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Carbon(IV) oxide Capture and Sequestration in Nigeria: Prospects and Challenges

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Abstract

The capture and storage of carbon dioxide (CCS) produced during the combustion of fossil fuels now offers one option for attaining large scale reductions in the emissions of greenhouse gases and thus, promote a clean environment. It is now becoming clear that CCS technologies could promote the use or consumption of fossil fuels than otherwise previously thought.

This paper presents an overview of the techniques involved in the capture and sequestration of carbondioxide(CO_2). The opportunities and the challenges of the application of CCS in Nigeria are considered.

It is concluded that the development of gas utilization schemes and power plants makes it imperative for Nigeria to give attention to CCS technologies.

Introduction

Fossil fuels will continue to meet a significant share of world primary energy demand for many years to come, and their consumption is increasing[1,2]. It has therefore become important to introduce efficient technical solutions to make their use less damaging to the environment. The capture and storage of carbon dioxide produced in combustion of fossil fuels offers one option for attaining large scale reductions in the emissions of anthropogenic greenhouse gases (Figure 1).

Other mitigation options include energy efficiency improvements, the switch to less carbon-intensive fuels, nuclear power, renewable energy sources, enhancement of biological sinks, and reduction of non-CO_2 greenhouse gas emissions.

Carbon dioxide capture and sequestration deals with the removal and storage of CO_2 in order to obtain cleaner fossil fuels and hence a cleaner environment. The stages invoved include capture, transportation, compression and injection of CO_2 into a storage medium.

CO_2 produced during the use of oil and gas can be captured before it is released to the atmosphere and then transported for storage in suitable underground formations, such as depleted oil and gas reservoirs, deep saline aquifers and un-minable coal seams. Provided that their leak-tightness can be demonstrated over the long term, CCS appears to hold out the most promise for CO_2 emission reduction.

Global Perspective

World population is increasing, and so the demand for energy. The economic growth of developing economies has also increased energy demand in recent years.

However, there has been increasing concern over global warming and the resultant climate change associated with the use of fossil fuels and CO_2 emissions.

CO_2 emissions from human activities arise from a number of different sources, mainly from the combustion of fossil fuels used in power generation, transportation, industrial processes, and residential and commercial buildings. CO_2 is also emitted during industrial processes like cement manufacture, hydrogen production and the combustion of biomass. Tables 1 and 2 show the global and Nigerian CO_2 Emissions by economic sectors and by sources respectively.

International concern about climate change led to the United Nations Framework Convention on Climate Change (UNFCCC) in 1992. The ultimate objective of that Convention is the stabilization of greenhouse gas concentrations in the atmosphere at a level that prevents dangerous anthropogenic interference with the climatic systems.

Energy Policy Issues

Fossil fuels will be the predominant fuel for a long time[3]. It is estimated that the global energy demand will still be dominated up to 90% by fossil fuels till 2030 as renewable energy sources will not be sufficient in the short to long term[4].

Thus, the fact that the world has to live with fossil fuels for years is in support for carbon dioxide capture and sequestration. In terms of cost, it is now known that carbon capture systems can be significantly cheaper than many other competing energy technologies, as demonstrated in Table 3.

Furthermore, while it is generally accepted that the "ultimate fuel" is hydrogen fuel, hydrogen is most likely to be produced cheapest from fossil fuels.

It is also important to note that all over the world, significant investment has been made in infrastructures for the use of fossil fuels. It therefore makes economic sense to find ways of continual use of the infrastructure.

CO_2 Capture

The most prominent targets for carbon capture at the present are:

- Existing industrial processes that produce highly concentrated streams of CO_2 as a by-product;
- Power plants,
- Plants for producing hydrogen fuels from carbon-rich feedstocks.

There are therefore three main approaches to capturing the CO_2 generated from primary fossil fuels (coal, natural gas or oil), biomass, or mixtures of these fuels: post-combustion, pre-combustion and oxyfuel combustion (Figure 2).

CO_2 Sequestration

Carbon sequestration could be undertaken through:

- The removal of greenhouse gases directly from industrial or utility exhaust and storing them.
- Promoting the so-called natural sinks, ie. by enhancing the uptake of CO_2 in soils, vegetation or the ocean. This has technical and political dimensions which have become points of contention in the Kyoto protocol negotiations[5].
- Improved energy efficiency on promoting non-fossil energy sources.

Geological formations have received extensive considerations for the storage of CO_2. Depleted oil and gas reservoirs, deep saline formations and unminable coal beds are prime candidates. In each case, geological storage of CO_2 is accomplished by injecting it in dense form into a rock formation below the earth's surface.

Tables 4 and 5 show the storage capacity and estimated cost of storage in the global potential reservoirs.

Current Practices of CO_2 Sequestration

Table 8 gives an overview of some current CCS projects in other parts of the world. By mid-2005, there were three commercial projects linking CO_2 capture and geological storage: the offshore Sleipner natural gas processing projects in Norway, the Weyburn Enhanced Oil Recovery (EOR) project in Canada and the In Salah Natural gas project in Algeria. About 3-4Mt CO_2 that would otherwise be released to the atmosphere is captured and stored annually in geological formations. In addition to the CCS projects currently in place, 30 $MtCO_2$ is injected annually for EOR, mostly in Texas, USA, where EOR commenced in the early 1970s. Most of this CO_2 is obtained from natural CO_2 reservoirs found in western regions of the US, with some coming from anthropogenic sources such as natural gas processing. Much of the CO_2 injected for EOR is produced with the oil, from which it is separated and then reinjected. At the end of the oil recovery, the CO_2 can be retained for the purpose of climate change mitigation, rather than venting to the atmosphere [6].

CCS Prospects in Nigeria

Nigeria produces and flares significant gas. The growing emphasis on gas utilization through power generation in Nigeria makes it important for national interest in CCS. This is because CO_2 emission is expected to rise with increasing use of natural gas domestically.

Energy consumption has been on an increase in Nigeria since 1980 as shown in Figure 3. A large percentage of the energy consumed is from oil and natural gas utilization. Table 6 shows different gas development options open to Nigeria and which should continue to increase gas utilization. With the given trend in the consumption of energy (including natural gas), there is bound to arise some issues associated with gas production. One such issue is gas flaring and its subsequent greenhouse gas emissions. Table 7 shows the gas produced vs. gas flared between 1999 and 2003. Figure 6 shows the profile for the global oil produced and gas flared between 1980 and 2000 while Figure 7 shows the similar profile for Nigeria between 1958 and 2000.

Significant increase in gas consumption through the existing and proposed power plants with the cement industries will lead to significant increase in CO_2 emissions. Figure 4 shows that CO_2 emissions have been increasing in Nigeria since 1960 due to industrialization. Thus, there is potential for CCS in the power and manufacturing sectors.

Futhermore, OPEC now realises that promotion of CCS technologies could ultimately lead to increased demand for oil and gas. Member states are therefore being encouraged to promote CCS technologies.

Enhanced oil recovery using carbon dioxide offers one of the most viable and environmentally acceptable options for sequestering captured CO_2. It is one of the opportunities in Nigeria.

The advantages of promoting EOR using CO_2 include:

- Utilisation of the large estimated storage capacity (in heavy oils and depleted reservoirs);
- The application of a proven and mature technology;
- Hazards are well known and can be minimized;
- Local expertise is developed;
- Increased production of heavy oils.

Apart from EOR and promotion of clean environment through the removal of greenhouse gases, CCS could bring other benefits to Nigeria, these include:

- The industrial utilization of the captured CO_2. This can be used directly for various applications like refrigeration, food packaging, etc.
- Keeping abreast of international trends in CO_2 emissions as well as CCS.
- Development of local capacity for CCS technologies.
- Promotion of fossil fuel utilization.
- Reduced hostility from communities located in areas prone to CO_2 emissions.

Challenges

- Technology: Local expertise in carbon capture and sequestration must be developed.
- Cost: additional costs to be incurred include cost of capture, compression, transportation and injection. This could translate to increased energy costs.
- Legal: Is CO_2 a waste? What are the environmental implications of CO_2 sequestration?
- Resources: there are a number of multi-disciplinary issues associated with CCS.

The major problem posed to CCS in Nigeria is the technical know-how and the cost of implementing the technology. Process and plant redesign would have to be undertaken on existing power plants. New power plants must think ahead in terms of CO_2 capture. Policy makers need to know what specifications and standards to put in place in future power plants. Infrastructural development (e.g. CO_2 pipeline networks) for the transport of captured CO_2 must be put in place. All these have cost implications which could make energy more expensive than it is today.

Legal frameworks need to be developed for CO_2 capture and storage, these must cover

- Policy enactment.
- Enforcement of CO_2 capture policy in the industry.
- The long-term safety and monitoring of CO_2 storage facilities.

Public awareness and the willingness of the public to pay more for energy in order to have a cleaner environment is a major challenge.

Recommendations

The following steps are recommended in implementing CCS in Nigeria.

- Research on CCS technologies should be encouraged in the tertiary institutions and energy research institutes.
- There is a need for a study on the actual CO_2 storage capacity in Nigeria.
- There is a need for greater awareness on CO_2 emissions by current and proposed power plants in Nigeria, as well as by cement manufacturing companies.

Conclusion

Gas flaring, solid fuels, liquid fuels, power generation and cement manufacture all contribute to CO_2 emissions. Carbon dioxide capture and sequestration technologies reduce these emissions and promote clean environment. Nevertheless, there are opportunities and challenges involved in the implementation of CCS. One opportunity is to convert the CO_2 "waste" to wealth through EOR.

There is need to study and know the national storage capacity for CO_2 and to acquire the technology for CO_2 capture and sequestration, in order to keep abreast of international development and best practices.

Acknowledgments

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Abbreviations

CCS	-	Carbon Capture and Storage
CO_2	-	Carbon dioxide (Carbon (IV) oxide)
EGR	-	Enhanced Gas Recovery
EOR	-	Enhanced Oil Recovery
GHG	-	Greenhouse gases
IGCC	-	Integrated Gasification Combined

		Cycle
IPCC	-	Intergovermental Programme for Climate Change
LPG	-	Liquified Petroleum Gas
NGCC	-	Natural Gas Combined Cycle
PC	-	Pulverised Coal
UNFCCC	-	United Nations Framework Convention on Climate Change

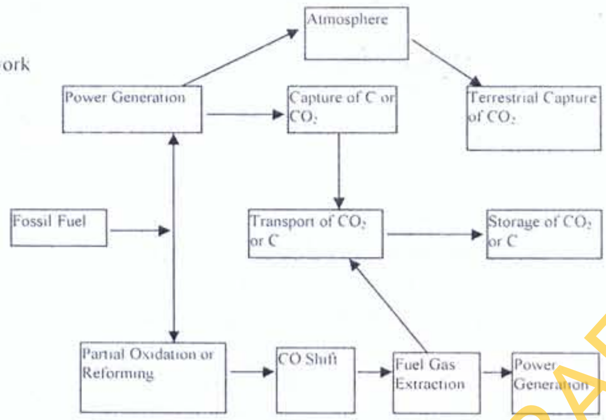


Fig 1: Capture and Sequestration of CO_2 from fossil fuels

Source: IPCC Special Report Carbon Dioxide Capture and Storage

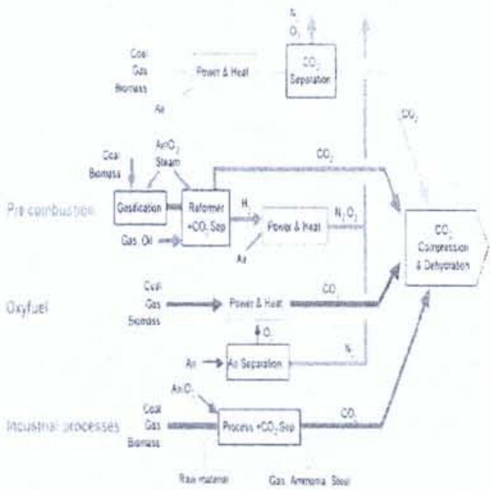


Figure 2: Overview of CO_2 capture processes and systems

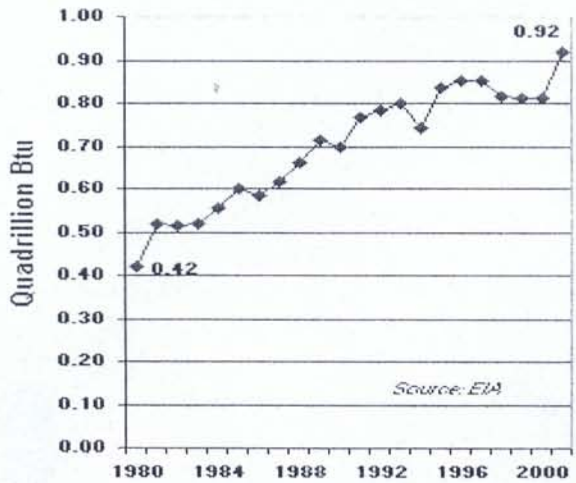
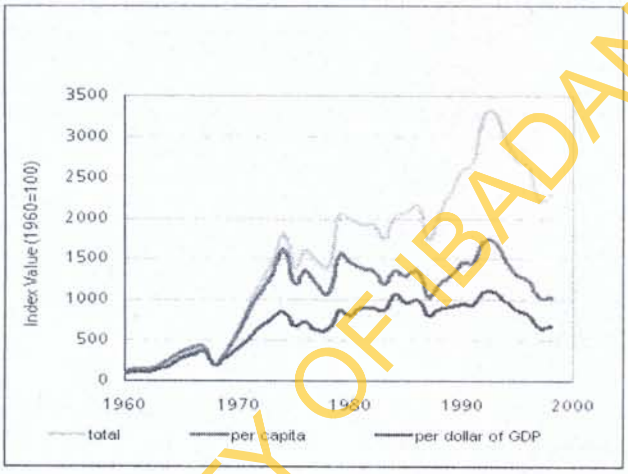


Fig. 3: Nigeria Energy Consumption (1980-2000)



Source: http//:earthtrends.wri.org

Fig. 4: CO_2 emissions: Relative Trends in Nigeria, 1960-1998

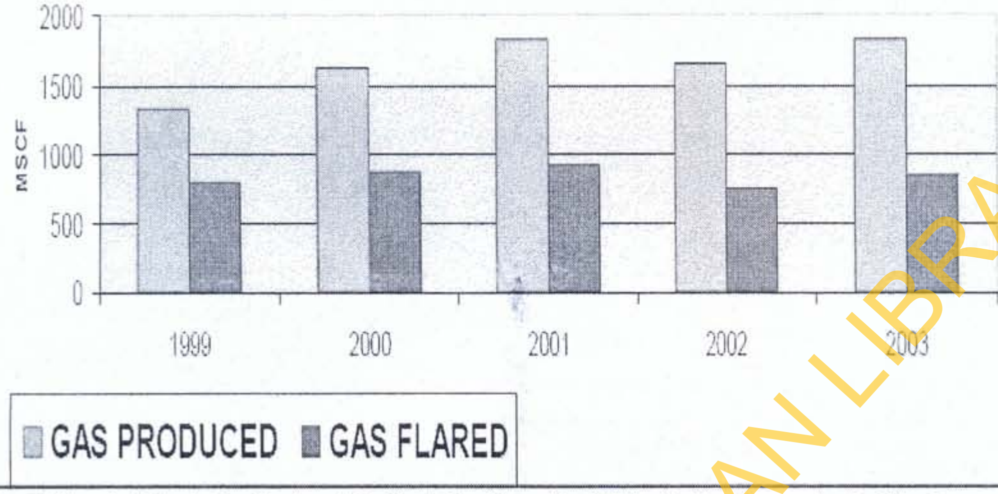
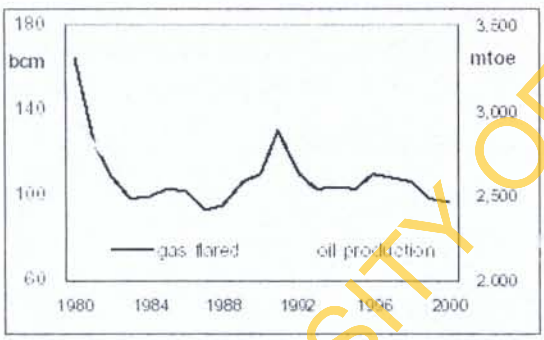
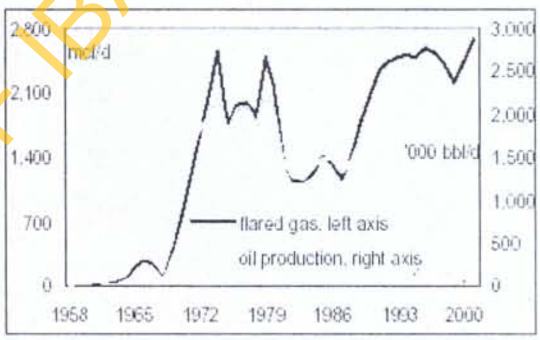


Fig. 5: Trend of Total Gas Produced Vs Total Gas Flared by Oil Producing Companies in Nigeria 1999-2003



Source: Johnston (2003)

Figure 6: World oil production and gas flaring



Sources: Harrison (1984) and Central Bank of Nigeria.

Figure 7: Nigerian oil production and gas flaring

Table 1: Carbon Dioxide (CO_2) Emissions by Sector (million metric tons), 1999 and 2001

	Total CO_2 Emissions	Public Electricity & Heat Production	Other Energy Industries	Manufacturing Industries & Construction	Internal Transportation	Residential	Other Commercial, Public and Agricultural Sectors
NIGERIA ('99)	43	6	7	9	16	3	2
WORLD ('99)	27,180	8,693	1,205	4,337	18.4	1,820	5,640
NIGERIA ('01)	56.1	6.7	6.45	6.17	23.3	5.2	0.0
WORLD ('01)	27,898	10,378	1,311	4,687	5,133	2,176	1,562

Sources: Harrison (1984) and Central Bank of Nigeria.

Source: http//:earthtrends.wri.org

Table 2: Carbon Dioxide (CO_2) Emissions by Source (thousand metric tons), 1998 and 2000

	Total CO_2 Emissions	Gaseous Fuels	Liquid Fuels	Solid Fuels	Gas Flaring	Cement Manufacture
NIGERIA ('98)	78,455	11,325	25,410	172	40,203	1,345
WORLD ('98)	24,215,376	4,470,080	10,160,272	8,654,368	172,208	758,448
NIGERIA ('00)	71079	13,674	21,057	172	34,930	1,246
WORLD ('00)	27,180	4,744,880	10,636,592	8,112,096	148,514	824,400

Source: http//:earthtrends.wri.org

Table 3: Cost of Electricity Generation for the US. (2020)[5]

Fuel	Cents/KW hr
Hydrgen	3.2
Natural gas	3.4
Coal	3.8
Gas (with Capture)	4.0
Coal (with Capture)	4.6
Conventional Oil	4.8
Biomass	5.3
Oil (with Capture)	5.4
Nuclear	5.8
Hydrogen Fuel cell	8.1

Solar	12.3

Table 4. Five Potential Reservoirs

Reservoirs	Range (billions of tonnes C)	
	Low	High
Deep Ocean	1,391	27,000
Deep Aquifers	87	2,727
Depleted gas Reservoir	136	300
Depleted oil Reservoir	41	191
Coal Seam	>20	

Table 5: Global Estimates of CO_2 Storage Capacity and Cost [5]

Global Carbon Storage Reservoirs	Range ($/tonnes C)	
	Low	High
Deep Ocean	$2.75	$13.50
Deep Aquifers	$3.50	
Depleted gas Reservoir	$6.00	
Depleted oil Reservoir	$6.00	
Coal Seam	< 0	$135.00

Table 6: Gas Development Options

	LPG plant	Gas cycling	Power generation	Methanol	Ammonia/ Urea	LNG
Product	LPG, condensate	Reinjection	Electricity	Methanol, hydrogen	Granulated Urea	Liquefied methane and ethane
Threshold field size to feedstock (BCF)	300-400	250-400	650	500	600	5000
Minimum feed (mcf/d)	60-80	40-75	85	60	80	385 tcm
% produced a year of project life	5-10%	7%	5%	5%	5%	4%
Project life, years	10-20	13	20	20	20	25
Capacity	60 mcf/d	30 mcf/d	500 MW	2000 tonnes/day	1,750 tonnes/day	5.5 mln tonnes/year
Markets	Local, export	Local	Local, grid needed	Export	Local	Export
Plant location	Local, port city	Local	Local	Port city	Local	Port city
Plant capital cost ($M)	50-60	75-100	350-400	250-300	300-400	2,500-3,000
Lead time	3 years	2-3 years	1 years	4 years	5 years	7-10 years

Source: adapted from Johnston (2003)

Table 7: Gas Produced Vs. Gas Flared by Companies (Mscf) between 1999 and 2003

COMPANY	1999			2000			2001			2002			2003		
	QTY Produced	QTY Flared	%Flared	QTY Produced	QTY Flared	%Flared	QTY Produced	QTY Flared	%Flared	QTY Produced	QTY Flared	%Flared	QTY Produced	QTY Flared	%Flared
JOINT VENTURE:															
SHELL	369,028,639	262,631,373	71.17	511,346,756	301,433,988	58.95	593,587,893	321,866,427	54.22	527,922,606	212,456,424	40.24	703,097,857	262,661,338	37.36
MOBIL	404.936.932	100.213.284	24.75	422,340,865	123,963,940	29.35	431,631,620	135,229,930	31.33	378,350,669	123,981,525	32.77	320,757,623	181,228,300	56.50
CHEVRON	202,525,614	198,112,501	97.82	214,291,482	204,239,820	95.31	216,161,767	148,239,311	68.58	197,133,906	102,960,919	52.23	207,250,100	128,284,853	61.90
ELF	37,632,831	34,815,054	92.51	98,128,755	37,512,462	38.23	111,953,117	42,134,124	37.64	122,444,099	44,002,030	35.94	138,676,284	49,644,800	35.80
NAOC	268,230,886	151,193,882	56.37	323,281,911	158,781,280	49.12	410,613,099	216,151,951	52.64	375,748,053	212,203,266	56.47	381,206,202	156,210,687	40.98
TEXACO	34,423,000	34,261,683	99.53	33,880,537	33,737,054	99.58	33,390,760	33,210,246	99.46	20,215,464	20,084,262	99.35	15,938,409	15,796,986	99.11
PAN-OCEAN	11,575,947	11,020,188	95.20	17,465,121	16,617,646	95.15	23,319,037	22,212,576	95.26	22,156,600	20,997,851	94.77	20,184,097	19,222,841	95.24
SUB-TOTAL	1,328,353,849	792,247,965	59.64	1,620,735,427	876,286,190	54.07	1,820,657,293	919,044,565	50.48	1,643,971,397	736,686,277	44.81	1,787,110,572	813,049,805	45.50
PRODUCTION SHARING															
ADDAX	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	40,723,887	32,261,507	79.22
SUB-TOTAL	0	0	0	0	0	0	0	0	0	0	0	0	40,723,887	32,261,507	79.22
SOLE RISK/INDEPENDENT															
NPDC	N/A	N/A	N/A	N/A	N/A	N/A	2,264,818	1,861,106	82.17	7,620,091	7,421,759	97.40	246,831	230,337	93.32
SUB-TOTAL	0	0	0	0	0	0	2,264,818	1,861,106	82.17	7,620,091	7,421,759	97.40	246,831	230,337	93.32
GRAND-TOTAL	**1,328,353,849**	**792,247,965**	**59.64**	**1,620,735,427**	**876,286,190**	**54.07**	**1,822,922,111**	**920,905,671**	**50.52**	**1,651,591,488**	**744,108,036**	**45.05**	**1,828,081,290**	**845,541,649**	**46.25**

SOURCE: From Monthly returns of the

Table 8:Some Major Current Sequestration Sites in the World[6]

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Project name	Country	Injection start (year)	Approximate average daily injection rate ($tCO_2\ day^{-1}$)	Total (planned) storage (tCO_2)	Storage reservoir type
Weyburn	Canada	2000	3,000-5,000	20,000,000	EOR
In Salah	Algeria	2004	3,000-4,000	17,000,000	Gas field
Sleipner	Norway	1996	3,000	20,000,000	Saline formation
K12B	Netherlands	2004	100 (1,000 planned for 2006+)	8,000,000	Enhanced gas recovery