Nigeria has all it takes to deploy Carbon Capture and Storage (CCS) technology for carbon emissions mitigation

EcoDataTrend

REMTrack

By

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Highlights

- Amongst the different greenhouse gases, carbon (IV) oxide (CO_2) remains one of the most significant, accounting for about 76% of total greenhouse gases globally and ~75% of total global warming
- The need for a rapid adoption of Carbon Capture and Storage (CCS) on a global scale is in line with the analysis provided by Intergovernmental Panel on Climate Change (IPCC) and International Energy Agency (IEA) that annual CO_2 storage rate needs to get to 10 Gtpa by 2050
- The entire value chain of the oil and gas industry provides an easy route where CCS can be deployed
- Natural gas processing and fertilizer manufacturing plants provide an avenue where there is existing technical expertise about handling the gas and also offers considerable low of cost of operations since the CO_2 gas is of high purity
- There are extant challenges and drawbacks that must be addressed before the sector can be on the right trajectory for CCS deployment in Nigeria; these are mainly rooted in lack of regulations and frameworks that would operate within the CCS industry

1. Introduction

The impact of climate change, particularly the occurrence of extreme weather events, is no longer a thing of the future–it is here. Global warming records are at an all-time high, with February 2024 being the world's hottest February, exceeding the previous hottest February 2016 by 0.12ºC [1]. This is in addition to the increasing occurrence of drought, deforestation, melting of polar ice caps, increasing sea levels and flooding of coastal areas all over the world. Due to these overwhelming impacts, there is a global agreement to address climate change as a transnational problem in line with the Paris Agreement of 2015.

According to the agreement, the world needs to limit temperature rise to below 1.5ºC compared to pre-industrial levels to avoid catastrophic effects of climate change. Hence, the need to comprehensively address the issue of greenhouse gas emissions, which is identified as the driving factor of increasing global temperatures. Amongst the different greenhouse gases, CO_2 remains one of the most significant, accounting for about 76% of total greenhouse gases globally [2] and ~75% of total global warming [3]. This is due to the continuous increase in the emission of CO_2 globally, as shown in Fig. 1 below. As a result, there is increased attention on mitigating the emission of CO_2 into the atmosphere.

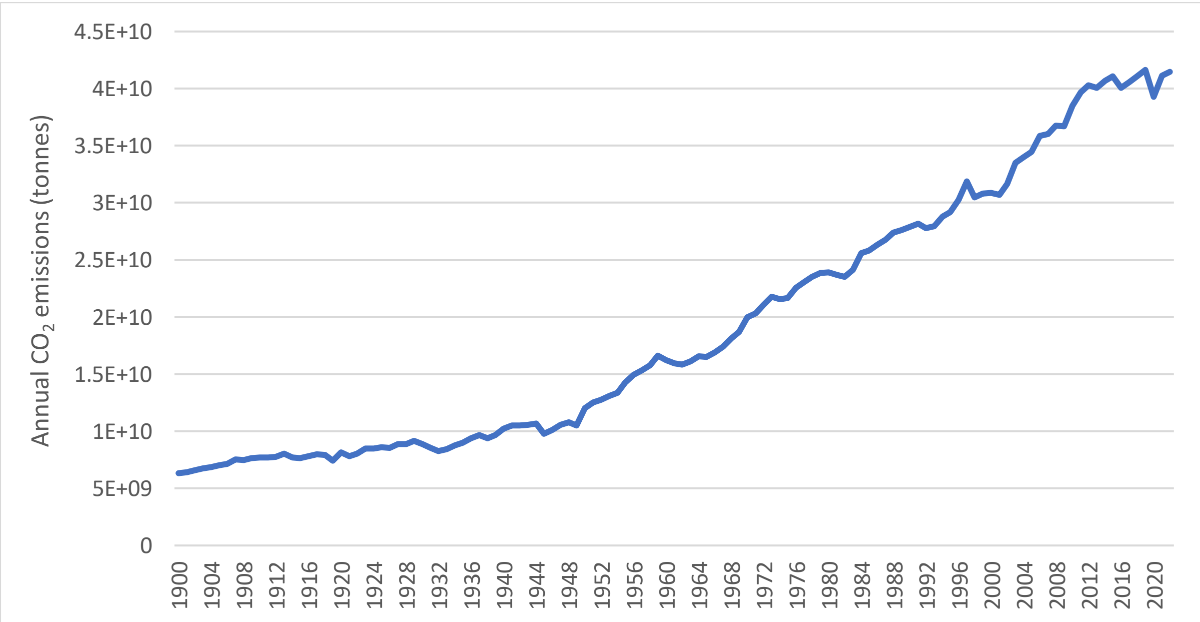

Fig.1. Global Annual CO_2 emissions from fossil fuels, industrial applications and land-use; Data Source: Ritchie and Roser [4]

The need to limit CO_2 emissions is further hinged on the fact that concentration of the gas in the atmosphere is currently at 424.55 ppm (in the month of February 2024) [5], a figure that is close to 430 ppm CO_2 ppm threshold, which climate scientists say the world would have gone beyond avoiding the dangerous impact of climate change. It is on this note that there is rapid development of different technologies that remove CO_2 from the atmosphere or limit its emission by capture, storage and utilization. These technologies include carbon dioxide removal (CDR) technologies (such as direct air capture, carbon mineralization, afforestation and reforestation and ocean fertilization etc.), and carbon capture and storage (CCS) technologies. However, it is important to note that this categorization remains a grey area as some authors posit that any technology that captures CO_2 for use is basically CCS; hence it is sometimes regarded as an umbrella term. Nonetheless in this article, CCS is distinguished from CDR.

Carbon Capture and Storage (CCS) has gained widespread acceptance amongst industry professionals and also some level of acceptance within the climate change mitigation community as an indispensable tool that needs to be deployed to reduce the amount of CO_2 released from industrial source points into the atmosphere. In fact, it is identified as a vital option to limit temperature rise in the scenarios modelled by the Intergovernmental Panel on Climate Change (IPCC). This acceptability is also based on the fact that CCS is a proven technology that has been in use within the last decades, especially in the oil and gas sector.

2. What are Carbon Capture and Storage Technologies?

Carbon Capture and Storage (CCS) technologies are used to capture CO_2 from industrial processes (e.g. steel and cement production facilities, power generating stations and operations of the oil and gas sector), transport the captured CO_2 to a site and consequently safely store in an underground system for permanent storage. It is important to note that there is also dimension of the utilization of the captured CO_2 [which is referred to as Carbon Capture, Utilization and Storage (CCUS)], however that is not the focus in this article. Technically, there are suites of technologies applicable at each stage of the CCS process; these technologies whose adoption is based on the emission source are currently at different stages of technological readiness level. Meanwhile, an overview of CCS technology that shows the utilization part is presented in Fig. 2 below.

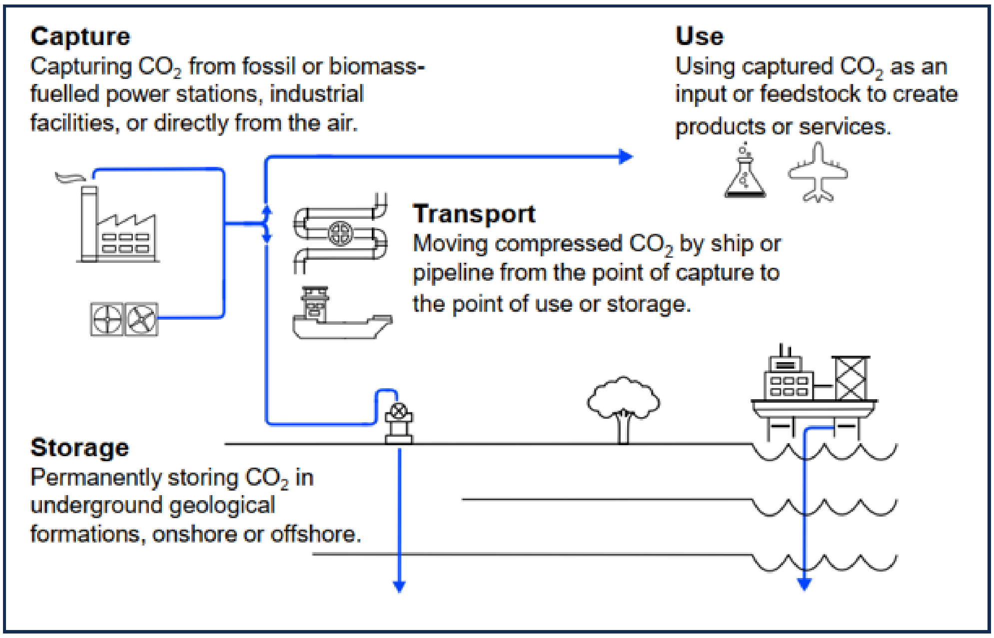

Fig. 2. Simple schematic of the CCS process. Adopted from McCulloch [6]

For the carbon capture phase, the popular technologies include post-combustion, pre-combustion and oxy-combustion CO_2 capture; post-combustion capture (particularly amine scrubbing technology used in the oil and gas industry) is well known and deployed, while others include adsorption, calcium looping technology, cryogenic, membrane and microbial which are at early stages of development. As for the transportation phase, there is the compression and transportation technology (using pipeline transportation of CO_2, ships or trucks; pipeline is found to be most cost effective). As regards the storage phase, it entails storing CO_2 in geological formations (such as depleted oil and gas reservoirs, saline formations and unmineable coal seams) or using CO_2 for enhanced oil recovery (which is currently utilized in the oil and gas industry).

Meanwhile, some analysts are of the opinion that the use of CCS is only necessary as climate change mitigation technology under certain circumstances. As outlined by Dr. Emily Grubert, an associate professor of sustainable energy policy of University of Notre Dame, there are four basic themes under which CCS infrastructure use falls. These are (i) extension of the end-of-life of fossil fuel infrastructure, (ii) use in systems where there are no zero carbon alternatives such as cement and petrochemical production (in cases where they are, their technological readiness level is low), (iii) its usage in removing carbon to compensate for other emissions (offsets) and (iv) its usage in removing legacy emissions.

The arguments about the applicability of these different CCS infrastructure usage are rooted in the fact that deployment of CCS is done to extend the use of fossil fuels, which most environmentalists frown against. For instance, as at the end of 2023, data shows that there are 45 CCS facilities deployed for the natural gas processing systems, power generation has 53 CCS facilities and the ethanol industry has 70 CCS facilities [7]. All these sectors depend on use of fossil fuels either as feedstock or source of energy, which can be replaced with other clean alternatives. The argument therefore lies in the fact that since there are alternatives [at advanced and commercial technological readiness level (especially renewable energy for electricity production)] that can replace the use of fossil fuel inclined technologies, resources that are currently committed to the adoption of CCS facilities should be directed to towards facilitating increased adopted of clean energy systems.

Considering these arguments, the key role of CCS as an energy transition technology is therefore inherent in the fact that it can decarbonize hard-to-abate industries (such as cement plants, steel mills and petrochemical facilities), whose entire operations would be difficult to transition to the use of clean energy sources (fuel switching inclusive) in the nearest future. Also, such possible alternatives are currently at low technological readiness level. In other words, CO_2 emission from these sectors is inherent in the chemical processes of these industries which cannot be switched for other alternatives.

Therefore, CCS remains an indispensable and critical technology that needs to be massively adopted by both public and private sector in these selected industrial application points, if the goals of Paris Agreement of 2015 will be achieved. Ironically, the cement industry that has no commercially ready alternative to its operations has the lowest number of CCS facilities at 22 as at the end of 2023 [7]. Further, the need for a rapid adoption of CCS on a global scale is in line with the analysis provided by Intergovernmental Panel on Climate Change and International Energy Agency that annual CO_2 storage rate needs to get to 10 Gtpa by 2050 [7], if global climate targets would be met.

With this in mind, the deployment of CCS technology has witnessed growth within the last decade, with over 300 million tonnes of CO_2 safely stored underground. In fact, within the last six years, the construction and development of CCS facilities have increased year-on-year at an average of 50.83% [7]. Currently, the total CO_2 capture capacity of global CCS facilities stands at 361 Mtpa as at July 31st, 2023 [7], which is equivalent to carbon emissions from about 88 million passenger vehicles on a yearly basis. Also, CCS has gained prominence in the public policies of most countries especially as a technology that can facilitate achievement of their Nationally Determined Contributions (NDCs).

Hence, it has become important for a country such as Nigeria that has indicated in its updated NDCs that it intends to unconditionally reduce emissions by a minimum of 20% by 2030 (compared to business-as-usual) [8], coupled with its net-zero target by 2050 as outlined in its energy transition (deep decarbonization) plan, to adopt CCS facilities in its hard-to-abate industries.

3. The value chain of the oil and gas industry remains a low-hanging fruit for deployment of Carbon Capture and Storage (CCS) technology in Nigeria

In spite of the arguments that CCS should not be used in fossil fuel-inclined industries, this position may not provide an enabling ground for the adoption of CCS in most emerging economies and developing countries, where there is little or no incentives to enable CCS usage in only hard-to-abate industries. For instance, in most of these countries, there are no tax credits/holidays/breaks that can incentivize industry stakeholders to adopt CCS, as that would increase the cost of operations. Also, there is a low tendency for customers to be willing to pay premium prices for products manufactured using this clean energy technology, which makes the business case unattractive.

Within this in mind, it is therefore important to focus on sectors that already have strong inclinations towards the technology–sectors that are not green horns to CCS infrastructure development and usage. In Nigeria, the oil and gas industry is one of such sectors that can be considered as a low-hanging fruit for CCS deployment, from where hard-to-abate sectors can be lobbied into adopting the technology. The entire value chain of the oil and gas industry provides an easy route where CCS can be deployed. Particularly, natural gas processing provides an avenue where there is existing technical expertise about handling the gas and also offers considerable low of cost of operations since the CO_2 gas is of high purity. It is important to note that the cost of CCS is largely determined by CO_2 capture process, hence a stream of high purity that does require extensive capture process reduces cost of operations [9].

Nigerian Liquefied Natural Gas (NLNG) Facility in Bonny Island, Nigeria. A natural gas processing facility with production capacity of 22 million Tons Per Annum (Mtpa) of LNG and 5 Mtpa of Natural Gas Liquids from its six-train plant complex

Also, fertilizer processing sector (which is a derivative of the oil and gas sector) is another action point where CCS can be deployed; the CO_2 stream from this process is also relatively pure and suited for capture. In Nigeria currently, there is some sort of integration between natural gas processing and fertilizer production, which allows for transference of technical know-how about handling the gas. For instance, most of these fertilizer processing plants are connected to network of pipelines can be re-purposed for CO_2 transport to storage sites. Also, a significant number of these natural gas processing and fertiliser manufacturing plants are located in same region (Niger Delta) where are there are existing depleted oil and gas reservoirs that can be used for gas storage.

This creates a potential system that can become a CCS cluster hub through extensive development of necessary infrastructure. Supporting this is the findings of Iain Macdonald[10] from Oil and Gas Climate Initiative (OGCI) who stated that there are four emissions hubs in Nigeria, with three of them emitting about 13 million tonnes of CO_2. In these hubs, Iain reported that CO_2 capture cost is estimated at about USD 100/tonne of CO_2, a figure that is in similar range where CCS facilities are deployed in other countries. In other words, these hubs can become CCS cluster under right conditions.

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Meanwhile, it is important to note that data about these reservoirs are available to oil and gas operators of these fields (which through effective collaboration can be shared), which eliminates the need to run extensive characterisation and investigation on these sites. With these advantages, it is possible to induce natural gas processing companies [such as Nigeria's foremost natural processing company, Nigerian Liquefied Natural Gas (NLNG) Company (although the company already stated their intention to adopt the technology) and Greenville LNG] and fertiliser companies to adopt CCS, using right policies that can make the business case of technology attractive to players in the sector. Such policies can be similar to the 45Q tax credit in the US that allows tax credit of USD 85 per tonnes of CO_2 captured and stored in a geological formation for a period of 12 years [11]. If such regulation is passed, these sectors are bound to become receptive to the technology.

Further, selected regulations and legislations driving the energy sector in Nigeria supports the use of clean energy technology; these include Petroleum Industry Act (PIA) 2021, Climate Change Act 2021, Nigeria Economic Sustainability Plan, Updated 2021 Nationally Determined Contribution and the country's Energy Transition Plan. These regulations all point to the fact that the country industrial sector needs to clean up its operations to make it sustainable in line with the tenets of energy transition. For instance, Climate Change Act provides a legal framework that dictates the need to attain low greenhouse gas emissions and foster climate action. In this case, although the Act does not mention any technology, CCS offers an evidence-based solution that can enable low emissions (especially in industrial applications). The PIA also lends it voice to the need to ensure environmentally safe operations, under which the Nigerian Upstream Petroleum Regulatory Commission has highlighted that CCS is a technology that it seeks to adopt.

In fact, a draft regulation recently released by the Nigerian Upstream Petroleum Regulatory Commission states that "with the consent of the Commission, the lessee may provide carbon capture and storage services with respect to reservoirs contained in the lease area". Such acreage is bound to provide opportunity where dry wells would be used for CO_2 storage if a CCS cluster hub is eventually developed. In essence, with these regulations, the oil and gas industry (and its entire value chain) is positioned to be a front runner industry can adopt the use of CCS, as an energy transition technology.

4. An Insight into the challenges and possible solutions of Carbon Capture and Storage (CCS) Adoption in Nigeria

In spite of the potential that the entire value chain of Nigeria's oil and gas industry has shown for adoption of CCS, there are extant challenges and drawbacks that must be addressed before the sector can be on the right trajectory for CCS deployment. One of challenges is inherent in the uncertainty that lies in the CO2 storage aspect, especially as concerning ownership of the pores in which CO_2 will be stored underground and by inference, who will be responsible for maintenance of these pores to prevent leakages in the long run. This ownership needs to be outlined in legislations so as provide clarity to companies that would want to develop CCS implementation programs, that would require identification of key stakeholders in the process. With such clarity, it also becomes possible to develop a functional CCS cluster hub.

Another challenge lies in the fact that there is currently no legislation in Nigeria that clearly presents a framework for CCS adoption. It is no brainer that players in the oil and gas sector would want a legal framework that would guide the functionality of CCS cluster hubs if they are to invest resources into the clean energy technology. Although there are extant laws and legislations that provide some context to CCS, these regulations fall short because they do not elaborately state the terms and conditions that would be adhered into when deploying the technology. Nonetheless, these laws should be consulted to provide foundational knowledge that would be critical to identifying any legal barriers that may impede the deployment of CCS and development of a legal framework for the technology. International Energy Agency developed an outlay of which regulatory categories to consider when developing a CCS framework for either the capture, transport and storage phase of the technology; this is presented in Fig. 3 below.

	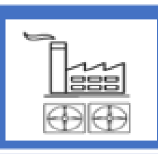	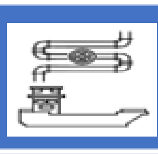	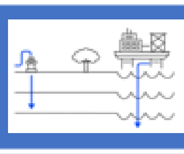
	Capture and Compression	Transport	Storage
Frameworks of the oil and gas industry	Pollution con troll requirements	Rights of way	Regulations of enhanced oil recovery
			Regulations of underground injection
		Regulations controlling abandonment and decommissioning of projects	
		Regulations influencing Development rights	
Safety and waste management	Regulations influencing hazardous waste materials		
	Regulations controlling occupational health and safety		
Frameworks of environment protection		Regulations controlling groundwater protection	
	Regulations influencing environmental impact assessment and permitting		

Fig.3. Outlay of extant regulatory categories to review when developing CCS regulatory framework, adopted from IEA[12]

Another challenge that faces deployment of CCS in Nigeria is the availability of finance. Recently, it is found that fossil fuel inclined projects are facing dwindling finance, which is further compounded by the fact that Nigeria received only 4% of total investment in Africa's oil and gas industry [13]. In similar vein, increased global competition for gas projects (which can be considered as transitional projects) has dropped for Africa from 12% in 2015 to around 5% [14]. This trend is attributed to growing interest for renewables amongst investors as sustainable investment gains ground. Therefore, getting the necessary finance to support the development of CCS in Nigeria, whose macroeconomic dynamics are unattractive might become difficult.

Nonetheless, innovative financing mechanisms [such as green and climate bonds, government-related finance (e.g. Inflation Reduction Act in the US), carbon pricing, climate finance and risk sharing mechanisms amongst others] can be explored to address this challenge. It is however important to note that equity financing is gaining grounds in global CCS financing totalling about USD 196 billion in 2022 [7] hence, it can be encouraged in this situation. Also, equity project finance can become an option in the future when the government incentives CCS projects and their economics become attractive due to learning curve effects.

Another challenge that needs to be addressed is the social acceptability of the technology. There is general distrust towards CCS amongst civil society organisations, with most of them seeing the technology as an excuse to continuously produce and utilize fossil fuels. Hence, if this concern is not addressed, the widespread adoption of CCS in Nigeria would likely face rebuffs from the general population, which may affect investment in the technology. As a result, there needs to be extensive stakeholder engagement on the suitability of CCS to enable energy transition in hard-to-abate sectors as the focus and their application in natural gas processing and fertilizer manufacturing sector as a low-hanging fruit opportunity.

5. Conclusion

In summary, the oil and gas industry (and its derivative value chains such as natural gas processing and fertilizer manufacturing plants) offers a low-hanging fruit for the deployment of CCS in Nigeria. While this is a summary drawn from the discourse in this article, it is vital to accentuate that there is a lot to be done to bring this to actualization, so that the technology can facilitate the achievement of the country's net-zero target by 2060, according to the country's Energy Transition Plan. Considering the disposition of the successive governments of Nigeria towards improving sustainable practices in industries, it is believed that the current government would likely follow suit, providing the right legislation and economic pedestal needed to enable adoption of CCS in this "low-hanging fruit" industrial application point. In essence, Nigeria has all it takes to be at the forefront of deploying carbon capture and storage technologies for CO_2 emission mitigation.

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