Climate Change Mitigation Approaches for Nigeria: Actualization of National Climate Policy Commitments

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Abstract

To meet the climate change policy commitment, Nigeria has to explore myriads of opportunities for mitigations of carbon emission while safeguarding the quests for modernization and industrialization. Barring the cost-intensiveness and technical capacity requirements, geological carbon sequestration in Nigeria, was estimated to possess CO_2 storage capacity that can last over 500 years. The estimate was chiefly based on the use of depleted oil reservoirs with the targeted emission sources from the current gas flaring level as well as industrial emissions. Potential in the coal bed storage of CO_2 is also there to be tapped, while simultaneously extracting methane gas for energy purpose. Nigeria possesses unlimited potential in natural carbon-harvesting plantation schemes with the use of reforestation, perimeter tree plantation by industries, enhanced ocean fertilization, street and household tree plantations. To enhance this scheme, research is needed in the improved seedling of carbon-harvesting plants. Nigeria needs to impose and expand carbon tax scheme to cover GHGs emission sources like refineries, automobiles, cement, plastic, petrochemical, fertilizers, power, steel, paper, transportation and other industries. This is the better way for Nigeria and other developing economies, where strives for development and industrialization are very much steep, while safeguarding our quests for industrialization and modernization

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INTRODUCTION

Indiscriminate emission of carbon and other greenhouse gases have raised global concerns. The resultant effects of global warming have led to ocean surge, desert encroachment, heat waves, etc. (Metz *et al*., 2005). To arrest the situation, Carbon dioxide (CO_2) Capture and Storage (CCS) is being encouraged and demonstrated across the globe. CCS is a process consisting of the separation of CO_2 from industrial and energy-related sources, transport to a storage location and long-term isolation from the atmosphere.

Nigeria is the sixth-largest exporter of oil and it is rated in the world development indicators (World Bank, 2015) as number 39 in the world ranking of carbon emissions from all sources. Globally, 22 billion tonnes of CO_2 are emitted into the atmosphere from man-made sources (Benson and Surles, 2006) while Nigeria emits about 80.51 million metric tons of CO_2 annually (Yelebe and Samuel, 2015). Owing to oil-production activities, Nigeria is considered as one of the world's most gas flarer and the largest CO_2 emitter from Sub-Saharan Africa (Galadima and Garba, 2008). Nevertheless, the technology concept of CCS in the country is not well understood and the perspectives of the government towards the research and development in the area of CCS is very poor (Galadima and Garba, 2008) when compared with the developed countries such as Germany, Canada and United Kingdom that have advanced in the CCS technology (Mertz *et al*., 2005). This explains the reality that Nigeria needs to acquire technical knowhow and local expertise while, at the same time, invests heavily on the technological equipment to implement CCS.

Main stationary sources of carbon emission in Nigeria are from fossil fuel processes such as refineries, large combustion units involved in power generation, cement, petrochemical and allied industries. However, there exist thousands of non-stationary and distributed sources, such as automobile cars, furnaces, wooden and kerosene stoves, bush burning as well as ubiquitous household generators. These multitudes of sources can have combined effects that cannot be easily quantified.

CCS would most likely be applied to large point sources of CO_2, such as power plants or large industrial processes (Mertz *et al*., 2005). Industrialised nations such as USA, Norway and

Australia are utilising these sources with concentrated capacity to generate decarbonised fuel such as hydrogen to the transportation, industrial and building sectors. This, in effect, reduces emission from the small and poorly controlled distributed sources. However, developing countries like Nigeria, with limited resources and technical capacity, should strive to utilize cheaper and easier option like the natural carbon-harvesting scheme to manage its distributed sources.

CCS involves the separation of CO_2 from fuel or effluent gases of an industrial plant. The separation can be effected by decarbonising the fuel prior to combustion or in effluent gases after combustion with each carrying its own advantages. This is followed by compression to high density to facilitate transport and storage at a chosen site, often at hundreds of meters away from source. Candidate sites for storage have been recognised to include subsurface geological formations, deep ocean or mineral carbonation using inorganic minerals. It can also be stored in depleted oil reservoir and coal seams. Third assessment report (TAR) of Mertz *et al*. (2005) states that, "most model results indicate that known technological options could achieve a broad range of atmospheric CO_2 stabilization levels", but that "no single technology option will provide all of the emissions reductions needed". Rather, a combination of mitigation measures will be needed to achieve stabilization. This implies that nations should employed mix approaches based on the comparative advantages within its geographical and political spaces. In reality, investment requirement for CCS would be affordable for countries that have significant sources of CO_2 suitable for capture and that have technological, economic and manpower strengths needed to kick-start and maintain the technologies. However, many developing countries are not in this category.

In the Mertz *et al.* (2005) report, residential, commercial and transportation sectors were not considered because of their wide distribution, size as well as their mobility which make them unsuitable for capture and storage. However, while major source of emission in the developed nations is from the power plant, the developing countries like Nigeria with poorly functioning power plants rely heavily on generators and other mobile sources for power generation. Also, the second and third hand used vehicles that flush the streets of poor countries make them more vulnerable to mobile and distributed emission sources. With poor automobile regulation, these unserviceable vehicles are real culprits in the mobile sources of environmental pollution. According to Carbon Dioxide Information Analysis Centre (CDIAC), Nigerian emission grows from nothing in the early part of the twentieth century to almost 30,000,000 metric tons (30MMton) in the year 2010 (Figure 1). Breakdown shows that the trend began from mainly solid fuel. This was succeeded by the flaring of gases in the early 70's. This was also surpassed at the moment by liquid fuel which had started growing since the 70's. Figure 1 further shows that the combined effects of various sources have serious additional effect. Emissions have been growing in Nigeria even after 2010 (Falode and Alawode, 2014). Thus, the current rate can be imagined as higher.

This work intends to take a critical look at how Nigeria can curtail its emission profile through myriads of methods available to check carbon pollution. It is understood that single method may not be applicable as do-it-all, but combinations of approaches can actually position Nigeria as an emission-compliant nation while safeguarding our quests for industrialization and modernization. In this paper, approaches that can be explored in Nigeria to cut carbon are discussed while emphases are placed on the low-cost and easy methods.

Carbon-Cutting Approaches

Methods like carbon capture and storage, carbon utilization, reforestation, lifestyle adjustment, renewable energy etc., are being applied globally to address the scourge of global warming arising from carbon emission into the atmosphere. Each of these methods has merits and downsides. Thus, it is expected that Nigeria will explore the best of them within its geographical space.

Carbon Capture and Storage in Geological Reservoirs/Aquifers

Depleted Oil Reservoirs

The major contributors to CO_2 emissions in Nigeria are gas fuels, liquid fuels, solid fuels, gas flaring, cement production, etc. CO_2 from these sources can be captured and stored in geological brine aquifers, depleted oil reservoirs and un-minable coal seams. Nigeria has abundance of these resources and can be utilised to face the challenge of carbon emission. CO_2 storage in depleted oil reservoirs or deep saline formations is generally expected to take place at depths below 800m, where the ambient pressures and temperatures will usually result in CO_2 being in a liquid or supercritical state. Under these conditions, the density of CO_2 will range from 50 to 80% of the density of water. This is close to the density of some crude oils, resulting in buoyant forces that tend to drive CO_2 upwards. However, a well-sealed cap rock over the selected storage reservoir is important to ensure that CO_2 remains trapped underground (Mertz *et al*., 2005). Figure 2 shows schematic scenes from geological storage approach.

From the figure, it is shown how CO_2 can be injected to recover oil in the reservoir. This has the advantage of recovering remnant oil while CO_2 can as well be stored in the oil-depleted pore spaces. This is a very economical way of tackling carbon emissions while enhancing economy of oil exploration.

Nigeria is endowed with many geological aquifers and depleted oil reservoirs. Most of the depleted oil reservoirs can be found in the Niger Delta region of Nigeria. Example of depleted site, known as brown field, is shown in Figure 3. For effective storage, parameters like permeability, porosity, caprock thickness and geothermal gradient should be suitable. For example, the reservoir depth of at least 800 m, porosity and permeability of more than 10 percent and 20 mD respectively, and a caprock thickness of at least 10 m, in addition to geothermal gradients of 13.46 to 33.66 ^{o}C /km are the ideal conditions for the efficacy of storage (Ojo and Tse, 2016).

Ojo and Tse (2016) studied the sites at brown field and reported a theoretical total storage capacity of 147MM ton for three reservoirs. Judging from Figure 1, the depleted site (Figure 3) can be banked upon to take up the total emission of Nigeria for close to 5 years (i.e., 30MMton per year for 5 years). Considering the impracticality of capturing emission from non-stationary sources, the emissions from flaring (approximately 10MMton annually in 2010 (Figure 1)) can be stored safely for close to 15 years in these three wells at brown field Niger Delta, shown in Figure 3.

According to Nigerian National Petroleum Corporation (NNPC), out of the 606 oil fields in the Niger Delta area, 355 are on-shore while the remaining 251 are offshore. Out of these, Shell Oil Company is said to have abandoned 32 of their oil wells in Akwa Ibom State axis of Nigeria (http://businessandmaritimewestafrica.com/oil-gas/32-oil-wells-abandoned-in-niger-delta). It can be safely assumed that one-third of the onshore wells will be abandoned in the next decades. That will make about 100 reservoirs available for carbon sequestration. If we also assume similar reservoir properties as in the brown field described above. Thus, emissions from gas flare and other stationary sources can be stored for over 400 years. This is a reasonable approximation considering the fact that Nigeria is currently taking measures to stop gas flaring. If this is implemented, the other stationary sources like cement industries, petrochemical refineries and other stationary sources of emissions can enjoy carbon storage space for longer number of years. For example, if three depleted reservoirs can take approximately 150MM ton CO_2 from mainly gas flaring for 15 years, it will imply that the envisaged 100 reservoirs can store carbon for approximately 500 years, if media characteristics are similar.

But apart from depleted and abandoned oil reservoirs, there are many suitable storage brine aquifers all over the country. These aquifers can also play role in addressing greenhouse gas emissions. However, challenges will be posed about their proximity to emission sources. To use these aquifers, the nature of overlying rock plays determinant role in the fraction of CO_2 that will remain permanently trapped once injected. The overlying rock will also be critical to the safety of the sequestration projects.

Some mechanisms are known to promote immobilization of CO_2 in the storage reservoir. For example, there are physical and geochemical trappings. The former is provided by a layer of shale and clay rock above the storage formation. This impermeable layer is known as cap rock which prevent the movement of stored CO_2 into the atmosphere. In addition, capillary forces add to the strength of the physical trapping retaining the molecules in the pore spaces of the formation. Since some spaces remain open in the formation, in many cases, lateral migration of CO_2 beneath the cap rock is still possible. This gives more probability to leakage and therefore need additional trapping mechanism. Geochemical trapping takes place as CO_2 reacts with the in situ fluids and host rock. It starts with the dissolution of CO_2 in the in situ water. Over time, CO_2-rich water becomes denser and sinks down into the bottom of the formation, losing its buoyancy. This is followed by chemical reactions between the dissolved CO_2 and the rock minerals such as magnesium, calcium and manganese forming ionic species leading to the formation of solid carbonate over millions of years.

CO_2-Enhanced Coal Bed Methane Recovery (CO_2-ECBM)

Coal bed often serves as a natural gas basin while it can simultaneously be used for the storage of CO_2. The characterisation of coal seam is very complex because of its complicated polymeric media (Li and Fang, 2014; Rabiu *et al*. 2017b; Falode and Alawode, 2014). CO_2 injection into coal seam to replace methane is one of the CO_2 sequestration technologies. In this process, methane can be used as clean energy resources and storage of CO_2 is mainly by the adsorption mechanism called CO_2 enhanced coal-bed methane recovery (Li and Fang, 2014; Rabiu *et al*., 2017a,b).

The discovery of coal in Nigeria was in 1909 and its mining began with a drift mine at Ogbete, Enugu in 1915. The coal production attained its climax within the period of 1958 and 1959 and since then, there had been a significant fall in its production in successive years. In addition, some mines were abandoned. It is therefore necessary for Nigeria to develop her own deep un-mineable coal bed to meet expanding demand of methane in the different global markets. CO_2-ECBM project implementation in Nigeria would help to build confidence in CCS technology and at the same time, more energy such as methane can be recovered (Falode and Alawode, 2014; Voormeij and George, 2004).

The main challenges of CO_2-ECBM recovery projects are identified to include long implementation time, inefficient technology, gas leakage from geological storage, and high capture and storage costs (Galadima and Garba, 2008; Falode and Alawode, 2014).

Though, coal mining in Nigeria is on the decline, the methane gas resource can be tapped from the existing ones while CO_2 is trapped in place. Coal bed has preferential adsorption of CO_2, resulting in the release of coal-bed methane. This will also boost our economy. In this case, CO_2 will remain in place as long as pressures and temperatures remain stable. Abu *et al.* (2016) performed numerical recovery of methane from coal bed at Onyeama in Anambra State, Nigeria. They found that volume of methane gas recoverable at 15.2% efficiency is 19866.1 MMSCF. If captured CO_2 is used for the purpose of methane recovery, huge amount of carbon can be stored in the coal beds. Cities like Enugu, Benue, Kogi, Delta, Kwara, Plateau, Abia, Anambra, Bauchi, Edo, Ondo, Adamawa and Imo are blessed with large deposits of coal. According to reports, Nigeria's present coal deposit stands at about 2.8 billon metric tonnes reserves in 17 identified coalfields (https://www.vanguardngr.com/2017/08/nigeria-yet-transform-2-8-bn-metric-tonnes-coal-17-fields-wealth/). Stanton *et al.* (2001) reported USGS assessment of coal resources in the Powder River Basin (Fort Union Coal Assessment Team, 1999) in which 326 billion tons of coal could, theoretically, sequester about 290 Tcf CO2. This is about 0.9 billion ton of coal to 1 Tcf of CO_2. Also, at Wyodak Anderson coal zone, 460 billion ton could sequester another 400 Tcf CO_2 (Stanton *et al.*, 2001). This again goes for about 0.9 billion ton of coal to 1 Tcf of CO_2. From the 2.8bn metric tonnes coal deposit, reported from Nigeria, we can infer the possibility of about 3 Tcf. For efficiency purpose, this storage capacity can be put at 2 Tcf. To convert the Tcf to metric ton of CO_2:

One ton of CO_2 = 1000kg CO_2

One cubic meter of CO_2 = 1000 liters CO_2

One mole CO_2 = 44.0g (CO_2 = 12.0g + 32.0g = 44.0g)

One ton contains 22730 moles of CO_2 (1,000,000g / 44.0g/mole)

One mole is 24.47L (Boyle's law at 25°C and 1 atmosphere pressure)

Volume of one tonne CO_2 = 22730moles × 24.47L/mole = 556200L = 556.2m³

Thus, one ton of CO_2 occupies 556.2m³ volume. 1 Tcf is equivalent to 28.32 bn *m*³. 2Tcf is 56.6 bn m³. Thus, the amount of CO_2 in tonnes that can feasibly go into Nigeria coal bed can be put at 102MMton. This coal bed sequestration will also come with the benefit of methane recovery.

Saline Aquifer

Saline aquifer is a promising medium for CO_2 storage since the water contained in it does not meet human potable water requirement. The presence of high level of minerals and salts make it unfit for drinking or irrigation (Abidoye *et al.*, 2014; Mariyamma *et al*., 2015; Voormeij, 2001; Rabiu *et al.* 2017a,b; Mertz *et al.*, 2005). Saline aquifers have the largest storage capacity worldwide, but limited knowledge is still known about the reservoir (Akigwe *et al.*, 2013; Adel and Shedid, 2013). Due to its favourable characteristics such as thickness, permeability, depth, porosity and presence of the caprock formation as a seal, it is used as a major reservoir for injection of large scale carbon dioxide (Wickstrom *et al.*, 2006). Nigeria has a lot of saline aquifers, but the major challenge is the characterisation issue, for example, most formations have less previous data unlike depleted oil and gas reservoirs which have been used for exploration of hydrocarbon. The impact of CO_2 injection on the microbial community of saline aquifers have shown that sulphate reducing bacteria (SRB) and methanogenic microbes are capable to adapt to the enormous conditions of geological carbon sequestration (GCS) (Shabani and Vilcaez, 2018). Another issue with the saline aquifer in Nigeria is there proximity to the emission sources. Thus, it will require further study to establish their proximity to industrial sites. Saline aquifers regions have been reported in Niger Delta (Akinwumiju and Orimoogunje, 2013) and Lagos Zones (Adepelumi *et al.* 2009). But, the confinement nature of the aquifers can be ascertained. Thus, more study is needed.

Other Carbon Sinks

Geological carbon sequestration, as described above, is a costly project that is mainly being undertaken by wealthy nations. It also entails infrastructural complexes together with advanced technical knowhow. For the current lack of infrastructures in Nigeria, cheaper options should be recommended for the developing countries. The pattern of industries in Nigeria is largely scattered in the popular cities like Lagos, Kano Port, Harcourt, Ibadan, Agbara (in Ogun State), etc. The scatter pattern of industries had made capture of CO_2 emissions in large scale discouraging and costly.

Also, what is absent as industrial scale emission of CO_2, is being substituted by the ubiquitous non-stationary emission sources from out-dated and poorly service automobiles, swarming second-hand generators, open air combustion of polymers, woods and so on. In Lagos, hundreds of thousands of portable generators operate on a daily basis with some households putting them on, for more than 12 hours, owing to poor ventilation while some businesses cannot simply afford to put it off for the entire business hour.

In the light of the above, the following less-complicated routes to carbon sinks are recommended:

Biological Processes

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CO_2 can naturally be sequestered in trees, oceans and some geological media. As animals exhale CO_2, plants capture it to synthesize food in the process referred to as photosynthesis. So, the regulation of this carbon compound has been part of the natural system. But, the process of indiscriminate felling of trees for industrial and other activities has distorted this balance over years. Reforestation is an attempt aimed at regaining the balance in the carbon cycle mechanism by planting of trees on marginal crop and pasture lands in order to increase incorporation of carbon into biomass.

Many biological processes are being engineered to promote sequestration processes. Examples include iron fertilization of the oceanic phytoplankton which aims to remove the CO_2 from the atmosphere at least for a period of time. Urea, a nitrogen rich source, is also being considered for this approach (Metz *et al.*, 2005)

Grain for green project is another biological approach to carbon storage that is gaining ground. Although, this might face limitation owing to insufficient food production capability, but the aim may not be to encourage abandonment of agriculture farmlands but to raise and train good number of new and interested farmers in every locality to embark on perennial tree plantation. Example of this is found in the ecological programmes launched at Loess Plateau in modern China aimed at transforming the low-yield slope cropland into grassland and woodland (Chang *et al.*, 2011). The soil organic carbon had increased significantly as a result. This is put at a rate of 0.712 TgC/year in the top 20 cm soil layer for 60 years under the project across the entire Loess Plateau (Chang *et al.*, 2011).

Reforestation and managing depleted forest land to conserve carbon stock could potentially sequester 220 to 320 billion tonnes of CO_2 by the year 2050 (Kauppi and Sedjo, 2001). Plant roots, decaying biomass and a variety of complex organic molecules compose what is commonly referred to as soil carbon (Benson and Surles, 2006). Thus, soil and forest ecosystems are large reservoir of carbon. Industries across Nigeria should be mandated to embark on perennial trees plantation across the perimeters of their land spaces and even across the production units. This will ensure there are enough carbon sinks around the emission sources.

Furthermore, ocean fertilization is another natural sequestration that is drawing attention but facing acceptance challenge. Scientists are proposing that fertilizing the ocean with iron to promote biological productivity will also enhance CO_2 uptake. Results from Southern Ocean Iron Experiment (SOFEX) confirmed this (Buesseler *et al.*, 2004) but questions remain on long term impacts of this technique. However, Nigeria, being very blessed with vast water bodies like ocean and multitudinous rivers, should fund research into ocean fertilization around the concentrated emission sources across the country to verify the feasibility of this technique.

Chemical Processes

Carbon, in the form of CO_2 can be removed from the atmosphere by chemical processes and stored in stable carbonate mineral forms. This process is known as carbon sequestration by mineral carbonation or mineral sequestration. The process involves reacting carbon dioxide with abundantly available metal oxides–either magnesium oxide (MgO) or calcium oxide (CaO) to form stable carbonates. These reactions are exothermic and occur naturally (e.g., the weathering of rock over geologic time periods).

$$\mathrm{CaO} + \mathrm{CO_2} \rightarrow \mathrm{CaCO_3} \quad 2.1$$

$$\mathrm{MgO} + \mathrm{CO_2} \rightarrow \mathrm{MgCO_3} \quad 2.2$$

In nature, Calcium and magnesium are typically found as calcium and magnesium silicates (such as forsterite and serpentinite) and not as binary oxides. For forsterite and serpentinite, the reactions are:

$$\mathrm{Mg_2SiO_4} + 2\mathrm{CO_2} = 2\mathrm{MgCO_3} + \mathrm{SiO_2} \quad 2.3$$

$$\mathrm{Mg_3Si_2O_5(OH)_4} + 3\mathrm{CO_2} = 3\mathrm{MgCO_3} + 2\mathrm{SiO_2} + 2\mathrm{H_2O} \quad 2.4$$

These processes occur naturally over geological time scales, but anthropogenic technique is being employed to quicken the process and even adopt its products for various human uses. Since these reactions are exothermic, they are better favoured at moderate temperatures. Industries like cement, petrochemical, construction and others can utilize this technique to enhance permanent storage of carbon.

Man-made voids

Man-made voids with suitable characteristics can be utilized for CO_2 storage. These include abandoned sites for mines such as coal. These mine sites are very common around Enugu coal deposits which had been mined long ago. These need to be inspected for structural closures and traps. However, they can still be adapted for storage on a long-time basis. Mine sites for potash, gypsum, anhydrite which are also evaporites and their associated beds had restricted permeability. These can be found around the Northern Nigerian axis especially along Kogi where large amount of gypsum and limestone deposits are found. Also, South-western Nigerian had hundreds of such mines along Ewekoro where cement factories had been engaging in mining long ago.

Caverns could be constructed in the several impermeable rocks. Advanced nations had developed technologies to excavate caverns in the rock salt by pumping water down boreholes. Storage caverns in North Sea gas have been constructed in this manner in Permian salt deposits on the east of Yorkshire coast. But their development is limited to a small area where the salt is at sufficient depth and thickness to contain such caverns (Holloway and Savage, 1993). But the cost and technology will be determining factor in developing country like Nigeria. Though, the technology can be transferred; cost and importantly, maintenance may continue to be dissuading. However, such caverns can find good uses near emission sites especially cottage companies that scatter over the country where small but regular emission can be contained.

Synthetic Tree

New technologies are coming up to take care of distributed emission sources. These are particularly suitable for areas with crowded automobiles, cluster of small industries, farm settlements, etc. Example of such technology is the Synthetic Tree (https://phys.org/news/2009-07-synthetic-tree-captures-carbon-faster.html). It is designed to look like a small building and could absorb one tonne of carbon dioxide per day, an amount equivalent to that produced by about 20 cars, on average. After being trapped in a chamber, the carbon would be compressed and stored in liquid form for sequestration.
Synthetic tree can be deployed in Lagos, Port Harcourt, Kano and elsewhere. In fact, industries in these areas can be made to pay for the device. The device essentially captures from the air around the emission areas. Thus, it is very essential to tackle emissions from mobile sources.

Carbon Capture and Utilization

Rather than taking carbon dioxide as a waste that is polluting our atmosphere, alternative thinking is to consider the carbon dioxide as a raw material from which industrial and household products can be produced. This is the objective of Carbon Capture and Utilization (CCU). Example of CCU in practice include Enhanced oil and Gas Recovery (EOR, EGR), CO_2 mineralization which results in permanent storage, production of bio-oils, chemicals, fertilisers and fuels. It is considered as a complementary step to geological CO_2 sequestration. But, as oppose to CCS, CCU has the advantage of being profit-driven project that can entice investors. However, research is still needed to invent cutting-edge unique products from the venture in order to make the project very economical. Owing to the stable nature of CO_2, it is energy intensive to break the molecule. Thus, it is an energy consuming process.
However, developed nations like US, Germany, Australia, UK have spotted the potential for CCU and are investing billions of dollars. Nigeria can also take up the challenge in its little way to support innovation in the CCU.

Carbon Tax

Carbon tax scheme can serve a deterrent purpose for different industrial emitters of carbon in the country. Carbon tax refers to a tax on activities or production processes that can give rise to GHGs emissions. It is one of the policy instruments canvassed for the reduction of greenhouse gases (GHGs) by the United Nations. Similar taxation scheme exists in Nigeria at the earlier time to dissuade gas flaring. It has been one of the government's frontline policies in seeking to eliminate flaring. In 2008, the penalty was raised to US$3.50 for every 1,000 scf of gas flared (Akinwande, 2014).
The policy needs to be expanded to cover other GHGs emission system like automobiles, cement, plastic, petrochemical, power, steel, paper, transportation and other industries. This will be similar to the carbon tax regime in South Africa, where the 2010 proposed tax covers all direct, stationary sources, and process emissions, including those of methane, carbon dioxide, and nitrous oxide (Moarif and Rastogi, 2012). South Africa had earlier imposed similar tax on electricity generated from fossil fuel as well as new passenger cars are taxed on carbon dioxide emissions above 120 g/km (Finnern, 2013).
Measures like these can be adopted by Nigeria to meet its obligation of National Climate Change Response Policy. Sectors of the economy will experience positive response from such initiatives. This is because new manufacturers will find incentives in adopting green energy alternatives like wind, solar, etc. This is the better way for developing economies and countries where strive for development and industrialization is very much steep.

CONCLUSION

To meet the climate change policy commitment, Nigeria needs to explore myriads of opportunities for mitigations in its geographical system. Barring the cost-intensiveness and technical capacity requirements, geological carbon sequestration in Nigeria was estimated to possess capacity that can last over 500 years for CO_2 storage, especially the use of depleted oil reservoirs, judging from the current gas flaring level as well as industrial emissions. Potential in the coal bed storage of CO_2 is also there to be tapped, while simultaneously extracting methane gas for energy purpose. Nigeria possesses unlimited potential in natural green storage schemes with the use of reforestation, perimeter plantation by industries, enhanced ocean fertilization, street and household plantation. Research is needed in the improved seedling of carbon-harvesting plants. Finally, Nigeria needs to impose and expand carbon tax scheme to cover GHGs emission system like refineries, automobiles, cement, plastic,

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petrochemical, fertilizers, power, steel, paper, transportation and other industries. This is the better way for Nigeria and other developing economies like Ghana, Kenya and Congo, where strive for development and industrialization is very much steep.

Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

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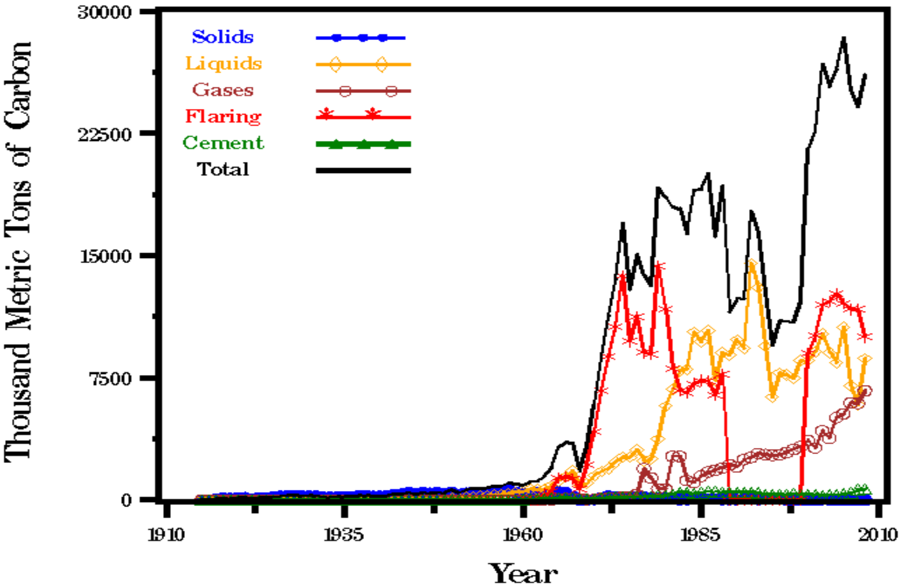
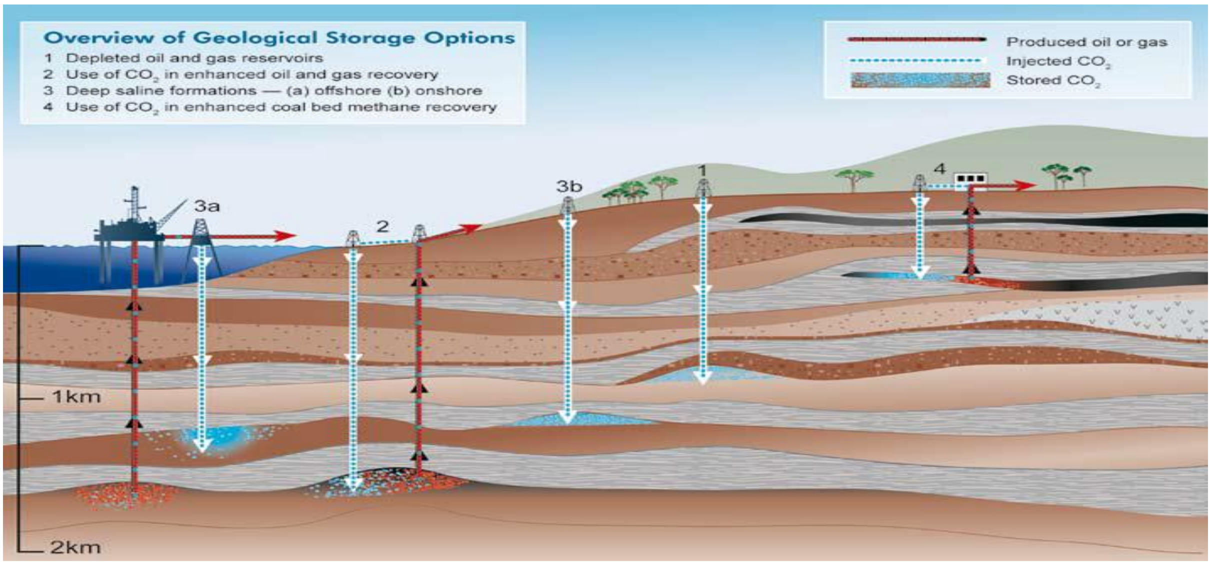
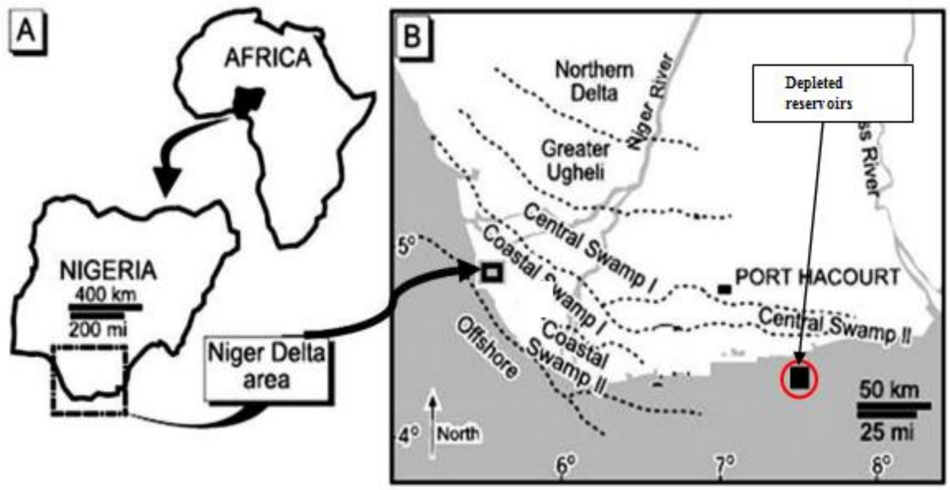
Appendix



Appendix 1: Carbon Emissions in Nigeria (Carbon Dioxide Information Analysis Centre: http://cdiac.ess-dive.lbl.gov/trends/emis/ngr.html).



Appendix 2: Methods for storing CO_2 in deep underground geological formations (Mertz *et al.*, 2005).



Appendix 3: General map of the Niger Delta showing the depleted reservoir site (modified from Ahiarakwem and Opara, 2012).