Decarbonizing Nigeria's Oil and Gas Industry: Strategies for Achieving Net-Zero Carbon Emissions

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Abstract- ***The urgency of decarbonization in the oil and gas sector cannot be overstated, as climate change poses a significant threat to the planet. It is also imperative as the global economy transitions toward a low-carbon future. Efforts to reduce carbon emissions are crucial for mitigating climate change and ensuring the long-term sustainability of energy industries. Nigeria, as one of the largest oil and gas producers in Africa, faces both challenges and opportunities in aligning with global decarbonization efforts. This paper examines key strategies for achieving net-zero carbon emissions within Nigeria's oil and gas sector, focusing on deploying carbon capture, utilization, and storage (CCUS), renewable energy integration, and electrification of operations. These technological innovations, alongside implementing firm policy frameworks such as those advanced by the Nigerian Upstream Petroleum Regulatory Commission (NUPRC), can accelerate Nigeria's decarbonization trajectory. Operational changes like optimizing energy efficiency, reducing flaring, and adopting cleaner fuels are explored as essential measures for the industry. The implications of these efforts for Nigeria's oil and gas sector are significant, requiring collaborative engagement from both the government and private sector. By adopting cutting-edge technologies and enhancing public-private partnerships, Nigeria can meet global decarbonization targets and secure a more sustainable energy future for the nation.***

Indexed Terms- ***Decarbonization, Oil and Gas Sector, Net-Zero Emissions, Carbon Capture, Utilization, Storage, Renewable Energy Integration, Electrification, Nigerian Upstream Petroleum Regulatory Commission (NUPRC), Public-Private Partnerships (PPPs), Sustainable Practices, Climate Change Mitigation, Energy Efficiency, Flaring Reduction, Clean Technologies, Government Initiatives, Investment Strategies.***

I. INTRODUCTION

In recent years, global decarbonization efforts have accelerated as climate change continues to pose significant risks to ecosystems, economies, and human livelihoods. The 2015 Paris Agreement marked a watershed moment in international climate policy, with 196 countries pledging to limit global warming to well below 2°C, preferably to 1.5°C above pre-industrial levels. Achieving these targets necessitates a drastic reduction in greenhouse gas emissions, particularly from carbon-intensive sectors like oil and gas. According to the International Energy Agency (IEA), the global energy sector is responsible for roughly three-quarters of global CO_2 emissions, with oil and gas production accounting for 42% of these emissions (IEA, 2022).

Countries and corporations are now investing in a wide range of decarbonization strategies, including carbon capture, utilization, and storage (CCUS), renewable energy adoption, and improving energy efficiency. In line with these efforts, energy companies are under increased scrutiny to adopt cleaner practices. Major oil-producing nations like Saudi Arabia, Norway, and the United States have set ambitious decarbonization targets. Norway oil company Equinor aims to reduce emissions from its oil and gas industry by 40% by 2030 and to achieve 70% by 2040, in line with the country's target to reduce emissions by 55% before 2030 (Reuter, 2020; Climate Action Tracker, 2023).

Nigeria, as the largest oil producer in Africa, is a major contributor to the global oil and gas industry. The sector contributes over 90% of Nigeria's value export earnings and a significant increase in government revenues (Statista, 2024). Nigeria's oil and gas sector, while contributing to economic growth, must balance its operations with environmental sustainability. Gas flaring, one of the industry's most significant environmental issues, contributes to 11.5 million

tonnes of CO_2 emissions annually in Nigeria, ranking it among the top flaring countries globally (Statista, 2024).

Decarbonizing this sector is critical for Nigeria's global climate commitments and also for the country's long-term economic viability. With the global transition towards cleaner energy sources gaining momentum, oil-exporting nations face the risk of reduced demand and stranded assets. Additionally, policies promoting decarbonization and the phasing out of internal combustion engines accelerate this decline. Consequently, oil reserves and infrastructure may become stranded—decreasing in value or becoming obsolete—posing significant economic challenges to oil-dependent economies. Environmental degradation in the Niger Delta region, where much of Nigeria's oil is extracted, has led to severe ecological damage, adversely affecting local communities and biodiversity. Implementing decarbonization strategies could reduce Nigeria's carbon footprint while improving environmental conditions and promoting economic diversification.

This article explores the strategic pathways for decarbonizing Nigeria's oil and gas industry, with a focus on technological innovation, policy frameworks, and regulatory measures. While the NUPRC's regulatory efforts are a step in the right direction, further advancements are required to fully realize the potential for carbon reduction in the Nigerian oil and gas industry. Stronger enforcement and adoption of innovative technologies are crucial to achieving this goal. (NUPRC, 2023). By examining existing decarbonization initiatives, emerging technologies like CCUS, renewable energy integration, and operational changes, this article seeks to highlight viable solutions for achieving net-zero carbon emissions in Nigeria's oil and gas sector. Also addressing the broader implications for the industry's future, considering both economic and environmental perspectives.

II. LITERATURE REVIEW

Overview of Global Decarbonization Technologies in Oil and Gas

The global oil and gas industry has been at the forefront of decarbonization efforts as countries and corporations strive to meet ambitious climate targets. Hon et. al. (2023) postulates that the global challenge of climate change requires concerted efforts from all nations. While a small group of countries has made significant strides in reducing emissions, many others continue to rely on fossil fuels. To mitigate the risks of climate change, it is essential to foster international cooperation and promote sustainable development practices. By working together, we can create a more sustainable future for generations to come. Among the key technologies driving these efforts is carbon capture and storage (CCS), which has proven essential in reducing emissions from hard-to-abate sectors like oil and gas. According to the Global CCS Institute (2023), CCS presently has 41 commercial-scale facilities with over 350 in development actively capturing over 49 million tonnes of CO_2 globally each year through CCS projects. While CCS offers a promising solution, critics argue it will potentially prolong fossil fuel reliance, with environmental risks such as CO_2 leakage from storage sites. High costs and infrastructure challenges also hinder its feasibility, especially in developing economies, where investments in CCS may divert resources from renewable energy solutions (Center for Biological Diversity, 2021).

Renewable energy integration is another critical strategy, where oil and gas companies are investing in renewable energy sources, such as solar and wind, to power their operations. This shift reduces their carbon footprint while allowing them to diversify their energy portfolios (Haiying Liu, Pengcheng Han, 2024). Hydrogen technologies are also gaining momentum as a means of decarbonizing energy-intensive industries. Blue hydrogen, produced from natural gas with carbon capture, and green hydrogen, produced via renewable energy, are seen as potential fuels for the future (Felseghi et al., 2014). The Oil and Gas Climate Initiative (OGCI) has identified hydrogen as one of the key pillars of the energy transition, with major oil companies working to scale up hydrogen production and infrastructure globally (OGCI, 2023).

Decarbonization Efforts in Nigeria's Oil and Gas Industry

Nigeria has been steadily making strides towards decarbonizing its oil and gas sector, demonstrating a commitment to environmental sustainability and a

greener future. One of the key initiatives includes tackling gas flaring, which has long been a significant contributor to Nigeria's carbon emissions. According to the World Bank, gas flaring in the country has been reduced by 45% in the last decade, yet it remains a persistent issue (World Bank, 2023). Another area of focus is energy efficiency in production facilities where Nigeria has adopted some measures to reduce energy consumption in upstream operations, although these efforts are largely concentrated within multinational companies with the resources to invest in cleaner technologies (Oruwari, Humphrey & Ubani, Ajuzieogu, 2023).

While significant strides have been made, Nigeria's decarbonization journey still has room for further progress. The industry still relies heavily on fossil fuels, and the country has yet to fully embrace cleaner technologies like CCS or hydrogen. Currently, renewables account for only 21% of the country's energy mix between 2011 and 2023. This presents a promising opportunity for expansion and diversification in the energy sector (Statista, 2024). Despite recent progress, Nigeria's oil and gas industry still faces significant challenges in achieving the level of decarbonization necessary to contribute to global climate goals.

Regulatory and Policy Frameworks for Decarbonization

The Nigerian Upstream Regulatory Petroleum Commission (NUPRC) has been instrumental in developing policies aimed at reducing carbon emissions in the oil and gas sector. One of the commission's key frameworks is the Nigerian Gas Flare Commercialisation Programme (NGFCP), which incentivizes companies to convert flared gas into useful products like liquefied natural gas (LNG) or electricity. The NUPRC has also introduced penalties for gas flaring, aiming to push companies towards reducing emissions (NUPRC, 2022).

Internationally, Nigeria has committed to various climate agreements, such as the Paris Agreement, which requires the country to submit national climate action plans, known as Nationally Determined Contributions (NDCs). Nigeria's revised Nationally Determined Contribution (NDC) reaffirms the country's commitment to reducing emissions by 20% by 2030, based on a business-as-usual scenario. Additionally, Nigeria has raised its conditional target for emissions reductions from 45% to 47%, contingent upon receiving international support (UNDP, 2023). Nigeria must address significant challenges to effectively enforce these policies and achieve desired outcomes. While efforts have been made to establish frameworks like the Nigeria Energy Transmission Plan, future success in achieving net-zero emissions will depend on strengthening monitoring and enforcement mechanisms.

Challenges of Decarbonization in Developing Economies

For developing economies like Nigeria, decarbonizing the oil and gas sector presents unique challenges. Infrastructure limitations are among the most significant barriers. CCS and hydrogen technologies require advanced infrastructure and investment, which Nigeria lacks. Ogbo et al., (2024) identified technical barriers such as inadequate infrastructure and expertise, high cost, regulatory policies, and lack of awareness as the main challenges faced by Nigeria in introducing CCS and other decarbonization strategies. Innovative solutions are required to address the limitations of the current energy infrastructure and accelerate the transition to a low-carbon future. Funding constraints are also a main challenge in decarbonization as the oil and gas industry is capital-intensive, and while developed economies have access to green financing and investment, Nigeria faces difficulties attracting the necessary funding (UKNIAF, 2024). Political instability and regulatory uncertainty further increased the problem, discouraging foreign direct investment (FDI) in clean energy projects. Increased political will is required to accelerate the transition to a low-carbon future. The economic considerations associated with transitioning away from fossil fuels can pose significant challenges for developing nations like Nigeria. Balancing the need for energy security with environmental sustainability requires careful planning and policy implementation. (Ochi et al. 2022).

III. TECHNOLOGICAL INNOVATIONS FOR DECARBONIZATION IN NIGERIA

Carbon Capture, Utilization, and Storage (CCUS)

Carbon Capture, Utilization, and Storage (CCUS) is a key technology that can significantly reduce CO_2 emissions in Nigeria's oil and gas sector. CCUS involves capturing CO_2 emissions from industrial sources, then either utilizing them in commercial products or storing them underground to prevent them from entering the atmosphere.

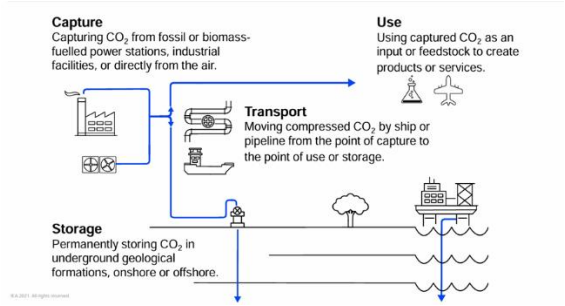

Fig 1: Carbon Capture, Utilization, and Storage (CCUS): An Overview

Source: International Energy Agency (IEA)

Globally, CCUS is considered essential for achieving climate goals set by the Paris Agreement. However, the deployment of CCUS technologies in Nigeria has been slow due to high costs, limited infrastructure, technical challenges, and proper legal framework (A. P., and A. S. Nwosi-Anele, 2024). Major players like ExxonMobil, Shell, Chevron, and TotalEnergies have initiated CCUS projects globally and are exploring options for Nigeria, but large-scale adoption is limited. Shell's "Quest" project in Canada has sequestered over 3 million tons of CO_2 between 2015-2018, showing the potential for similar deployments in Nigeria (Doung et al., 2018).

Renewable Energy Integration

The integration of renewable energy into the oil and gas sector is an increasingly viable path toward reducing emissions. Nigeria has vast solar energy potential, and integrating solar power into oil and gas operations, such as powering some parts of offshore rigs or onshore facilities, can drastically cut emissions. A 2021 report by Osman et al., 2023 highlighted that the adoption of renewables, including solar, wind, and hydropower, could help Africa reduce its energy-related CO_2 emissions by nearly 90% by 2050. Nigeria's oil companies, such as TotalEnergies, are already moving towards incorporating solar into their operations. However, infrastructure challenges and investment shortfalls remain significant barriers to widespread adoption (TotalEnergies, 2023).

Integrating renewable energy, such as solar power, into Nigeria's oil and gas sector as part of a decarbonization strategy is both visionary and challenging. Given Nigeria's position as a developing nation, the feasibility of solar panels powering oil plants is indeed complex. The sheer scale of solar infrastructure needed to significantly power oil and gas operations would be immense. Nigeria's oil facilities are extensive, and to generate enough power solely from solar would require a vast number of solar panels, which may be financially and logistically overwhelming.

While Nigeria is blessed with abundant sunlight, which is advantageous for solar energy, the capital and technology requirements for extensive solar infrastructure present significant hurdles. The manufacturing, installation, and maintenance of such large-scale solar systems are costly, and without subsidies or substantial investment, they might be out of reach for the industry in the short term. Additionally, solar power's intermittent nature means that additional systems—like battery storage or supplementary energy sources—would be necessary to ensure consistent power, particularly given Nigeria's unreliable grid.

However, this doesn't rule out the possibility of integrating solar power in a phased or hybrid approach. Rather than aiming to have solar power the entire operation, it may be more realistic and effective to integrate solar alongside other low-carbon energy sources, like natural gas, in a modular way. This approach allows for reduced emissions while maintaining reliable energy supply without overwhelming financial strain. In the long term, as renewable technologies evolve and costs decrease, solar could play a more prominent role in powering Nigeria's oil and gas facilities.

Thus, while solar alone might not be feasible right now as the sole power source for oil and gas operations, a blended approach that gradually increases the share of renewable energy could be a practical pathway toward decarbonizing Nigeria's oil and gas industry.

Also to improve renewable energy, the Daystar power project was introduced by Shell to reproduce 594kWp of solar capacity with 600kW battery storage in conjunction with RMI (Daystar Power, 2023).

Hydrogen and Other Clean Technologies

Hydrogen, particularly green and blue hydrogen, is becoming an increasingly important technology in decarbonization efforts. Green hydrogen, produced using renewable energy, and blue hydrogen, made from natural gas with CCUS, are seen as potential game-changers for the oil and gas industry. Aminul et al., 2024 described Hydrogen as a viable alternative source of energy if the cost of production and challenges such as transportation are addressed, providing a cleaner and sustainable energy source compared to other sources such as fossil fuel. In Nigeria, hydrogen could serve as a clean energy source for industrial processes, particularly in refining and petrochemical production. Globally, hydrogen technologies are being adopted by energy giants such as BP and Shell, who are exploring hydrogen projects that could potentially be replicated in Nigeria (Reuters. (2022). However, Nigeria is currently working on the necessary infrastructure and investment to scale up hydrogen production and usage.

Electrification of Oil and Gas Operations

Electrification of oil and gas operations, such as replacing gas-powered equipment with electric alternatives, offers a direct method for reducing carbon emissions. Electrification would allow Nigerian oil and gas operations to transition away from fossil fuel-based energy sources, particularly in upstream and midstream activities. Electrification is a demand-side decarbonization approach that currently lacks systemic coordination, resulting in scattered, case-by-case applications. However, the transport sector—specifically in mobility—has seen alignment between demand and supply through electrification initiatives, such as electric vehicles, which benefit both decarbonization efforts and business objectives (Icaro, 2023). The Nigerian National Petroleum Corporation (NNPC) and multinational companies like Chevron have begun exploring electrification as part of their broader decarbonization strategies. However, achieving this at scale requires significant upgrades in Nigeria's energy infrastructure, including the expansion of the national grid and the development of renewable energy capacity to power these operations (Belhouari, 2022).

IV. POLICY AND REGULATORY FRAMEWORKS FOR DECARBONIZATION

Nigerian Upstream Regulatory Petroleum Commission (NUPRC)

The NUPRC has introduced several policies to drive decarbonization within Nigeria's oil and gas sector. These include initiatives such as the introduction of environmental guidelines for greenhouse gas (GHG) emissions, initiatives on gas to power, and efforts to curb gas flaring, which has long been a major contributor to Nigeria's carbon footprint. One key policy is the Gas Flaring (Prohibition and Punishment) Act, aimed at reducing flaring and encouraging the development of gas for domestic use. It imposes penalties on companies that flare gas and requires the development of gas utilization projects to ensure that gas is captured and used efficiently. The commission promotes best practices in emissions management, requiring operators to adopt cleaner technologies and energy-efficient processes (Nwokike, 2020). Another policy introduced by the NUPRC to enforce environmental management standards is through the Environmental Guidelines and Standards for the Petroleum Industry in Nigeria (EGASPIN) guidelines. These guidelines address emissions control, waste management, and pollution prevention within oil and gas operations. They also mandate regular environmental audits and compliance monitoring to ensure that companies adhere to emissions reduction targets (IEA, 2022). The Nigerian Gas Master Plan (NGMP), although primarily a broader national initiative, NGMP is integrated into NUPRC's regulatory framework and promotes the development of gas infrastructure to facilitate gas-to-power projects and reduce gas flaring. By providing a strategic framework for gas utilization, the NGMP encourages companies to invest in gas processing and transportation infrastructure, further reducing the industry's carbon footprint (Nigeria Ministry of Petroleum Resources, 2008). However, enforcement has been challenging, and the NUPRC is working to strengthen the penalties and compliance measures to meet its decarbonization goals.

Government Initiatives and Global Commitments

Nigeria has committed to global decarbonization targets, most notably through its ratification of the Paris Agreement. Under this framework, Nigeria has pledged to cut carbon emissions by 20% by 2030 (rising to 45% with international support). The country's Nationally Determined Contributions (NDCs) outline a commitment to expanding renewable energy use, reducing gas flaring, and improving energy efficiency in oil and gas operations (UNDP, 2023). Also, Nigeria's Energy Transition Plan (2022) created with COP26, further outlines the country's roadmap toward achieving net-zero emissions by 2060 while ensuring energy access and economic growth. The plan is built on five critical sectors, power, oil and gas, cooking, transport, and industry with a focus on scaling renewable energy, electrification, and cleaner fuels. It highlights Nigeria's ambition to decarbonize its energy sector by expanding solar and other renewable sources while reducing reliance on fossil fuels like oil and gas. The plan also addresses the need for increased financing, technological advancements, and policy reforms to facilitate the transition, especially given Nigeria's dependence on oil revenue (UKNIAF, 2024).

Opportunities for Policy Improvements

Despite these commitments, there remains significant potential for enhancing Nigeria's regulatory framework in addressing emissions, particularly in terms of penalties for non-compliance. Current penalties for gas flaring, while undergoing consistent review, could benefit from stronger enforcement measures to ensure companies strictly adhere to regulations. Strengthening these penalties, through more stringent fines and enhanced surveillance, would act as a more powerful deterrent against environmentally harmful practices. Expanding incentives to encourage the adoption of cleaner technologies is also important. Policymakers could offer increased tax breaks or financial support for companies investing in renewable energy solutions such as solar and wind, or adopting advanced carbon capture and storage (CCS) technologies (Energy Capital & Power, 2023). In addition to fiscal incentives, the introduction of a carbon pricing mechanism could be instrumental in accelerating Nigeria's decarbonization efforts. A carbon pricing system, which charges companies based on their carbon emissions, would create a financial disincentive for high-emission activities. This would not only encourage a shift toward cleaner energy alternatives but also drive investment in low-carbon technologies. Following global best practices such as the European Union's Emission Trading System (ETS), Nigeria could significantly bolster its decarbonization efforts by integrating carbon pricing policies (UNFCCC, 2018).

Role of Public-Private Partnerships

Public-Private Partnerships (PPPs) are essential in advancing decarbonization efforts by ensuring collaboration between the government and private sector entities. In Nigeria, these partnerships are crucial for driving investments in clean energy technologies, particularly in the oil and gas sector. Chevron Nigeria Limited (CNL), in collaboration with the Nigerian government, has been actively involved in reducing gas flaring and investing in cleaner technologies. One notable example of how this partnership works is the Chevron Escravos Project. The project, which focuses on gathering and processing gas to reduce flaring, has significantly lowered emissions while creating economic benefits for the region. Chevron's ongoing initiatives align with Nigeria's Energy Transition Plan, aiming to reduce greenhouse gas emissions and support cleaner energy alternatives (Hydrocarbons Technology, 2013). In collaboration with the Nigerian government, TotalEnergies has also been involved in initiatives aimed at transitioning Nigeria's oil and gas sector toward a lower-carbon future OML 100 Flare Out project (Petroplat, 2023).

V. OPERATIONAL CHANGES REQUIRED TO ACHIEVE NET-ZERO TARGETS

Optimizing Energy Efficiency in Oil and Gas Operations

Improving energy efficiency in oil and gas operations is essential for reducing carbon emissions and achieving net-zero targets. Strategies include upgrading equipment, employing advanced technologies such as automation systems and active data analytics, implementing energy management systems to detect inefficiencies, and allowing operators to take cost-effective corrective actions that limit emissions. TotalEnergies has made significant

strides in energy efficiency by integrating smart technologies into its operations, leading to reduced energy consumption and lower emissions (TotalEnergies, 2023). Chevron implemented a comprehensive and detailed system known as the Operational Excellence Management System (OEMS). Its purpose is to enhance health, environmental, and safety performance through structured practices and continuous improvement measures. Chevron's initiatives in Nigeria, focusing on energy efficiency audits and the optimization of production processes, have demonstrated notable reductions in energy use across their operations (Chevron, 2022).

Reducing Flaring and Venting

Gas flaring and venting are among the most pressing operational challenges in Nigeria's oil and gas sector. Gas flaring, a significant issue in the oil and gas industry, involves burning excess gas due to safety concerns or infrastructure limitations. There are different types of flaring which include production flaring during oil extraction, routine flaring from daily operations, non-routine flaring during equipment failures or emergencies, and well-testing flaring during exploration. Venting, where gases like methane are released unburned, poses a significant environmental hazard. Reducing these practices, particularly through gas capture technologies, is crucial for decarbonization in the industry (Global Gas Flaring Reduction Partnership, 2021).

Despite efforts such as the Nigeria Gas Flare Commercialization Program (NGFCP), flaring remains widespread due to infrastructure deficits and the high costs of gas capture technology. The NGFCP was designed to monetize flared gas by inviting investors to turn it into electricity or liquefied natural gas (LNG) (Anioke et al.,2020). Although promising enforcement has been inconsistent and penalties for non-compliance have been rolled out by NUPRC policies, stringent enforcement is needed to dissuade companies from flaring. Projects like the OML 100 Flare Reduction Project aim to minimize flaring through improved gas capture technologies, showcasing the potential for operational changes to enhance environmental performance (NNPC Group, 2024).

Transitioning to Cleaner Fuels

The transition to low-carbon fuels and biogas in oil and gas operations is important for reducing the carbon footprint. Companies are exploring the use of liquefied natural gas (LNG) and biogas as alternatives to traditional fossil fuels. The Nigerian government supports initiatives to promote LNG, which emits fewer greenhouse gases compared to crude oil (IEA, 2023). While natural gas has been promoted as a cleaner alternative to diesel in power generation, its integration into oil and gas operations has been slow due to infrastructure limitations. The shift to biogas and other renewable energy sources faces similar obstacles, including high upfront costs sustainability, and lower emissions, providing a dual benefit of waste management and energy production (Jameel et al., 2024). Notable progress in this area can be seen in TotalEnergies' hybrid power plant in Nigeria, which combines solar energy with conventional power to reduce emissions in oil and gas operations. Expanding the use of renewable energy, alongside alternative fuels, will require increased investment in R&D and enhanced infrastructure (TotalEnergies, 2023).

Sustainable Supply Chain Practices

Encouraging sustainable procurement and transportation practices within the oil and gas supply chain can be significant to achieving net-zero goals. This includes adopting sustainable sourcing policies, enhancing logistics efficiency, and minimizing waste. Sustainable procurement involves the selection of low-emission equipment and materials to reduce the environmental impact. Chevron's supply chain initiatives emphasize local sourcing and the use of renewable energy in transportation to decrease the environmental impact (Chevron, 2024). Similarly, TotalEnergies has committed to working with suppliers to implement sustainability criteria, ensuring that environmental considerations are integrated into the supply chain (TotalEnergies, 2023). Optimizing transportation networks through electrified logistics or switching to low-emission vehicles can reduce carbon emissions associated with the movement of raw materials and finished products (Chevron, 2020). However, Nigeria's supply chain infrastructure remains a significant challenge, and more collaboration between the government and private sector is required to set, monitor, and enforce sustainability standards (Emam, 2015).

VI. CASE STUDIES

Case Study 1: Decarbonization Efforts in Nigeria's LNG Sector

Nigeria LNG (NLNG) has made significant strides in reducing carbon emissions through a combination of technological advancements and operational efficiencies. NLNG has optimized its gas liquefaction processes, leading to reduced energy consumption and fewer emissions during production. The company has been effective in the National Gas Flare Commercialization Programme, utilizing technologies to capture and repurpose flared gas by which NLNG has been able to reduce gas flaring by 20%. Escravos Gas to Liquid project in the Niger Delta is an example of this initiative. This initiative aligns with Nigeria's broader goals to reduce flaring and boost energy efficiency, significantly cutting down emissions. More initiatives like this have been developed over the years in the creation of gas to liquid, some of which include; The company has also invested in cleaner alternatives for powering its operations, such as natural gas-based solutions, which are less carbon-intensive than traditional fossil fuels. These decarbonization efforts mark a shift toward sustainable operations, though scaling these technologies across Nigeria's oil and gas sector will be important to meeting broader environmental goals (NLNG, 2022; Alozie, 2024; Hydrocarbons Technology, 2024)

Case Study 2: Global Best Practices in Decarbonization

Global examples like Norway and Qatar demonstrate how decarbonization in the oil and gas industry can be achieved through both policy and technological investment. In Norway, the state-owned company Equinor has implemented carbon capture and storage (CCS) projects such as Sleipner and Snøhvit, capturing over 23 million tonnes of CO2 since their inception. These CCS initiatives not only curb emissions but also set an international standard for carbon management (Equinor, 2023; IEEFA, 2023; Maldal et a;, 2004). In Qatar, heavy investments in CCS and renewable energy integration within the liquefied natural gas (LNG) sector have significantly lowered the carbon footprint of their energy exports. Qatar's long-term strategy includes enhancing energy efficiency and incorporating solar energy into the gas processing stages, reducing its overall emissions intensity (IEA, 2022; Alsheyab & Mohammad. 2017). Nigeria can adopt similar approaches by advancing carbon management policies and investing in clean technologies that integrate renewable energy and capture carbon emissions. Another notable case of CCU utilization is Malaysia Petronas, a project worth over U.S. 1 billion, implemented with the sole aim of achieving net-zero greenhouse gas emissions (IEEFA, 2023).

Case Study 3: Public-Private Collaboration in Oil and Gas Decarbonization

Public-private partnerships (PPPs) have been effective in decarbonization, one notable example is the technical partnership between the NNPC Energy Services Limited (EnServ) and Schlumberger (SLB) to improve energy production while addressing and ensuring reduction. This partnership cuts emissions and also produces a shift in energy production (Oil Review Africa, 2023). Another notable partnership is the partnership between the research, technology, and innovation unit of the NNPCL with Ceesolar Energy in decarbonization efforts through its partnership with the Nigerian government to reduce emissions by implementing sustainable solar utilization strategies, (CEE Solar, 2022). Other partnerships as noted by ICEED 2013, include ExxonMobil establishing a 500 MW Independent Power Plant (IPP) in Akwa Ibom State, contributing significantly to Nigeria's power generation capacity. Similarly, Nigerian Agip Oil Company (NAOC) developed the Okpai Power Plant, which operates at full capacity, supplying 480 MW to the national grid. Shell Petroleum Development Company (SPDC) created the Afam Integrated Gas and Power Project, designed to contribute 650 MW to the national grid. Mobil Producing Nigeria Unlimited (MPNU) launched the Eket Qua Iboe Terminal (QIT) IPP, enhancing power supply. Additionally, the SUNGAS project in the Niger Delta focuses on utilizing gas for power generation. The Living Earth Foundation, in partnership with SPDC, also initiated a community-based utility using associated gas to provide electricity to a community in the Niger Delta (ICEED, 2013). Expanding these partnerships to cover renewable energy projects and electrification initiatives like these projects can further accelerate Nigeria's progress toward achieving net-zero targets.

VII. FUTURE OUTLOOK AND RECOMMENDATIONS

To ensure long-term sustainability, Nigeria's oil and gas industry must embrace a diversified energy mix, including renewable energy sources, and explore innovative solutions to reduce its carbon footprint. As the global energy landscape evolves, Nigeria must adapt to the changing dynamics of the oil and gas industry and embrace a more diversified economic approach. The country's future depends on the successful integration of clean energy solutions and the reduction of greenhouse gas emissions across its oil and gas operations. Investment in renewable energy, sustainable practices, and innovative technologies will be critical in maintaining competitiveness.

Strategies for Accelerating Decarbonization

To accelerate decarbonization, Nigeria must adopt cutting-edge technologies such as carbon capture, utilization, and storage (CCUS), and invest in the electrification of its oil and gas operations. The country can also improve efficiency by implementing digital technologies like artificial intelligence and data analytics, which optimize energy consumption in both upstream and downstream operations. Strengthening regulatory frameworks to enforce emission reduction targets, while providing incentives for clean energy investments, will also improve the transition. Collaboration between private sector players and government agencies is very important for expanding these initiatives.

Investment in Clean Energy

Investment in renewable energy and clean technologies is fundamental to sustaining Nigeria's decarbonization efforts. Expanding solar, wind, and hydropower generation, particularly in partnership with multinational energy companies, will help reduce the country's dependence on fossil fuels. Investing in infrastructure for hydrogen production and electrification of transportation systems will also create new revenue streams and support the global energy transition. Diversifying investments beyond oil and gas, into areas such as energy storage and grid modernization, is necessary to ensure long-term economic stability.

Recommendations for Policymakers and Industry Leaders

Policymakers and industry leaders must take bold steps to drive the decarbonization agenda forward. Key recommendations such as strengthening regulations involve the introduction of stricter penalties for flaring and venting and creating incentives for adopting cleaner technologies. Public-private partnerships will ensure collaboration between the government and private companies to develop clean energy projects and infrastructure. Diversifying the Economy will encourage the development of non-oil sectors, such as agriculture, manufacturing, and renewable energy, to manage the risks associated with declining fossil fuel revenues. Lastly, capacity Building by investing in research, innovation, and workforce development to ensure Nigeria's energy sector can adopt new technologies and remain competitive globally.

CONCLUSION

The future of Nigeria's oil and gas industry is shaped by global decarbonization trends and the growing need to reduce carbon emissions. As international markets shift towards cleaner energy sources, Nigeria must prioritize operational changes and technological innovations to remain competitive. The deployment of carbon capture, utilization, and storage (CCUS), renewable energy integration, and electrification in oil and gas operations represent key opportunities for achieving significant emission reductions. Furthermore, sustainable supply chain practices and the transition to low-carbon fuels will contribute positively to optimizing energy efficiency.

Public-private partnerships (PPPs), such as collaborations between the Nigerian government, Shell, Chevron, and TotalEnergies, have already demonstrated the potential of joint initiatives to drive decarbonization. By expanding these partnerships to focus more on renewable energy and electrification, Nigeria can accelerate its transition toward a more sustainable energy future. However, to fully realize these benefits, Nigeria must also strengthen its regulatory framework, enhance incentives for clean energy adoption, and enforce stricter penalties for non-compliance with decarbonization targets.

The future outlook for Nigeria's energy sector highlights the importance of diversifying investments into renewable energy and clean technologies. Policymakers and industry leaders must take proactive steps, such as implementing carbon pricing mechanisms and enhancing public-private collaborations, to guide the country toward achieving its net-zero goals. By adopting cutting-edge technologies and aligning with global decarbonization commitments, Nigeria can position itself as a leader in sustainable energy, ensuring long-term economic growth and environmental stewardship.

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