number of similar and diverse process k (sectors and sub-sectors), as well as over spatial grids of interest. An emission inventory therefore aims to obtain accurate estimates of the unknowns A and F for each sector and generic sources. The values of A per sector in any country are obtained from available published national data.

For the energy sector, emissions may be provided through the top-down (TD) method which provides aggregate emissions based on certain factors such as production, imports, exports etc. of primary and secondary fuel without details of sectoral fuel use. The expressions for the primary and secondary fuels are given in (3) and (4) respectively.

$$Ca = P + I - E - IMB - SC \tag{3}$$

$$Ca = I - IMB - SC \tag{4}$$

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Ca is the apparent energy consumption by fuel type; P = production; I = imports; E = exports; IMB = international marine bunkers; SC = stock change for both primary and secondary fuels.

It is also shown in (5) that the aggregate emission of carbon from all fuels is based on the fuel carbon content, heating values, oxidation fraction and production/consumption data.

$$Ec = Ca \times Fc \tag{5}$$

Ec is the aggregate emission factor in Gg-C, is the apparent energy consumption in PJ and is the carbon emissions factor in tC/TJ.

The Intergovernmental Panel on Climate Change (IPCC) provides a more accurate method for national GHG inventory based on the bottomup (BU) approach for the energy sector which provides techniques for emission factor estimates for all subsectors processes based on the downstream energy technologies and technology efficiencies. Emissions from BU are based on the application of (5) to each downstream energy technology.

The results obtained applying these methods confirms that gas flaring, transportation and electricity generation (Figures 4 and 5) are the most significant energy consumption processes in Nigeria leading to GHG emissions (Nigeria’s First National Communication, 2003). Also energy and land use sectors (Table 3) were observed to be the main contributors of CO₂ to emissions. Again, these emissions are still low when compared with those of industrialized countries.

Having established an increasing population and that the content of Nigeria’s energy mix is fossil fuel based with commensurate propensity to emit CO₂ – a by-product of GHG – there is a high risk of climate change happening already, and continuing if unabated (IPCC/OCED, 2019) Climate change impacts development the same way population and energy do. Nigeria is highly vulnerable to negative impacts of climate change along its large coastal territories, such as, degradation of agricultural lands, desert encroachment, depleting water resources and low agricultural output among others. For instance, with the majority of Nigerians surviving on agricultural proceeds, the effect of climate change on rainfall makes it vulnerable. However, this research has primarily focused on how much the current energy mix in Nigeria has impacted climate change. The findings so far are that Nigeria is dominated by fossil fuel energy sources which have made it vulnerable to the adverse impacts of climate change. In general, the exploration of petroleum resources in the last 40 years has resulted in massive injection of hydrocarbons into the atmosphere as well as considerable environmental problems (Ahmed & Fakhruddin, 2018). In this regard, this has led to higher demand for electricity, changing patterns in

hydroelectric power facilities, as well as, destruction of existing power facilities.

Nigeria's GHG emission is at variance with that of developed countries, where it is mainly from fossil fuels (Nigeria and Climate Change Road to COP15). There is equally large contribution of GHG emissions from the agricultural sector as shown in Table 3. Much of the emissions from the energy sector come from gas flaring (see Figure 4). Again, the results from Table 3 which accounts for estimates in emissions from

land use and forestry, shows the greatest percentage for emissions from land use at 44%.

It can be argued though that the emissions of GHG in Nigeria is generally low based on available data, but as Nigeria becomes more industrialised with time and with a high population growth rate, the figure is expected to rise drastically based on the estimated values presented in Figure 3, if nothing is done to checkmate the trend.

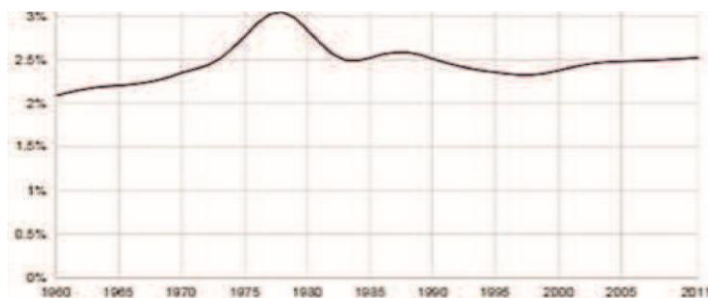


Figure 2: Population Growth Rate For Nigeria Source: World Bank, (2025)

Mitigation Options and Future Actions

The need to tackle the negative impacts of climate change in Nigeria is apt because of its devastating long term effects on the environment and economy. Already, this paper has revealed that energy plays a dominant role in the Nigerian economy and its dominance is expected to increase as population increases and as the industrial sector expands, which are bound to happen, the corresponding effects lead to climate change.

It is identified that the key institutional factors that defines mitigation capacity include effectiveness of government regulation and carbon cuts education and skills, public attitudes and level of awareness (Nigeria and Climate Change Road to COP15). To this end, mitigation options can come as economic capacity, extensively highlighted in reference awareness (Nigeria and Climate Change Road to COP15), and resource management, the former cited as being more critical

to the reduction of GHG emissions (Hatfield-Dodds et al., 2017). The opportunities for Nigeria to tackle climate change by adapting to clean energy projects is notwithstanding very substantial to emission reduction and spiced with great potentials. For example, specific clean energy technologies have been identified in the power, industry, transportation and household sectors, though with minimum public awareness and weak institution. In Nigeria's energy policy, the integration of renewable energy is highly encouraged; however, there are no strict regulations, targets or projects to realize the general policy (Akuru and Okoro, 2020).

In the energy sector, there are two possible scenarios for GHG mitigation. These are the baseline and GHG abatement scenario (Nigeria's First National Communication, 2013). The baseline scenario is what is obtainable in future energy patterns if inefficiencies occurring as omission in

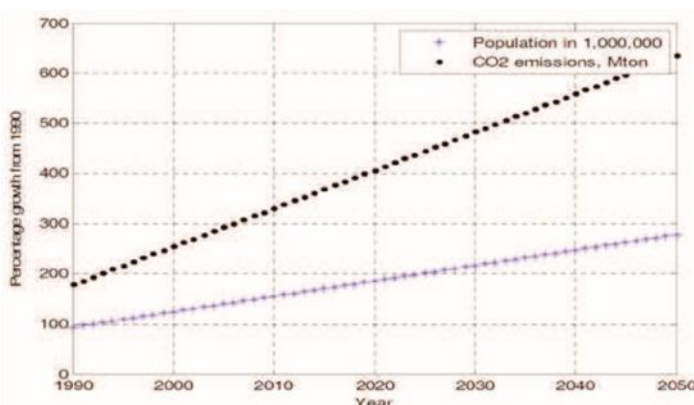


Figure 3: Population and CO₂ Emission Trends in Nigeria (1990-2050)

The current systems are not carried into the future, these omissions do not include all firm or proposed projects or policies. On the other hand, the abatement scenario is achieved by introducing a number mitigation efforts into the baseline scenario. These include:

- i. Efficiency improvement options
- ii. Increased use of renewable energy
- iii. Supply-side options and introduction of new technologies
- iv. Options for increased use of natural gas with respect to gas flaring

CONCLUSION

It is true that it is impossible for man to stop the natural causes of climate change however the human causes can be stopped or drastically reduced with the right approach (Rich & Steinmetz 2018). It is noteworthy to point out that a number of human activities have contributed and are still contributing to the depletion of the ozone layer, which causes global warming.

This paper has been written to highlight a number of these human activities and how it is contributing to climate change in Nigeria. Currently, Nigeria's energy sector is fossil fuel dominated and its associated processes lead to GHG emissions and ultimately, climate change. If the current trend is unabated, then climatic variability currently being experienced is definitely going to increase and intensify and the resultant impact will be catastrophic for the future of the country.

The case that Nigeria's contribution to global warming is insignificant when compared to that of developed countries is unsupported given the current trend that threatens to spare no one. Hence, this paper has attempted to correlate using certain indices, the disturbing extent to which climate change is affecting Nigeria.

The results reached on the proliferation of climate change via Nigeria's fossil-based economy is very revealing and so requires urgent mitigation actions and proactive measures of which the deployment of renewable energy into the country's energy mix has been advanced amongst other things.

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