Petroleum and Coal

Article **Open Access**

Policy Frameworks and Investment Needs for Scaling Oil and Gas Industry Decarbonization in Selected Niger Delta Fields

Emmanuel Emeka Okoro[1,2], Oscar I. O. Ogali[1,3], Samuel E. Sanni[4,5], Ohachosim P. Oluchi[1]

[1] *Department of Petroleum and Gas, University of Port Harcourt, Rivers State, Nigeria.*
[2] *Center of Petroleum Research and Training, University of Port Harcourt, Rivers State, Nigeria.*
[3] *Africa Centre Of Excellence in Oilfield Chemicals Research, University of Port Harcourt, Nigeria*
[4] *Department of Chemical Engineering, Covenant University, Ota, Ogun State, Nigeria.*
[5] *Department of Chemical Engineering, Gujarat, Parul University, India*

Received April 23, 2024; Accepted August 13, 2024

Abstract

This study examines the present efforts to reduce carbon emissions in the oil and gas industry in the Gulf of Guinea. It reveals that there are many challenges and obstacles due to the lack of coordination and issues linked to resources. The text advocates for a unified approach to address major obstacles such as budgetary constraints, technological deficiencies, and the absence of favorable policy frameworks. Despite these difficulties, the analysis highlights substantial possibilities for reducing carbon emissions that might lead to financial savings, enhanced environmental indicators, and increased industrial competitiveness. The recommended checklist for decarbonization plan emphasizes the importance of setting specific objectives, developing economically efficient methods to reduce carbon emissions, and promoting collaboration among stakeholders, all of which should be supported by favorable legislation. The strategy promotes particular policy and investment measures, suggesting significant consequences for decision-makers in the oil and gas sector, policy-making organizations, and investment entities. The goal is to promote a unified approach that harmonizes firm plans, governmental frameworks, and financial inflows with the overall decarbonization goals of the region.

Keywords: *Decarbonization; Low Cost-High impact; Oil and Gas Industry; Low-carbon Technology; Policy framework.*

1. Introduction

The oil and gas industry, which accounts for almost 10% of worldwide greenhouse gas emissions, has a substantial role in environmental deterioration, especially in areas such as the Gulf of Guinea [1]. This region encounters significant emissions originating from both primary operations at production facilities and secondary activities such as transportation. Considering the crucial importance of decarbonization in addressing climate change, as highlighted by the World Bank [2], it is imperative to adopt and improve technologies and methods that target the reduction of these emissions.

One of the most successful strategies is to enhance energy efficiency in the sector. One can accomplish this by updating to more efficient equipment, utilizing waste heat, and implementing advanced energy management systems [3]. Moreover, the act of flaring, which involves the burning of excess natural gas, is a significant contributor to emissions. Gas capture and reinjection are crucial in reducing flaring emissions, according to the International Energy Agency [3].

Electrification, the process of transitioning from fossil fuels to electricity produced from renewable sources such as solar and wind, or more efficient natural gas technologies, provides an alternative method for decreasing the carbon emissions associated with oil and gas opera-

tions [4]. In addition, Carbon Capture and Storage (CCS) is an emerging technology that effectively catches CO_2 emissions from industrial processes and securely stores them underground, thereby reducing their influence on the atmosphere [5].

Notwithstanding these technological developments, the Gulf of Guinea encounters multiple obstacles in reducing carbon emissions from its oil and gas activities. The hurdles encompass exorbitant expenses linked to decarbonization technology, inadequate infrastructure, and a dearth of strong government backing and legislative frameworks to aid these changes [6]. Nevertheless, there exist substantial prospects due to the rising worldwide need for sustainable energy and the growing expenses linked to carbon emissions, which may encourage the implementation of more environmentally friendly technology [7].

The energy sector in Nigeria is currently facing substantial inefficiencies and a strong dependence on oil, resulting in various economic, environmental, and health difficulties. Nigeria ranks among the countries with the greatest levels of energy inefficiency worldwide, as reported by the International Energy Agency [3]. A significant quantity of energy is dissipated during the stages of manufacturing, conveyance, and allocation, mostly as a result of obsolete infrastructure and technological deficiencies [3]. The nation's reliance on oil increases its susceptibility to global market volatility and possible interruptions in supplies, which can significantly affect the domestic economy and energy stability.

The environmental consequences of Nigeria's energy habits are equally significant. The burning of fossil fuels is a primary cause of air pollution, resulting in substantial health problems among the population, such as respiratory diseases. Moreover, the release of greenhouse gases resulting from the utilization of fossil fuels intensifies the process of global warming, a phenomenon to which Nigeria is especially vulnerable [8]. The nation is currently facing the detrimental consequences of climate change, evident in the increased frequency and intensity of weather events and the escalating sea levels, posing a threat to its coastal populations and agricultural livelihoods.

To address these difficulties, the Nigerian government is implementing proactive steps to encourage energy efficiency. Efforts to promote the use of energy-efficient equipment and lights are measures aimed at minimizing energy wastage. Furthermore, there is a deliberate effort to broaden the range of energy sources. The government's objective is to enhance the utilization of renewable energy sources, such as solar and wind power, which are plentiful in the area [9]. This transition not only aids in lessening the negative effects on the environment but also strengthens energy security by decreasing reliance on imported oil.

Furthermore, enhancing the current energy infrastructure is crucial. To reduce the significant levels of energy loss, it is crucial to upgrade power plants and improve the transmission and distribution networks. The government is now enacting climate change policies with the objective of diminishing greenhouse gas emissions, in accordance with international endeavors to address climate change [9].

The development of Nigeria's energy sector is supported by an intricate combination of social, economic, and environmental variables. Stakeholders, such as government agencies, private sector participants, and foreign partners, are all working together to tackle these issues. Nigeria aims to achieve a more sustainable and resilient energy future by enhancing energy efficiency, diversifying energy sources, and improving infrastructure [8,10]. These endeavors are backed by contemporary theories in sustainable development, which highlight the significance of combining economic expansion with environmental stewardship to promote enduring community welfare.

To tackle the reduction of carbon emissions in the oil and gas industry in the Niger Delta region, a comprehensive strategy is needed. This strategy should involve utilizing advanced technology, updating policy frameworks, and attracting significant investments. The region can effectively reduce its global greenhouse gas emissions and actively participate in the global movement towards a sustainable energy future by implementing these comprehensive measures [11]. This study presents a thorough analysis and enhancement of a complete decarbonization plan, with the goal of substantially decreasing the carbon emissions produced by oil and gas activities in the Niger Delta Selected fields.

2. Gaps and successful decarbonization projects in the oil and gas industry

The oil and gas industry are presently facing substantial pressure to reduce its greenhouse gas emissions due to increasing environmental concerns and regulatory requirements [12]. Numerous oil and gas businesses have undertaken aggressive decarbonization programs, demonstrating successful projects that emphasize the potential and feasibility of reducing emissions within the sector.

An exemplary instance is Equinor's Troll A CCS project in Norway, acclaimed as the inaugural full-scale carbon capture and storage endeavor for an offshore oil and gas platform worldwide. This innovative initiative successfully catches around one million metric tonnes of carbon dioxide every year, which is equivalent to the emissions generated by 250,000 automobiles yearly [13]. This demonstrates a significant impact in reducing emissions. ExxonMobil has made substantial measures to decrease its carbon footprint at the Bayonne Energy Refinery in New Jersey. This includes replacing steam turbines with electric motors, a move that is expected to lower the refinery's greenhouse gas emissions by around 30% [14].

The Pearl GTL project in Qatar, operated by Shell, is a pioneering initiative that runs one of the world's largest gas-to-liquids plants. The project employs modern GTL technology to transform natural gas into synthetic fuels, resulting in considerably lower emissions of greenhouse gases when compared to conventional fossil fuels [15]. BP's Clair Field Redevelopment Project in the North Sea integrates environmental factors into its design by implementing an electric subsea compression system and prioritizing the reduction of flaring. This highlights the oil industry's capacity for environmentally friendly advancements [16].

Moreover, TotalEnergies is setting a high environmental standard with its Mozambique LNG project. With the goal of becoming one of the largest liquefied natural gas projects globally, this initiative aims to minimize its ecological footprint by integrating carbon capture and storage technology to substantially decrease emissions [17]. Chevron's flare reduction project at the San Ramon Refinery in California has achieved a significant decrease of over 90% in flaring, demonstrating the successful use of appropriate techniques to control emissions [18]. ConocoPhillips' Carma Carbon Capture Project in Texas and Eni's Angola LNG project are examples of innovative initiatives that aim to capture and store CO_2 emissions. ConocoPhillips focuses on capturing CO_2 from natural gas processing, while Eni employs novel technology to capture and store CO_2 from gas production [19].

These numerous case studies demonstrate that decarbonization in the oil and gas industry is both achievable and encompasses a wide range of options, including technology such as carbon capture and storage, electrification, and fuel switching. In response to the global economy's shift towards low-carbon energy sources, the oil and gas industry is obligated to persistently pursue innovation and investment in decarbonization initiatives to uphold its competitiveness and sustainability [20]. The Intergovernmental Panel on Climate Change contribution provides a thorough evaluation of the fundamental scientific principles underlying climate change. Their approach encompasses a literature study, modeling, and data analysis. However, it is evident that there is a significant absence of regional and worldwide collaboration in their efforts to reduce carbon emissions. This discrepancy highlights the necessity for more coherent worldwide plans and concerted efforts across various countries and organizations to successfully tackle climate change.

The World Bank's 2021 research examines the economic aspects of reducing the impact of climate change. It uses economic modeling, scenario analysis, and case studies to get insights. Nevertheless, it faces criticism for its inadequate focus on finance mechanisms for decarbonization initiatives. This underscores the necessity for comprehensive investigation into economic models and financial frameworks that might facilitate the shift towards a low-carbon economy, particularly within the oil and gas industry. The 2021 study by the International Energy Agency (IEA) examines the role of oil and gas in the process of transitioning to alternative sources of energy [3]. By employing literature review and data analysis as research methods, this study reveals a deficiency in the existing research regarding the effects of decarbonization on the just transition, particularly in oil and gas regions. This highlights a lack

of research in the socioeconomic dimensions of the energy transition, specifically in terms of appropriately addressing the effects on employment, energy access, and regional economies.

The International Renewable Energy Agency in 2021 provides a plan for achieving a carbon-free energy system by 2050 using modeling, scenario analysis, and involving stakeholders. Their research highlights the little attention given to the social and environmental consequences of decarbonization. This indicates a requirement for more comprehensive research that integrates the wider impacts of energy transition on both society and ecosystems. Equinor's 2021 case study of the Troll A CCS project concludes that there is a requirement for better comprehension of the significance of innovation and technology in the process of decarbonization [13]. This conclusion is based on the utilization of project evaluation, emissions monitoring, and stakeholder interviews as research methods. This study aims to explore the implementation and reception of technical innovations in the oil and gas industries with the goal of efficiently reducing carbon emissions.

The energy savings and environmental implications of ExxonMobil's electrification project at the Bayonne Energy Refinery are being closely examined. This project evaluation represents progress in the decarbonization process [14]. However, the existing literature highlights a significant lack of thorough assessments of decarbonization strategies that are specifically designed for various oil and gas regions. This indicates the necessity for region-specific research that considers the unique environmental, social, and economic factors of each area.

The decarbonization plans of Shell are evaluated by examining literature, analyzing business statistics, and conducting expert interviews. Nevertheless, the analysis highlights a deficient examination of the influence of policy and regulation on decarbonization endeavors, suggesting that future research should prioritize investigating how policy frameworks can efficiently facilitate or impede such activities [15]. The BP Clair Field Redevelopment Project encompasses emissions modeling and assessments of environmental effect [16]. Nevertheless, the case study reveals a dearth of data regarding the efficacy of various policy instruments and regulatory methods that are tailored to the oil and gas industry. This highlights the necessity for thorough assessments of current regulations and the creation of novel regulatory frameworks to promote sustainable behaviors.

The decarbonization initiatives of Total Energies are also examined, utilizing literature reviews and expert interviews as the basis for their comprehensive analysis [17]. However, there is a scarcity of study about the impact of different funding methods, such as public and private investments, as well as the contribution of international financial institutions, in supporting these decarbonization initiatives. The primary objective of Chevron's flare reduction project at the San Ramon Refinery is to assess the project's effectiveness and closely monitor emissions [18]. One notable deficiency found in this analysis is the lack of comprehension regarding the wider socioeconomic consequences of decarbonization, specifically in relation to the well-being of oil and gas employees and local populations. This emphasizes the necessity of adopting a comprehensive approach that takes into account the principles of a fair transition, guaranteeing that efforts to reduce carbon emissions are fair and advantageous for all parties involved.

The energy savings and environmental implications of ExxonMobil's electrification project at the Bayonne Energy Refinery are being closely examined. This project evaluation represents progress in the decarbonization process [14]. However, the existing literature highlights a significant lack of thorough assessments of decarbonization strategies that are specifically designed for various oil and gas regions. This indicates the necessity for region-specific research that considers the unique environmental, social, and economic factors of each area. The decarbonization plans of Shell are evaluated by examining literature, analyzing business statistics, and conducting expert interviews. Nevertheless, the analysis highlights a deficient examination of the influence of policy and regulation on decarbonization endeavors, suggesting that future research should prioritize investigating how policy frameworks can efficiently facilitate or impede such activities.

The BP Clair Field Redevelopment Project encompasses emissions modeling and assessments of environmental effect [16]. Nevertheless, the case study reveals a dearth of data regarding the efficacy of various policy instruments and regulatory methods that are tailored

to the oil and gas industry. This highlights the necessity for thorough assessments of current regulations and the creation of novel regulatory frameworks to promote sustainable behaviors. The decarbonization initiatives of Total Energies are also examined, utilizing literature reviews and expert interviews as the basis for their comprehensive analysis. However, there is a scarcity of study about the impact of different funding methods, such as public and private investments, as well as the contribution of international financial institutions, in supporting these decarbonization initiatives.

The primary objective of Chevron's flare reduction project at the San Ramon Refinery is to assess the project's effectiveness and closely monitor emissions. One notable deficiency found in this analysis is the lack of comprehension regarding the wider socioeconomic consequences of decarbonization, specifically in relation to the well-being of oil and gas employees and local populations. This emphasizes the necessity of adopting a comprehensive approach that takes into account the principles of a fair transition, guaranteeing that efforts to reduce carbon emissions are fair and advantageous for all parties involved. The effectiveness of ConocoPhillips' efforts to reduce carbon emissions is evaluated by conducting literature reviews and analyzing business data. This assessment highlights a lack of awareness regarding the potential of upcoming technologies in achieving comprehensive decarbonization. This indicates a requirement for further investigation into cutting-edge technologies, their ability to be expanded, and their incorporation into existing oil and gas activities.

The case study conducted by Eni on the Angola LNG carbon capture project utilizes project appraisal, emissions modeling, and environmental impact assessments. This reveals a significant lack of understanding on the obstacles to adopting emerging decarbonization technologies. It emphasizes the need for studies that specifically examine the legislative, financial, and technical problems that hinder the deployment of these technologies [21]. The International Labour Organization examines the consequences of climate change on the concept of a fair transition, employing methods such as reviewing literature, analyzing case studies, and involving relevant stakeholders. The research identifies a gap in studies regarding the social and environmental consequences of decarbonization, specifically in relation to probable employment cuts and community effects. This highlights the necessity for further research that aligns with the just transition framework.

These studies collectively emphasize that although there is extensive research on decarbonization strategies and their implementation, there are still significant gaps, especially in comprehending the wider consequences of technology adoption, the socio-economic effects of transition, the functions of financial mechanisms, and the efficacy of policy and regulatory frameworks. It is essential for the oil and gas industry to address these gaps in order to make progress towards a more sustainable and socially fair low-carbon future.

Although there have been significant advancements, the existing research on the decarbonization of the sector tends to concentrate on individual technologies or specialized tactics [22]. This highlights a need for comprehensive evaluations that incorporate several approaches customized to different regional settings. This entails taking into account the local availability of resources, the current state of infrastructure, and the socioeconomic conditions. In addition, although there is often extensive analysis of the technical and financial aspects of decarbonization, there is a noticeable lack of research focusing on the social and environmental consequences of these transitions. These factors encompass possible employment reductions, effects on local communities, and compromises in environmental aspects [23]. In addition, there is a need to further investigate and develop effective policy instruments, regulatory methods, funding mechanisms, and international cooperation in order to facilitate widespread initiatives to reduce carbon emissions. To achieve a fair and balanced shift towards a sustainable energy future, it is crucial to address these disparities through comprehensive initiatives.

3. Methodology

Figure 1 presents a systematic research process for creating a decarbonization plan, specifically within the oil and gas sector. The initial phase entails delineating the parameters of

Figure 1. Research workflow

the research including identifying the precise obstacles related to decarbonization within the oil and gas sector. This step establishes the trajectory for the research, specifying the required data and the goals of the ensuing analysis. After defining the problem, a thorough process of gathering data commences. The data may encompass emissions figures, existing decarbonization techniques, technological capacities, and industry norms. The analysis phase entails the interpretation of this data to comprehend the present state of emissions and decarbonization endeavors in the oil and gas industry. This stage involves identifying obstacles that hinder the successful implementation of decarbonization methods, including technological constraints, economic limitations, regulatory challenges, and concerns related to social acceptance.

Simultaneously, it is essential to acknowledge and take advantage of opportunities that can be utilized, such as advancements in technology, market trends that support sustainability, and incentives provided by policies [24]. After gaining a thorough understanding of the obstacles and opportunities, the research moves forward to create a decarbonization plan or prototype. This strategy could integrate a range of initiatives such as carbon capture and storage (CCS), energy saving measures, electrification, and the utilization of alternative energy sources [25]. Additionally, it may entail the development of models or experimental projects to assess the feasibility of suggested solutions. The last step involves distributing the findings and the formulated strategies to the relevant parties involved. Dissemination guarantees the sharing of research findings with industrial actors, policymakers, and the scientific community, with the aim of promoting the adoption of efficient decarbonization techniques.

The process of disseminating research is crucial for transferring knowledge from academic spheres to practical, real-world implementation. Each of these steps will be thoroughly examined, taking into account the intricacies and special characteristics of the oil and gas business, and how these general stages are customized to tackle its distinct decarbonization difficulties. The workflow prioritizes a systematic and analytical approach to problem-solving that relies on factual facts and takes into account the viewpoints of different stakeholders.

3.1. Examination of existing decarbonization initiatives

The report undertook a thorough examination of the current status of decarbonization initiatives in the oil and gas sector, with a specific emphasis on Niger Delta region. This analysis included an assessment of current regulations, investments, technology, and operating methods across the whole industry's value chain. The aim was to identify current deficiencies and gaps that impede the implementation of successful decarbonization initiatives. The research technique was designed with three clearly defined phases to guarantee a comprehensive investigation:

i. ***Literature review*:** The first step comprised a methodical examination of existing research, academic papers, and industry reports on efforts to reduce carbon emissions in the oil and gas sector of the Niger Delta. This comprehensive literature analysis was conducted to provide a strong foundation of information, emphasizing important activities and evaluating their effects. This phase was essential for comprehending the historical and present context of decarbonization activities and for selecting critical research and data pertinent to further analysis.

ii. ***Data collection*:** The second phase was the acquisition of relevant data from various sources:
   a. Government reports are official papers that contain statistical data and policy frameworks that serve as guidelines for industrial practices.
   b. Industry data: This data was gathered from multiple companies in the sector and provided insights on operational procedures and ongoing trends that could impact decarbonization efforts.
   c. Academic research: These sources provided comprehensive examinations and innovative perspectives on technological and operational progress.
   d. NGO reports: These reports provided a critical analysis of the wider effects of oil and gas operations, with a specific focus on the social and environmental consequences of industry actions.

iii. ***Expert interviews***: The last stage entailed carrying out organized interviews with a varied range of individuals who have a stake in the matter, such as industry professionals, policymakers, and academic researchers. The interviews were specifically crafted to obtain profound insights and personal anecdotes that are not easily accessible through public or published information. A survey was created to facilitate these conversations, centering on subjects such as changes in the sector, difficulties and possibilities, existing methods, and practical suggestions. The participants were chosen based on criteria such as employment position, industry experience, level of proficiency, and geographic location. The interview method was directed by the concept of data saturation, which aimed to achieve a full grasp of the subject matter by reaching a point where no further new insights were noticed. Every stage of the study was crucial in cultivating a sophisticated comprehension of the process of reducing carbon emissions within the oil and gas sector in the Niger Delta. This systematic methodology for a comprehensive examination of both the macro and micro elements influencing decarbonization endeavors and established a strong basis for proposing strategic recommendations.

4. Results and discussion

The main findings of this study suggest that the existing efforts to reduce carbon emissions in the oil and gas industry of the Niger Delta region are significantly insufficient and lacking coordination. The decarbonization efforts in this region face significant obstacles, such as a lack of financial resources, limited technological expertise, and a lack of supportive policy frameworks. Despite these obstacles, the region presents significant opportunities for promoting decarbonization [26]. These opportunities are characterized by potential economic benefits and improved environmental outcomes. The presence of both challenges and opportunities underscores the urgent requirement for a comprehensive strategy to effectively utilize these possibilities, with the goal of achieving sustainable development in the energy sector of the region.

4.1. Existing decarbonization initiatives in the Niger Delta region

The current condition of decarbonization in the oil and gas industry of the Niger Delta region is marked by a lack of comprehensive and unified efforts, despite the region's significant contribution to global energy output. The Gulf of Guinea, which includes countries abundant in oil such as Angola, Nigeria, and Ghana, has started several decarbonization initiatives to reduce environmental effects and comply with international carbon reduction requirements. Angola is utilizing public-private partnerships to accelerate its decarbonization endeavors.

When comparing these regional initiatives with the wider body of literature on decarbonization in the oil and gas sector, it is evident that these efforts are in line with established tactics such as carbon capture and storage (CCS), integration of renewable energy sources, reduction of methane emissions, and improvements in energy efficiency. Nevertheless, despite these endeavors, numerous enterprises in the Gulf of Guinea have not yet implemented comprehensive decarbonization plans or set defined objectives, which aligns with similar findings in other locations that also indicate fragmented and restricted decarbonization initiatives [10]. The policy environment in the Niger Delta region frequently lacks coherence and explicit incentives for reducing carbon emissions, which hinders the widespread implementation of sophisticated decarbonization methods. The Gulf of Guinea Gas Master Plan is a regional program

aimed at addressing these gaps by promoting sustainable gas extraction and consumption. However, achieving significant emission reductions requires greater cooperation and allocation of resources. Overall, the decarbonization efforts in the Niger Delta region are insufficient in comparison to the urgent environmental challenges and the potential for advancements in technology and policy in this important sector [9]. Although there are notable advancements in certain projects and partnerships, the overall scale and integration of these efforts are lacking.

Figure 2 depicts the main discoveries derived from current efforts to reduce carbon emissions in the oil and gas sector of the Niger Delta region. These findings are divided into three distinct categories:

i. Progress and positive Efforts (30%): This category indicates the percentage of decarbonization initiatives that have demonstrated advancement. Examples of initiatives falling into this category include collaborations for low-carbon technologies, financial commitments to renewable energy, and experimental endeavors for carbon capture and storage. These endeavors demonstrate an acknowledgment within the sector of the necessity to shift towards more environmentally friendly practices.
ii. Difficulties and barriers (40%): This substantial segment suggest that a noteworthy proportion of the industry's endeavors are hindered by diverse problems. The challenges that may arise include limited financial resources, technological deficiencies, and inadequate policy structures that hinder the widespread adoption of decarbonization methods. This implies that although there is a desire to reduce carbon emissions, there are underlying problems that are impeding significant advancements.
iii. Emerging opportunities (30%): This section highlights the potential for the sector to grow its current decarbonization efforts or create new projects. The existence of new possibilities indicates an unexplored capacity that, if utilized efficiently, might enable the region to shift towards low-carbon energy sources and techniques. This may entail using emerging technologies, formulating inventive commercial frameworks, or capitalizing on worldwide trends towards sustainability.

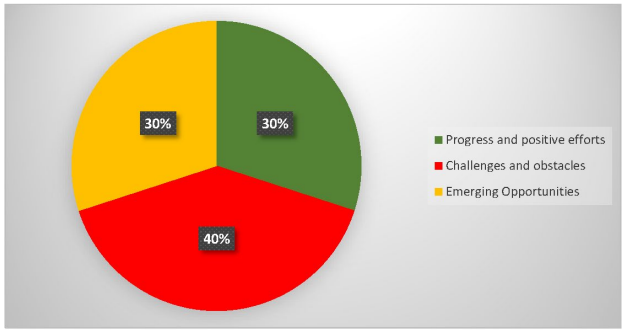

Figure 2. Existing decarbonization initiatives in Niger Delta region

In general, Figure 3 highlights a situation in which the oil and gas industry in the Niger Delta region is facing a critical decision point. The balance between positive action and emergent potential is roughly equal, but there is a greater proportion of challenges that must be handled to make substantial success in decarbonization initiatives. The future trajectory of the industry will probably hinge on its ability to successfully surmount current obstacles and take advantage of chances for sustainable expansion and enhancement of environmental performance.

Figure 3. Proposed decarbonization strategy hierarchy.

4.2. Decarbonization strategy and policy formulation check box

This study presents a systematic approach designed to guide the development of a comprehensive decarbonization strategy specifically adapted to the unique needs of the oil and gas industry in the Gulf of Guinea. The proposal presents specific policy directions and investment strategies that are crucial for promoting the implementation of the recommended decarbonization initiatives. By implementing this comprehensive decarbonization protocol, which includes crucial components, the oil and gas industry in the Gulf of Guinea is expected to significantly reduce its carbon emissions. This will support a sustainable future and promote long-lasting economic growth in the region. The framework has multiple essential elements, with each one playing a crucial role in the development of a strong decarbonization plan. These actions encompass the creation of specific decarbonization objectives, thorough evaluations of technologies to identify the most suitable solutions, development of supportive policy frameworks, prioritization of investments that result in significant decarbonization benefits, comprehensive engagement with stakeholders to ensure inclusiveness, and careful monitoring and evaluation to monitor progress [27]. The framework also emphasizes the importance of adjusting policies to accommodate specific regional difficulties, strengthening collaboration among stakeholders, and improving transparency and accountability throughout the process of reducing carbon emissions.

Table 1 illustrates a "Decarbonization Strategy Checklist" that acts as a thorough manual for creating a decarbonization framework in the oil and gas sector. The checklist is organized into multiple thematic sections, each delineating a series of strategic tasks and considerations that form the foundation of a successful decarbonization transition.

Goal Setting: This section highlights the significance of setting explicit and ambitious decarbonization goals that are in line with both domestic and global climate obligations. It promotes the adoption of precise targets for reducing emissions in different time periods and sectors.

Technology Assessment: it involves assessing the viability and cost-efficiency of different decarbonization technologies and prioritizing actions that have substantial potential for reducing emissions, such as carbon capture and storage (CCS), integration of renewable energy, and improvements in energy efficiency.

Policy Framework: The checklist requires the adoption of policy instruments, such as carbon pricing, to provide incentives for reducing emissions. Furthermore, it emphasizes the necessity of providing monetary motivations for projects and implementing regulatory structures that require the reduction of carbon emissions and provide benchmarks for performance.

Investment Priorities: This emphasizes the importance of allocating resources towards the development of clean energy infrastructure and the advancement of decarbonization technology. This can be achieved through collaborations between the public and private sectors, as well as the establishment of specific funding structures. Providing fiscal incentives to the private sector is considered crucial in promoting investment.

Stakeholder Engagement: The primary objective is to promote cooperation and exchange of information among all entities involved in the industry, such as corporations, policymakers, and investors. This encompasses actively interacting with local communities and advocating for transparency and accountability.

Evaluation and Monitoring: The checklist promotes the implementation of comprehensive monitoring and evaluation frameworks to evaluate progress, facilitate adaptive management, and communicate developments and policy changes to stakeholders.

Further factors to take into account: This concluding section encourages reflection on the wider ramifications of decarbonization, including the distinct difficulties faced by offshore operations, the effects on local economies and labor markets, and the economic advantages of decarbonization, such as cost reductions and improved competitiveness.

This checklist offers a comprehensive action plan for the oil and gas industry in the Gulf of Guinea to transition towards a low-carbon trajectory. It is based on a strategic approach that

Table 1. DECARBONIZATION STRATEGY CHECKLIST

Goal Setting

[ ] Establish clear and ambitious decarbonization goals for the Gulf of Guinea oil and gas industry.

[ ] Set specific targets for emissions reductions by sector and timeframe.

[ ] Align decarbonization goals with national and international climate commitments.

Technology Assessment

[ ] Evaluate the feasibility and cost-effectiveness of various decarbonization technologies for Gulf of Guinea oil and gas operations.

[ ] Prioritize low-cost and high-impact mitigation measures, such as carbon capture and storage (CCS), renewable energy integration, and energy efficiency improvements.

[ ] Encourage research and development of innovative decarbonization technologies tailored to the region's specific context.

Policy Framework

[ ] Implement carbon pricing mechanisms to incentivize emissions reductions and promote clean energy adoption.

[ ] Provide financial incentives and subsidies for decarbonization projects, such as CCS, renewable energy, and energy efficiency investments.

[ ] Establish regulatory frameworks that mandate decarbonization efforts and set performance standards for oil and gas companies.

Investment Priorities

[ ] Increase investment in clean energy infrastructure, including renewable power generation, grid modernization, and energy storage solutions.

[ ] Support research and development of decarbonization technologies through public-private partnerships and dedicated funding mechanisms.

[ ] Encourage private sector investment in decarbonization projects through tax breaks, loan guarantees, and other financial incentives.

Stakeholder Engagement

[ ] Foster collaboration and knowledge sharing among oil and gas companies, policymakers, investors, and research institutions.

[ ] Engage with local communities to address social and environmental impacts of decarbonization efforts.

[ ] Promote transparency and accountability in decarbonization planning and implementation.

Monitoring and Evaluation

[ ] Establish a robust monitoring and evaluation framework to track progress towards decarbonization goals.

[ ] Regularly review and update the decarbonization strategy based on new data, technological advancements, and policy changes.

[ ] Communicate progress and learnings to stakeholders to maintain transparency and support continued efforts.

Additional Considerations

[ ] Address the unique challenges of decarbonizing offshore oil and gas operations in the Gulf of Guinea.

[ ] Consider the potential impact of decarbonization on local economies and labor markets.

[ ] Emphasize the economic benefits of decarbonization, such as cost savings, improved energy security, and enhanced competitiveness.

is rooted in sustainability theory and incorporates industry best practices. The statement proposes an inclusive and collaborative strategy that is crucial within the framework of the United Nations Sustainable Development Goals, namely Goal 13 which focuses on addressing climate change. The checklist emphasizes the significance of implementing a comprehensive transformation in industrial operations, guided by the triple bottom line principle of ensuring environmental, social, and economic sustainability. Furthermore, it is in line with the idea of the energy transition, which requires a transition to more environmentally friendly energy sources while taking into account the social and economic aspects of the affected areas.

This framework diverges from existing literature and established theories by embracing a comprehensive approach endorsed by researchers in environmental management. It aligns with the demand for integrated strategies that combine technical solutions with socio-economic factors. Moreover, it is in line with the United Nations Sustainable Development Goals, specifically emphasizing the significance of collaborations (Goal 17) and advancements in the business sector (Goal 9) to address the issue of climate change (Goal 13). This congruence highlights the checklist's capacity to function as a practical framework for aligning operational practices with environmental requirements in the energy industry.

4.3. Proposed decarbonization strategy

The analyzed strategic approach prioritizes effectiveness, starting with the identification of mitigation strategies that produce the greatest impact while using the least amount of resources. The approach carefully identifies activities such as improving energy efficiency, implementing thorough methane leak detection and repair systems, and transitioning to greener fuels as initial but significant measures. These fundamental actions represent the first installment of a gradual process to reduce carbon emissions, providing immediate reductions and paving the way for increased investment in sustainable technologies. Nevertheless, this method goes beyond immediate mitigations. It establishes the fundamental framework necessary for long-term reduction of carbon emissions. The report recommends tailored policy and investment solutions that align with the unique circumstances of the region's challenges and potential. Within this framework, there are carbon pricing instruments that aim to encourage reductions in emissions, fiscal assistance mechanisms to promote the adoption of green technology, and streamlined regulatory structures that create a favorable climate for achieving complete decarbonization. These significant investments now are the indicators of a prosperous and environmentally-friendly future for the region.

Figure 3 illustrates a tiered approach to decarbonization strategy that prioritizes efficiency and effectiveness. The hierarchy is organized into three tiers:

The "Low cost-High Impact" level represents the highest point in the hierarchy, indicating that the decarbonization strategy should prioritize activities that need minimal financial investment but can generate substantial environmental benefits. The objective is to discover and execute cost-effective methods that can result in significant reductions in carbon emissions. Investment policies tailored to specific needs:

The second tier of the hierarchy explores the mechanisms that facilitate the attainment of the high-impact objectives. It emphasizes the need of creating laws that make it easier to reduce carbon emissions. Investments should be focused on technology and projects that help achieve this objective, taking into account the specific requirements of the region or industry. This tier necessitates the customization of the strategy to address the specific difficulties and possibilities that exist in the context where it is being implemented.

Collaboration is emphasized as the fundamental principle of the hierarchy, highlighting the significance of working together. The statement acknowledges that decarbonization is a multifaceted problem that necessitates the involvement of several parties. Collaboration entails the formation of alliances among governments, industries, communities, and other groups. The primary focus is on the exchange of knowledge, resources, and optimal methods to collectively work towards the shared objective of decreasing carbon emissions.

The hierarchy illustrates that the desired outcome of low-cost, high-impact actions can only be attained by implementing well-crafted policies, making focused expenditures, and addressing the specific requirements of the industry or region. Moreover, the entire framework relies on teamwork, underscoring the necessity of collective endeavors for the approach to be successful. This implies a methodical strategy for reducing carbon emissions, in which each level reinforces the others, starting with collaboration and progressing towards the ultimate objective of achieving significant and economically efficient emission reductions.

The research highlights the need for a comprehensive and strategic approach to reducing carbon emissions in the petroleum industry in the Niger Delta region. The current status of decarbonization efforts is marked by fragmentation and inadequacy, as the region faces significant obstacles including budgetary limitations, a lack of technological expertise, and the absence of supportive regulations. However, the scenario is filled with significant prospects for reducing carbon emissions, which might result in economic efficiency, improved environmental protection, and increased market competitiveness. The proposed decarbonization strategy emphasizes the importance of setting clear and ambitious goals for reducing carbon emissions. It also emphasizes the need for cost-effective measures that have a significant impact on reducing emissions. Additionally, it promotes collaboration and cooperation among different stakeholders and the implementation of supportive policy frameworks. The strategy carefully outlines detailed policy guidance and proposals for financial commitment to support these efforts to reduce carbon emissions.

The findings of this study hold great importance for decision-making processes in organizations such as oil and gas enterprises, regulatory agencies, and investment circles. Oil and gas companies must develop and implement comprehensive decarbonization plans that align with the local goals for reducing carbon emissions

5. Conclusion

The results of this study emphasize the need for a comprehensive and cooperative strategy to reduce carbon emissions in the oil and gas sector of the Gulf of Guinea. In order to go beyond the current state of scattered efforts and take advantage of the hidden prospects for economic and environmental advancement, it is crucial to implement a comprehensive strategy. The suggested checklist functions as a fundamental instrument for participants in the industry, providing a step-by-step method for establishing ambitious goals to reduce carbon emissions, utilizing cost-effective and impactful strategies, and promoting collaboration across different sectors. Policy proposals are offered to facilitate the establishment of this strategic approach, encouraging strong policy frameworks that can stimulate comprehensive transformation across the industry. Oil and gas businesses must prioritize the integration of comprehensive decarbonization strategies into their operating culture. Policymakers should actively create favorable policy environments, while investors are urged to invest cash in initiatives that drive the region towards a more environmentally friendly and sustainable future. The synchronized execution of these initiatives is crucial not just for attaining regional decarbonization goals but also serves as a progressive model for other industries grappling with the twin demands of operational effectiveness and environmental stewardship.

Appendix: Questionnaires used for this study

QUESTIONNAIRE

I. Background Information (Confidential):

1. **Job Title:** _____
2. **Company/Organization:** _____
3. **Years of experience in the oil & gas industry:** _____
4. **Geographical focus of your work:** _____ (National/Regional/Specific country)
5. **Your involvement in decarbonization initiatives (select all that apply):**
   - ○ Policy development
   - ○ Technology implementation
   - ○ Operational practices
   - ○ Research and development
   - ○ Advocacy and community engagement
   - ○ None of the above

II. Decarbonization Efforts:

1. **Are you aware of any existing decarbonization initiatives in the Gulf of Guinea oil & gas industry?** (Yes/No)
2. If yes, what are the types of initiatives you are familiar with? (Select all that apply)
   - ○ Energy efficiency upgrades
   - ○ Renewable energy projects
   - ○ Carbon capture and storage (CCS)
   - ○ Policy and regulatory frameworks
   - ○ Technology transfer and knowledge sharing
   - ○ Financial support mechanisms
   - ○ Community engagement and education
   - ○ Other (please specify) _____
3. In your opinion, how effective have these initiatives been in achieving their goals? (Highly effective/Somewhat effective/Ineffective/Unsure)
4. What are the key challenges hindering the success of decarbonization efforts in the region? (Select all that apply)
   - ○ Lack of government funding and incentives
   - ○ Limited access to advanced technologies
   - ○ Inadequate regulatory frameworks
   - ○ Difficulty in changing established operational practices
   - ○ Lack of awareness and knowledge sharing
   - ○ Social and community concerns
   - ○ Other (please specify) _____
5. What are the biggest opportunities for advancing decarbonization in the Gulf of Guinea? (Select all that apply)
   - ○ Technological advancements and cost reductions
   - ○ Stronger policy commitments and investment from governments
   - ○ Collaboration and knowledge sharing across stakeholders
   - ○ Increased public awareness and demand for sustainability
   - ○ Development of innovative financing mechanisms
   - ○ Other (please specify) _____

III. Policy and Regulations:

1. Do you believe current policies and regulations in the Gulf of Guinea are supportive of decarbonization efforts? (Strongly agree/Somewhat agree/Disagree/Strongly disagree)
2. What specific policy changes or regulations would be most helpful in promoting decarbonization in the region? (Open-ended question)
3. How effective is the current level of collaboration between governments, industry, and NGOs on decarbonization policy? (Highly effective/Somewhat effective/Ineffective/Unsure)
4. How can collaboration on policy development be improved to accelerate decarbonization progress? (Open-ended question)

IV. Technology and Innovation:

1. What are the major technological barriers to achieving large-scale decarbonization in the Gulf of Guinea oil & gas industry? (Select all that apply)
   - ○ High cost of new technologies
   - ○ Lack of technical expertise and skilled workforce
   - ○ Insufficient infrastructure and support systems
   - ○ Uncertainties about long-term performance and profitability
   - ○ Other (please specify) _____
2. In your opinion, which technological advancements hold the most promising potential for decarbonization in the region? (Select all that apply)
   - ○ Advanced energy efficiency technologies
   - ○ Renewable energy integration and grid modernization
   - ○ Carbon capture and storage (CCS) solutions
   - ○ Hydrogen production and utilization
   - ○ Other (please specify) _____
3. How can technology transfer and knowledge sharing be improved to promote the adoption of advanced decarbonization technologies in the region? (Open-ended question)

QUESTIONNAIRE II

1. **Can you describe the current practices and technologies used in the oil and gas industry in the Gulf of Guinea that contribute to carbon emissions?**
2. **How aware are industry professionals of the environmental impact of their operations, particularly in terms of carbon emissions?**
3. **What are the main challenges faced by companies in the Gulf of Guinea when it comes to implementing decarbonization strategies?**
4. **Are there any specific government regulations or policies in place to encourage or enforce decarbonization efforts in the oil and gas industry in the region?**
5. **How do companies in the Gulf of Guinea approach the assessment and measurement of their carbon footprint? What are the key metrics used?**

References

[1] Jaffe AM, and Silberman J. The decarbonization dilemma: Rethinking oil and gas company business models. Journal of Economic Perspectives, 2020; 34(1): 95–114.
[2] World Economic Forum. Decarbonizing Oil and Gas: The Role of Digitalization and Decentralization. Geneva: World Economic Forum, 2020.
[3] International Energy Agency (IEA). Net Zero by 2050: A Roadmap for the Global Energy Sector, 2021. Retrieved from https:// www.iea.org/reports/net-zero-by-2050
[4] Jaffe AM, and Silberman J. The decarbonization dilemma: Rethinking oil and gas company business models. Journal of Economic Perspectives, 2020; 34(1): 95–114.
[5] Raza SA, Raza MA, Hammad MA, and Rasheed A. Renewable energy in the oil and gas industry: A review. Journal of Cleaner Production, 2021; 315: 128167.
[6] Rockström J, Gaffney O, Rogelj J, Meinshausen M, Nakicenovic N, and Schellnhuber HJ. A roadmap for rapid decarbonization. Science, 2017; 355: 1269-1271.
[7] Jiang Y, Yuan X, Liu S, and Wu X. Research on the talent training strategy for the transformation and upgrading of the oil and gas industry under the new energy revolution. Petroleum Exploration and Development, 2020; 47(5): 944–952.
[8] Okoro EE, Sanni SE, Ogali OI, Okoye LU, and Olafuyi SG. Nexus of Economic Growth, Technological Development and In-Country Utilization of Natural Gas: Evidence from Nigeria. Petroleum and Coal, 2024; 66(1): 230-244.
[9] Oruwari HO, and Itsekor L. Strategies for Decarbonizing the Oil and Gas Industries. Paper presented In: SPE Nigeria Annual International Conference and Exhibition, 2023, Lagos, Nigeria. https://doi.org/10.2118/217179-MS
[10] Alam MM, Czajkowski J, Mutale J. Decarbonizing the oil and gas industry: Insights from a technoeconomic analysis. Energy Policy, 2021; 153: 112227.
[11] Hsu C-W, Lai Y-L, Chen W-T, Chen W-T, and Chen Y-H. A roadmap to decarbonize the oil and gas industry. Journal of Cleaner Production, 2021; 307: 127114.
[12] Bazmi M, Jafarian F, and Siano P. Renewable energy and carbon capture utilization and storage (CCUS) technologies for a sustainable oil and gas industry. Journal of Cleaner Production, 2021; 290: 125619.
[13] Equinor. Troll A CCS Project: A Full-Scale Carbon Capture and Storage Project in Norway, 2021 Stavanger: Equinor.
[14] ExxonMobil. Bayonne Energy Refinery Electrification Project, 2021, Houston: ExxonMobil.
[15] Shell. Shell's Decarbonization Strategies, 2021 London: Shell.
[16] BP. Clair Field Redevelopment Project: A Major Offshore Oil and Gas Project with a Focus on Environmental Impact Reduction, 2021, London: BP.
[17] Total Energies. TotalEnergies' Decarbonization Initiatives, 2021, Paris: Total Energies

[18] Chevron. San Ramon Refinery Flare Reduction Project. San Ramon, 2021, Chevron.
[19] ConocoPhillips. Carma Carbon Capture Project. San Ramon, 2021, ConocoPhillips.
[20] Heesterman A. The pace and practicality of decarbonization. Clean Technol. Environ. Policy, 2017; 19: 295–310. https://doi.org/10.1007/s10098-016-1277-x
[21] Nordrum S, Lieberman D, Colombo M, Gorski A, and Webb C. Assessment of greenhouse gas mitigation options and costs for California Petroleum Industry Facilities: The shape of things to come. Energy Procedia, 2011; 4: 5729–5737. https://doi.org/10.1016/j.egypro.2011.02.568
[22] Newell RG, Jaffe AB, and Stavins RN. The effects of economic and policy incentives on carbon mitigation technologies. Energy Econ., 2006; 28: 563–578. https://doi.org/10.1016/j.eneco.2006.07.004
[23] Li HX, Edwards DJ, Hosseini MR, and Costin GP. A review on renewable energy transition in Australia: an updated depiction. J. Clean. Prod., 2020; 242: 118475. https://doi.org/10.1016/j.jclepro.2019.118475
[24] Niu S, Ding Y, Niu Y, Li Y, and Luo G. Economic growth, energy conservation and emissions reduction: A comparative analysis based on panel data for 8 Asian-Pacific countries. Energy Policy, 2011; 39: 2121–2131. https://doi.org/10.1016/j.enpol.2011.02.003
[25] Bistline JET. Roadmaps to net-zero emissions systems: emerging insights and modeling challenges. Joule, 2021; 5, 2551–2563. https://doi.org/10.1016/j.joule.2021.09.012
[26] Lau HC, Ramakrishna S, Zhang K, and Radhamani AV. The role of carbon capture and storage in the energy transition. Energy Fuel, 2021; 35 (9): 7364–7386. https://doi.org/10.1021/acs.energyfuels.1c00032
[27] Rockström J, Gaffney O, Rogelj J, Meinshausen M, Nakicenovic N, and Schellnhuber HJ. A roadmap for rapid decarbonization. Science, 2017; 355: 1269-1271.

To whom correspondence should be addressed: Emmanuel Emeka Okoro, Department of Petroleum and Gas, University of Port Harcourt, Rivers State, Nigeria, E-mail: emeka.okoro@uniport.edu.ng