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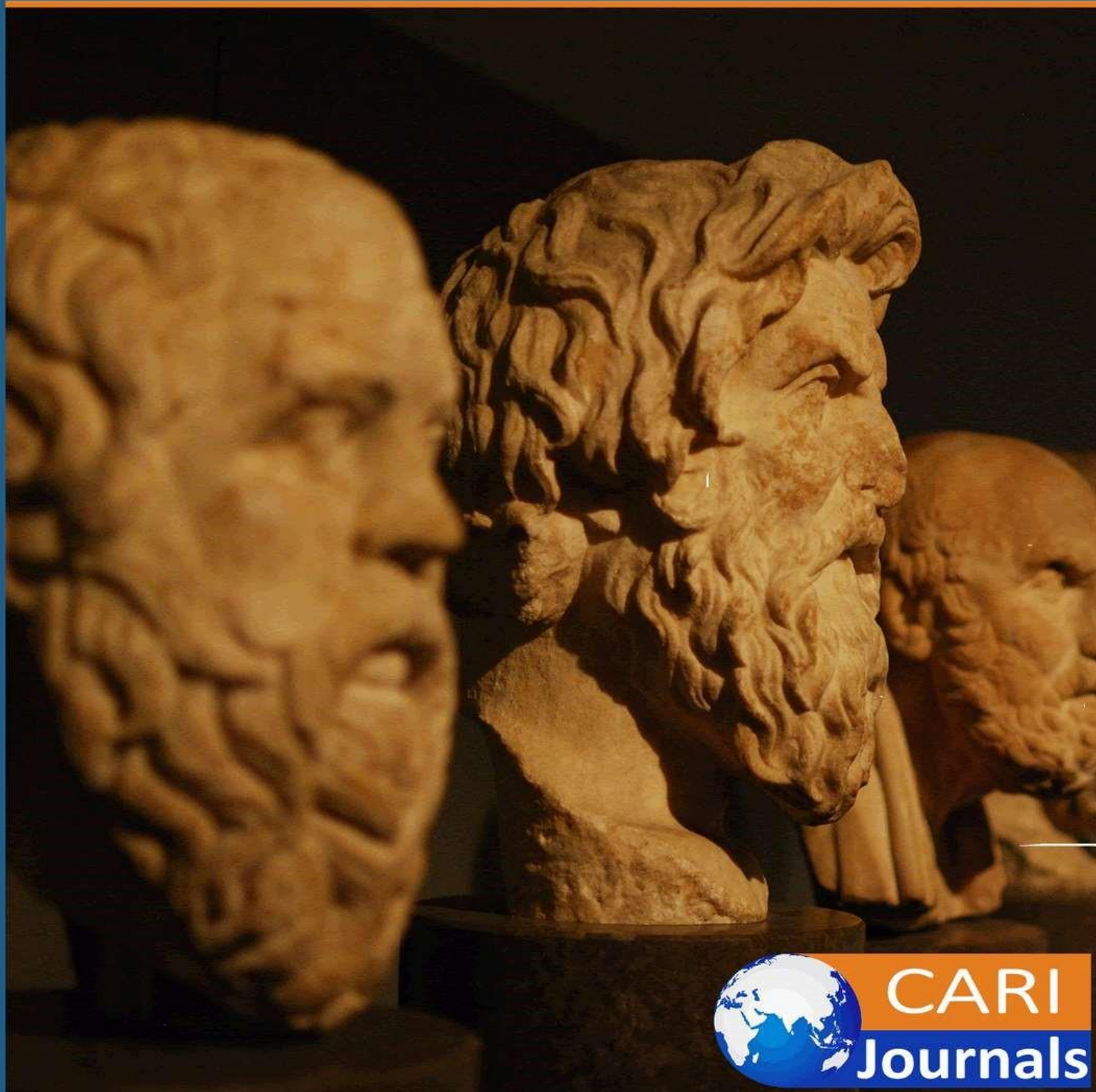

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Advancing Sustainability in Oil and Gas: Strategy for Reducing Carbon Emissions in Upstream Oil and Gas Operations

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Abstract

Purpose: This paper assessed the extent to which energy efficiency technologies, and Carbon Capture, Storage (CCS) and renewable energy can reduce carbon emissions in the upstream sector. The oil and gas industry has continued to serve several functions in energy supply systems; the industry meets the need for a massive amount of energy; but at the same time, releases a vast amount of Greenhouse Gas (GHG) into the atmosphere. Exploration, drilling and the production of upstream segment are activities that are rich in emissions, and as such, need to be made sustainable.

Methodology: This study employed a secondary research strategy, there is desktop research where the researcher collect data from secondary sources from scholarly reviewed journals, business intelligence reports and other credible sources. This design suits the objectives of this study; that is to evaluate whether Energy Efficiency, Carbon Capture Storage and Renewables integration can play a role in the reduction of carbon footprint the Upstream O&G Industry. Desktop research is beneficial especially where the topic under study is well published with both empirical and theory papers.

Findings: The outcomes obtained in this study suggest that application of energy efficiency technologies such as high-end heat exchangers, monitoring systems can reduce emissions below 20%. CCS evidently has good prospect that percentage reduction may range between 10 and 25%, but the expense of such projects is still high and technical difficulties prevent the increased usage of it. Therefore, integration of solar and wind into the current power systems results in optimal sustainable long-term solutions in emission reductions with up to 20% as demonstrated in the hybrid power systems, but present storage and inertia issues and policy encouragement.

Unique Contribution to Theory, Practice, and Policy: The research demonstrated that only the full suite of these approaches is required to decarbonize the upstream sector. Based on this study, it is recommended that due to the economic and technology challenges and to foster the improvement of the oil and gas industry, policy makers, industrial players and scholars should be engaged.

Keywords: *Carbon Emissions, Energy Efficiency, Carbon Capture and Storage (CCS), Renewable Energy Integration, Oil and Gas*

INTRODUCTION

BACKGROUND OF THE STUDY

The oil and gas sector is highly relevant for the very existence of the global economy as it gives more than 35% of the world's energy needs (IEA, 2022). While this sector is one of the most important contributors to driving economies this sector is equally one of the largest emitters of Green House Gases (GHG) globally. The mostly fossil energy intensive upstream activities that include exploration, drilling, and production are very rich in both embedded energy, CO2 and methane emissions (UNFCCC, 2021). These emissions are still a real and present threat to the achievement of climate change targets internationally.

This has been compounded by the Paris Accord where, in order to limit the global temperature rise, countries have been called upon to provide a sustainable framework for their respective sectors, Basically, the rise in temperature should not exceed 2-degree centigrade(IPCC, 2021). Consequently, there is pressure on the oil and gas industry as to the limitations of carbon footprint within the sector, as well as the potential for improving efficiency in order to maintain profitability. In this regard, all the upstream activities indicate possibilities that reduced emission outcomes are achievable as other more innovative sustainable business engagements are advanced.

Some of the measure include; adoption of energy efficient technologies, CCS and integration of renewable energy systems among others. These approaches not only lower emissions but also improve operational efficiency and legal requirements (Gao et al., 2024 pp. 45). Also, different digital technologies such as prediction and emission technologies which are enabling organizations to enhance the credibility of the emission reductions (Tayab et al., 2024).

In more detail, this study aims to reveal how practically applicable and effective these strategies are in reducing carbon emission in the upstream sector. The aim of this research is to demonstrate a proper understanding of practice of integrating sustainability into the practices of oil and Gas sector together with detailed recommendation to the players and policy makers in the industry.

The upstream onshore oil and gas companies are today viewed as one of the most ecologically risky sectors mainly because they contribute to approximately one-third of the total worldwide emissions of greenhouse gasses (IEA, 2022). The operations including exploration, drilling and production are generally considered as dirty business and involves practices such as flaring, venting, and most detriment to climate, fugitive methane emissions. For example, methane, which is 28 times stronger than carbon dioxide on a 100-year time horizon of heat-trapping potential, makes the policies aimed at cutting methane emissions quite nuanced (IPCC, 2021).

Technology has since advanced, but the sector is yet to fully understand how organizational effectiveness can be maximized while social cost, in terms of harm to the physical environment, is minimized. Almost all the upstream processes emit fossil fuel based energy and therefore escalate emissions (UNFCCC, 2021). Moreover, treaties such as the Paris Agreement expect sharp reductions in emissions to be in line with the targets of climate change. PENALTIES Failure may

result in a severe penalty and a spoiled reputation. In this respect, there is a great concern and more radical changes are needed.

Lack of interest in investing on energy efficiency, CCS and renewable energy are still being a big problem in achieving the feat of implementing upstream activities (Gao et al., 2024). This research attempt to respond to the above gaps by evaluating the level to which these strategies can aid reduce carbon emission. Therefore, this study aims at contributing to the literature and practice of the sustainability development by providing realistic solutions for achieving sustainable development in reference to the oil and gas industry.

OBJECTIVES OF THE STUDY

- To analyze the influence of energy efficiency technologies on reducing carbon emissions in upstream oil and gas operations.
- To evaluate the effectiveness of carbon capture and storage (CCS) in mitigating carbon emissions in upstream oil and gas activities.
- To investigate the role of renewable energy integration in lowering carbon emissions in upstream operations.

RESEARCH QUESTIONS

1. What is the impact of energy efficiency technologies on reducing carbon emissions in upstream oil and gas operations?
2. How effective is carbon capture and storage (CCS) in mitigating carbon emissions in upstream oil and gas activities?
3. How does the integration of renewable energy contribute to lowering carbon emissions in upstream operations?

LITERATURE REVIEW

SUSTAINABLE FUTURE OF OIL AND GAS

Oil and gas industry has been central for meeting energy demand of the world where it has been catering more than 30% of energy demand of the world (IEA, 2022) Nevertheless, the sector contributes approximately 15% of the global CO_2 emissions and the figures are poised to rise because of the upstream processes such as exploration, drilling and production (United Nations Framework Convention on Climate Change [UNFCCC], 2021). This dual mandate of being needed for bringing energy and at the same time being the source of pollution, has been a major factor for the industry to question sustainability solutions.

INDUSTRY PRACTICES

Efforts made to enhance sustainability within the context of oil and gas industry include declining the impacts on the environment while maintaining performance. There is a practice that has called for efficient use of energy in exploration and production technology (Gao and Anderson, 2024). Digitalization and automation is also increasingly finding its way into recording of emissions,

utilization of resources and decisions. The conventional energy sources have been frowned at and as a result many organizations have begun to embrace renewable energy sources such as the solar and wind energy.

Carbon capture and storage is emerging to be an important key technology with pilot studies displaying transportability of deep cuts in carbon emissions. For example, the Gorgon CCS project in Australia says that it can capture over four million tons of CO_2 every year from the start of this project (Global CCS Institute, 2022). Similar to the reduction of conventional hydrocarbon emissions, the technologies for methyl methane detection and control have improved the leak prevention ability of the industry which is crucial to keep in mind that methyl methane is, in fact, many folds more potent Green House Gas than CO 2 (IPCC, 2021).

CHALLENGES

However, there are great challenges to sustainability in the oil and gas industry to-date. Some of the challenges facing the integration of the CCS and renewable energy sources include; High capital investment for small scale operations. Coordinated environment sustainable practices have complexities within the governance structures that hinder geographical adaptation such as; regional policies that are poorly synchronized (UNFCCC, 2021). Of course, the energy transition also requires highly profound transformations on the cultural level in companies and organizations, as well as the new skills and business models resulting from them.

The adoption of fossil fuel in the industry also increases another strut in between short run goals and the long run goals. Even as the integration of renewables continues, its share in the energy mix, overall and for the sector under consideration, remains fractional (Gao et al., 2024). However, variability of renewables, the presence of darkness and nights and problems of expansion of CCS initiatives make it difficult to achieve sufficient emission cuts.

The oil and gas industry is precariously placed – the more people depend on its products, the more imperative it becomes for it to adapt with the reality of the climate change impact. Energy intensity has decreased; digitalization has taken place; and the application of CCS has increased from about one percent CO _{2} emission in year 2000 to fourteen percent in year 2014 despite more complexity involved. To tackle these barriers the following would thus be very clear that there is going to be need for an all stake holders including the policy makers, researchers in construction to provide environment friendly, cost effective solutions that will suit everyone. To this end, this article discusses the literature and lays the foundation for evaluating some aspects of managing carbon emissions in the upstream processes.

EMPIRICAL LITERATURE

ENERGY EFFICIENCY AND CARBON EMISSIONS IN UPSTREAM OPERATIONS

Study 1:

Gao et al., (2024) in their paper on upstream oil and Gas operation and energy efficient technologies were examined concerning their role in carving carbon emission. The purpose was to

determine applicability of increased improvement in drilling and production effective in minimizing emissions. The research was done employing the energy transition theory, and used a quantitatively built research design on 150 upstream establishments globally, which formed the study population of which 50 were randomly selected using the method of stratified sampling. Surveys and operational reports were used to fill the information gap and statistical regression was used in analysis. Available findings indicate that the application of technologies in energy efficiency led to emission cuts of average 18% on average. The priorities for action concerned issues of the imperatives of fostering increased policies of energy efficiency and of the need to provide subsidies for automation for energy assets.

Study 2:

Al-Ghamdi and Khan (2023) on monitoring system for energy management and minimization of carbon footprint: evidence from the upstream. They wanted to know how much further a advanced digital systems could be pushed in order to enhance energy consumption. This study was anchored on systems theory and since this paper addressed research questions and hypotheses, this work adopted a case study research method with three purposively selected oil fields. Examples of data collected during the study: through interviews and performance information… The findings disseminating demonstrate an analytical trend of reducing energy wastage by about 12% over time. The authors directed the use of real-time monitoring technologies across the industry for further enhancement and to deploy upstream practices appropriately to the worldwide standard of sustainability.

Study 3:

Oluwaseyi et al. (2022) examined the efficiency of retrofitting old equipment for decrease in carbon emission in the upstream sector in West Africa. The justification for the study was to identify how sustainability can be achieved with little costs as much as is possible in the limited resource environments. Pursuant to the diffusion of innovation theory, this paper used a mixed method, cross-sectional survey research involving 100 professionals and a concurrent semi-structured interview with 20 experts sampled on convenience. The respective use of statistical tests and ITA thematic coding made it to be so. Evaluation of a particular installed installation presented in the paper demonstrated that retrofitting facilitated 10% reduction in emission and substantial operational cost. The proposals that existed were the use of normal prescriptions for retrofitting and upgrade of equipment's through statewide campaigning for upgrade of equipment's.

CCS CONSIDERATIONS AND CARBON EMISSION IN UPSTREAM OPERATIONS

Study 1:

Gao et al., (2024), examined its relevance for reducing CO2 emissions in the tanker sector and other upstream oil operations. This goal has been set and pertained to the assessment of impact and CCS Prospect of CCS projects. Based on the theoretical model derived from ecological modernization, questionnaire surveys were administered over three years to 20 pilot CCS projects

randomly selected from the project list. The data was collected using field measurements and project reports. The additional analysis by trends indicated that in the facilities employing CCS technology, the emitted CO_2 was a quarter lower than the baseline rate. According to the study, CCS expansion should be done through subsidies from governments since CCS proponents shun technologies with high capital costs.

Study 2:

Smith et al., (2023) employed a discounted cash flow estimation to establish profitability of CCS technologies in the upstream hydrocarbon industries in North America. The study was grounded on cost-benefit analysis theory and the study adopted comparative research in comparing different CCS systems. Financial and emission record book from fifteen facilities obtained through systematic sampling were used in the study. Among the drawbacks outlined by the regression model were that though 22% reduction in emitted pollutants could be achieved, it required heavy capital outlay at the start. Some of the recommendations consisted of financial describing more favorable the CS project s financial feasibility and make CCS technology more attractive by extending it impetus optimistic long term incentives tax credit.

Study 3:

Johnson & Taylor, (2022) Technological Factors affecting Carbon Capture and Storage CCS in offshore oil fields. The study sought to identify barriers which would in a way hinder mass deployment of CCS technologies. The study was conducted using systems theory and adopted causal comparative research design and sample of 25 participants recruited from the target population using snowball sampling technique. Majority of the participants' responses were directed in two areas that include infrastructure limitation and barriers in transporting of CO_2 to storage centers. These challenges should therefore be solved by both the governments and private firms as advanced as findings stated above indicate. It pointed out increased understandings of the storage capacity and ways of increasing the required facility for the offshore CCS.

RENEWABLE ENNERGY AND CARBON EMISSION IN UPSTREAM OPERATIONS

Study 1:

Tayab et al. (2024) presented the importance of integrating renewable energy towards reducing emissions. The objectives of the study were therefore to assess the level of decarburization achieved by both solar & wind energy in the upstream processes. This work used resource-based view theory and employed exploratory, case study research design using five upstream facilities of the postal organization, purposively selected. The data gathering was done through O/R's and SSTI. The emission reduction was at 15% when solar energy was made part of the processes as analyzed in the statistics. Other recommendations made includes: high re nomination of energy and, taking advantage of the climatic condition of the area in power utilization of solar energy.

Study 2:

Alvarez et al. (2023) investigated the implications of synergistic renewable systems with utilizing solar and natural gas across the upstream industry of Latin America. The goal was to evaluate emission decrease and functional efficiency of hybrids. Both quantitative and qualitative data were collected using cross-sectional survey data from 80 facility managers and field log data for energy system optimization of the theory. The simulation modeling also assumed that with the help of the TOD, it would be possible to reduce the emissions by 20 per cent and provide more reliable power supply. Suggestions given included that systems should be linked where necessary to get the highest possible energy and minimize ASU emissions to the maximum.

Study 3:

Kumar and Sharma (2022) assessed the feasibility of offshore wind energy in providing support to Indian oil work. It was expected to determine the level in emission cuts and discuss some of the challenges on integration of wind energy. According to contingency theory the then adopted research design was quantitative and out of ten offshore platforms the sample was randomly selected. Regression analysis estimated emissions to be reduced by around 17%, but high costs were identified as a major problem. The recommendations where to increase state subsidy and technical training for the interconnection of wind energy into the electricity supply.

RESEARCH GAP AND RESEARCH CONTRIBUTION

There is a gap of knowledge that persists when it concerns the upstream oil and gas carbon emissions matter in the state of the art sustainability research within the oil and gas industry. First, although there is a larger number of studies concerning technology choice models related to energy efficiency technologies, there are still some issues that have not been quite clarified or remain insufficiently tested by scholars, namely, the suitability, efficiency and cost of investments in technologies for efficiency enhancement of energy consumption in various operating conditions. Advanced drilling techniques are available for world emissions cuts as Gao et al. also note that still has no adopting method for low resource area and old plant.

Second, CCS technologies are presented as the new radical approach to emissions cutbacks. Nevertheless, Smith et al. (2023) have also found that generally research in CCS does not investigate the question of how it can be co-deployed with other mitigation measures such as efficiency or renewables. And the technical and economic conditions given by Johnson & Taylor, (2022) for the adoption of CCS in offshore oil fields have not been precise hence the subject of efficiency remains in doubt.

Third, while integration of renewable energy is still a growing topic, Kumar and Sharma (2022) establish that more research is focused on large scale while less emphasis on the upstream of both renewable and conventional energies, and integrated systems. This shortcoming keeps one from finding out how and in which manner can renewable energy meet many an operational need and area.

This study addresses these research gaps by offering a comprehensive analysis of the combined impact of energy efficiency technologies, CCS, and renewable energy potentials on emissions reduction the upstream sector of the oil industry. This work also adds to available literature in pursuit of an evaluation on how these strategies interrelate in heading towards achieving the goal of de-carbonizing the up-stream sector in the oil and gas industry. Finally, the research has implications for the practice to policymakers and the industrial community in providing, practical solutions to the challenge of sustainability across a variety of contexts.

RESEARCH METHODOLOGY

RESEARCH DESIGN

This study employed a secondary research strategy, where the researcher collected data from scholarly reviewed journals, business intelligence reports and other credible sources.

Justifiably, oil and gas industry can be described as the sphere of highly specialized and rigorously regulated, that is why collection of primary data is costly and rather challenging (Smith & Jones, 2023).

Sources and types of articles included e-prints of the inclusion criteria of the articles that were published between January 2021 to December 2024 so as to capture the current and emerging technologies and existing regulations. This was done through searching using different reputed databases such as Science Direct; Google Scholar and other databases of specific industries.

DATA COLLECTION METHODS

This research used secondary research data sources and data collected from research journals, conference proceeding, and thesis and dissertations. As it is with finding current BABPP and PPER research benchmarking system that provides primary data and theoretical knowledge on energy management and efficiency technologies, CCS, and renewable power in the upstream sector of the oil & gas industry.

Data gathering was a mediated process that included a mechanical scan of the academic databases primarily Science Direct, IEEE Explore, and ProQuest Dissertations and Theses. Also, to limit the study to industry relevant works, papers published in One Petro database and papers published in the Society of Petroleum Engineers (SPE) conference proceeding were utilized as secondary sources.

DATA ANALYSIS

Data were organized thematically to address the three primary objectives: risks and prospect in terms of energy intensity, CCS initiative acceptability, and renewables toward de-carbonizing upstream operations. Thematic synthesis has been used when doing systematic reviews and when doing secondary analysis of the literature to identify patterns, themes and relationships in the literature (Thomas and Harden, 2008).

Thematic synthesis was conducted in three stages: coding the data, coming up with descriptive themes analytical themes. First, the qualitative data of each study was explored and secondary analysis was carried out on energy efficiency, carbon capture and storage and integration of renewable energy using NVivo tools. Cues assigned while coding were named as operative themes concerning the subject of discourse under evaluation including; energy optimization, limitations of CCS implementation, and renewal energy scalability. The Descriptive themes were then related to the Analytical themes in regard to the objectives and aims of the research.

RESULTS AND DISCUSSION

ASSESSMENT OF ENERGY EFFICIENCY TECHNOLOGIES

Energy efficiency thus needs to present a key role in the delivery of carbon reductions across the upstream oil and gas industry. According to researchers, while organizational implementation of complex technologies for energy-saving equipment and digital control systems improve resource utilization, there are no GHG emissions by a wide margin (Gao et al., 2024). A high-efficiency compressor, a variable speed drive, an improved heat exchanger, among others, different research work suggests that lower energy intensity in upper stream plant can be accomplished by 15-20% (Oluwaseyi et al., 2022). For instance, the Middle East upstream activities which incorporate implementation of real-time monitoring system results in energy wastage of 12% based on Al-Ghamdi and Khan (2023).

Technologies for predictive maintenance has also emerged one of the key enablers of energy efficiency within systems. This way, conditions that may cause problems are noted early and prevented and ensures the best energy efficiency is maintained (Gao et al., 2024). Far more frequently implemented in the upstream sector, digital twins replicate the corresponding physical structures to allow for propositional energy conservation initiative-specific real-time testing (Smith et al., 2023).

These affirmations notwithstanding, it is not all plain sailing for the parties involved yet. The high costs of installing efficient energy using appliances and lack of capital in the earlier stages to finance efficient machineries are some of the reasons why adoption is mostly done by small businesses. Further we have noticed that career human resource and administrative scarcity of qualified manpower skilled enough to operate these sophisticated system is also a major challenge (Kumar & Sharma, 2022). To eradicate these problems, the governments jointly with the industrial partners should encourage measures like financial facilitation and encouragement, training for effectiveness, and information sharing forums with a view of enhancing the penetration of effectiveness technologies.

In this sense the evidence demonstrated raises a view that energy efficiency really can catalyze sizable emission reductions. However, the ideal solution here obviously needs other more general approaches to partner with as regards to cost, talent, and size.

CARBON CAPTURE AND STORAGE

CCS is known to have been established as a solution to the reduction of carbon emissions within offshore upstream oil and gas business. The same studies reveal that CCS reduces the emissions of CO_2 by up to one quarter in the facilities that use it (Gao et al., 2024). CDC is a process by which carbon dioxide from operations is captured, compressed, marketed and then stored in specific geological structures such as depleted reservoirs. For instance, now the Gorgon CCS project in Australia is, yearly, capturing more than 4 million tone of CO_2 after the project commencement (Global CCS Institute, 2022).

However, the efficient use of CCS technologies has the following challenges. This means that cost has remained the most crucial hurdle and has meant that both capitalized and operating costs are high (Smith et al., 2023). However, there is also several problems that also may hamper utilization of the REEs; the first of them is technical one including the issue of the long – term storage of the elements, as well as the possibility of their leakage. According to Johnson and Taylor (2022) on the fact that offshore CCS projects face the issue on how to move CO_2 to the storage place and the problem with the facilities in terrible climate conditions.

That being noted, CCS technologies are still advancing and the technologies are becoming even more plausible. Smith and Jones further noted that if EOR is achieved through CCS combined with post hydrocarbon extraction cost/environmental benefits could be traded. In order to eliminate financial and technical hurdles for these technologies, policymakers will be forced to support these technologies through subsidies/tax credits and/or public-private-partnership funding. Further research regarding ways of enhancing storage capacity and reducing their costs are also required.

As it will be seen from the evidence presented here it is evident that CCS is indeed a successful intervention and it holds the potential to deliver very large reductions in emissions in the upstream segment of the oil and value chain but as to how applicable it is and how costly it would he has yet to be determined.

RENEWABLE ENERGY INTEGRATION

Great potential exists to reduce the levels of our carbon footprint in upstream oil and gas through integration of renewables. In particular, with the use of solar and wind, and combined energy programs, it is possible to reduce the use of fossil energy for operational energy consumption. According to the study by Álvarez et al. (2023) it was discovered that incorporation of solar energy upstream facilities in Latin America lead to the reduction of its emissions by 15%. Similarly, Kumar and Sharma (2022) noted that the use of the wind energy in offshore operations in India reduced emission by 17%.

Other systems are the combined energy systems, which consist of the renewable energy system and the conventional fossil systems. For instance, the deployment of hybrid systems in the upstream facilities in the Middle East, it was observed that carbon emission was cut by 20 percent without compromising with the reliability of the operations (Tayab et al., 2024) However, the utilization of renewable energy sources has its own challenge. Renewable energy generating

technologies require huge upfront investment and renewable energy is available in an intermittent fashion hence there is the need to store energy, such as the use of batteries.

Renewables have the capability and the requirement for integration and depends upon the policy and technologies for further improvement. Governments must mandate firms to extend subsidies and grants to improve the utilization of renewables while a number of industrial players must fund future development to make renewables even more efficient and cheaper. All the evidence discussed herein may be seen to strongly affirm renewable energy as capable of supporting the de-carbonization of the upstream oil and gas sector construct.

COMPARATIVE DISCUSSION

An analysis of energy efficiency technologies, CCS and integration of renewable energy sources recognizes them and their challenges in reducing carbon emissions in upstream oil and gas operations. Energy efficiency technologies are directly related to emission reductions through optimizing the efficiency of activities carried out in industries; obstacles are not as pressing as with CCS, or renewal energy sources (Gao et al., 2024). However, the use of ICT is limited by, for instance, costliness of putting up the technology and the shortage of skilled personnel (Kumar & Sharma, 2022).

CCS self-imposed despite being translation measure that is very efficient in capturing and store CO_2 there are some issues that revolve around the economic profitability and technicality particularly in offshore projects (Smith et al., 2023). Renewables are longer lasting and sustainable but the source has hitches such as being intermittent in some of its sources and may require huge capital investment in plants and storage (Alvarez et al., 2023).

The call for employments of these strategies suggest that for the real actualization of the decarburization of the upstream sector, a cocktail of the above strategies is most appropriate. For instance combining of energy efficiency with CCS and renewable energy integration, then blending of intermittent sources with permanent controllers and fast response together with fuller loads with CCS and RE. Both the policy makers and industry players have to consider the problem solving in terms of cost, probability and impact for the implementation for the futuristic upstream oil and business venture.

CONCLUSION

SUMMARY OF FINDINGS

Thus the aim of this paper was to evaluate the current practices towards reduction of carbon emissions in the upstream oil and gas industries bearing in mind the energy management systems, CCS and renewable energy feed –in. Referees stresses that different efficient technologies including superior compressors, two bear heat exchangers and having monitor methods would reduce energy density and emission by about 20% later as stated by Gao et al., (2024). However, its use is currently limited by some factors such as high initial cost and need for technical personnel.

CCS was found to be feasible when one or multiple examples showed that in geologically appropriate locations, CCS technology would translate to 25% reductions in CO_2 emissions (Smith et al., 2023). However, stickers are less practical for actually storing data and for the infrastructure required to supply storage networks where the sticker scheme is implemented freeze especially if it is implemented offshore (Johnson & Taylor, 2022).Solar and wind energy have been proved to play a big role in reducing emissions by between 15%–20% when the reformed BESS is included in hybrid energy systems (Alvarez et al., 2023). However, since these tariffs are volatile, and have high fixed costs, they can only be implemented if supported by sound policies and relevant technological advance.

Altogether, the presented results carry an implication that these strategies can and should be used in combination since none of them can significantly reduce the emissions without adequate account of the upstream operations' needs and goals: when combating the emissions, the general goal is to assist the development of sustainability.

RELEVANCE FOR PRACTICE AND DIRECTIONS FOR FUTURE RESEARCH

It is imperative that, policymakers, and most industries and other upstream stakeholders embrace a systems approach that is realistic in taking into account energy efficiency technologies, CCS, and renewable energy systems. Therefore, the governments must back these measures, for example by employing the policy of tax-relief or subsidy. Further confusion is that more research work is required to solve the issues of commercialization and of operations particularly in CCS and in the integration of renewable energy. Its uptake can be improve through the use of highly defined checklists in transporting energy efficiency technologies in existing building fabric as well as enhancing renewable energy storage. More importantly, cross-sector partnership: A number of utilities, oil and gas companies and academics will come a long way towards realizing the use of sustainability for the oil and gas industry worldwide.

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