INTERNATIONAL JOURNAL OF LATEST TECHNOLOGY IN ENGINEERING, MANAGEMENT & APPLIED SCIENCE (IJLTEMAS)

ISSN 2278-2540 | DOI: 10.51583/IJLTEMAS | Volume XIII, Issue X, October 2024

Analysis of Carbon Footprint from a Drilling Project in Niger Delta, Nigeria

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DOI : https://doi.org/10.51583/IJLTEMAS.2024.131013

Received: 17 October 2024; Accepted: 28 October 2024; Published: 08 November 2024

Abstract: The oil and gas industry plays a significant role in the release of carbon emissions into the atmosphere. Therefore, it is crucial to accurately gauge and minimize its carbon footprint which requires the thorough measurement of emissions and the identification of the primary sources of carbon emissions. By doing so, we can then determine the most effective methods for reducing these emissions.

This study aims to precisely quantify and decrease the carbon footprint associated with drilling operations. To achieve this, we evaluated the diesel and petrol consumption from an onshore drilling project in the Niger Delta and used an emissions model to assess carbon dioxide (CO_2) emissions from a drilling rig, thus gaining a comprehensive understanding of current emission levels and the potential for reduction. The data collected included the daily fuel consumption for power generation, transportation, and handling vehicles. The CO_2 emissions resulting from fuel consumption were calculated and measured to be 103.5 metric tonnes.

Our analysis determined that the primary contributor to the emissions was the energy generation on the site, primarily from the generators. Additionally, it was found that the circulating system on the rig was the main source of CO_2 emissions. The study underscores the necessity for long-term impact assessments of drilling fluids and new technologies, emphasizing the need for innovative solutions to further decrease emissions.

Keywords: carbon footprint, carbon dioxide emissions, drilling project, fuel consumption, Niger Delta

I. Introduction

The petroleum industry in Nigeria, particularly in the Niger Delta, plays a crucial role in the country's economy, generating significant revenue and employment. It is also the primary source of energy and a driver of development on a global scale. In Nigeria, the crude oil industry has played a vital role in shaping the country's economy. This sector has been a major source of wealth for the country, contributing 80% to government revenues and accounting for 90%-95% of foreign exchange earnings (Aaron, 2005). However, it also poses environmental challenges, including carbon emissions from drilling activities. The carbon footprint entails all forms of emissions, from burning to transportation to electricity generation. Besides just carbon dioxide, there are also other greenhouse gases, such as methane or chlorofluorocarbons (CFCs). It is usually calculated as a measure of the mass of CO_2 or similar gases produced in a region or a particular industry (Abeydeera & Wadu, 2019; Huang et al., 2021).

Understanding and addressing the carbon footprint in drilling projects is essential for environmental sustainability and the long-term viability of the petroleum and gas industry. Embracing global initiatives and trends for carbon footprint reduction is not only a responsible business practice but also a strategic move for staying competitive in a rapidly evolving energy landscape. The first step to reducing the carbon footprint of any process is a good estimation of the present carbon footprint (Al-Kuwari et al., 2021).

Andrews (2009) defined carbon footprint in the context of an organization as the total amount of greenhouse gas (GHG) emissions for which an organization is responsible. They explained that these greenhouse gases, such as carbon dioxide, methane, nitrous oxide, and halocarbons, absorb and radiate the heat from the sun. This is called the greenhouse effect. This effect is responsible for an increase in global temperature by $33^{O}C$. However, an uncontrolled increase in the concentration of these gases increases the warming effect. This is called global warming.

Johnson et al. (2022) emphasized the importance of reducing carbon dioxide emissions in well-construction operations. To achieve this, it is necessary to measure the current emissions and identify the main drivers of the footprint. Analyzing the data available from two modern land rigs, they found that the mud pumps are the biggest culprit for the CO_2 release. The top drive and draw works have a much less significant footprint comparatively. They built and verified an emissions model to ensure that their work is relevant to more than just a few high-end modern rigs. This model was created to calculate the amount of CO_2 released from drilling parameters and generate a real-time carbon emissions log from the contributions of the major systems on any rig for which fuel consumption data is available.

Aaron (2005) pointed out the paradox of the Niger Delta. This region is home to approximately 30% of the oil reserves in Africa and over 3 trillion cubic meters of gas reserves, which contribute to more than 85% of the nation's gross domestic product (GDP), over 95% of the national budget, and over 80% of the country's wealth. However, the Niger Delta remains one of the poorest regions in the country plagued with oil theft and Oil spills, primarily due to the environmentally harmful exploitation of oil and

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gas (Emeke & Maduewesi, 2022). The ecological implications of these activities have rendered farming and fishing useless, which were once the primary occupations of the rural people residing in the area. The ecologically unfriendly activities of oil Transnational Corporations (TNCs) and the state's petroleum development policies led to poverty in the Niger Delta. This, in turn, leads to environmental degradation. The oil TNCs are more concerned with maximizing their profits and often engage in activities that are detrimental to the environment. Emeke (2023) posited that the state's petroleum development policies are focused on the exploitation of oil and gas resources without considering the negative environmental impact of these activities. The lack of concern for the environment and the people living in the region has led to a vicious cycle of poverty and environmental degradation in the Niger Delta.

Kingston and Iragunima (2020) conducted research on the regulatory frameworks governing offshore drilling of oil and gas in Nigeria, focusing on the challenges related to enforcing regulations and ensuring accountability in the petroleum sector of the country. The study emphasized the complex nature of implementing regulatory instruments and ensuring that the offshore production activities of crude oil companies are held accountable. By drawing comparisons with global practices, the research highlighted the need for structured measures to monitor compliance and enforce laws effectively while balancing crude oil production with considerations for safety, environmental responsibilities, economic equilibrium, fiscal stability, and adherence to customary international laws. The article aimed to devise strategies for improving oversight and addressing omissions and lapses in laws, regulations, and institutional management of offshore facilities by identifying fundamental defects in the existing legal and regulatory framework governing offshore oil drilling in Nigeria. Ultimately, the research aimed to contribute to the discourse on enhancing regulatory effectiveness and promoting sustainable practices in Nigeria's onshore oil and gas industry to ensure greater accountability and environmental stewardship in petroleum operations. The window to transit to cleaner energy sources holds great future for our developing economy (Oyegbile et al., 2024).

This study aims to carry out an analysis of the carbon footprint from a drilling project in the Niger Delta, Nigeria. By analyzing the carbon footprint across various stages of drilling operations, the research can provide valuable insights into the environmental impact of petroleum and gas extraction activities. This knowledge can inform the development of more sustainable drilling practices and technologies within the field of petroleum and gas engineering.

II. Methodology

This section provides a description of the methods used to carry out this study, a description of the drilling location and the tools used.

Methods

A combination of quantitative evaluation and qualitative assessments have been used. As the major sources of carbon emissions during drilling come from fuel consumption from the major equipment on location, the daily diesel and petrol consumption was monitored daily and aggregated over the drilling project duration of about seven months. Subsequently, an emission model (Poroma et al. (2013); Ferrari et al. (2021); Johnson, et al. (2022)) for quantifying carbon emissions based on energy consumption was used as shown in Section 2.3. The emission model was implemented in MS Excel using Visual Basic coding.

Qualitative assessments, on the other hand, involved gathering subjective insights through secondary data from published surveys and reviews. This approach facilitates a deeper understanding of the socio-economic and environmental dynamics surrounding the drilling project. It allows for the exploration of community perceptions, stakeholder perspectives, and potential mitigation strategies.

Description of the Drilling Location

The drilling rig considered for this study is a 1,300 HP workover land rig used for well re-entry and drilling shallow wells operated in the Niger Delta. Some key specifications about the well of interest and equipment used on the drilling location are outlined below:

- Well Total Vertical Depth (TVD): 10,400 ft
- Completion status: 3-1/2" string selective dual injector
- Vehicles and personnel transport: 4 Hilux vehicles
- Material transport and handling vehicles: Crane, Forklift

Power ratings of the major equipment on the drilling location have been obtained as shown in Table 1.

Table 1: Power Rating of the drilling rig systems

System	Power Rating (HP)
Hoisting system	600
Rotary system	200
Well Control system	50

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Power system (4 diesel generators)	1600
Circulating system	
Mud pumps (2)	600
Shale shakers	70

Basis for calculation of CO_2 emissions

The calculation of carbon emissions during drilling is based on the fuel burned to generate energy. For every liter of fuel used, there is an equivalent mass of CO_2 produced. The calculation is preceded by stating the applicable chemical reaction which relates fuel consumption to CO_2 production. The reactions are different for diesel and gasoline.

For Gasoline:

1 liter of petrol is 0.74 kg on average. Therefore, using one mole of petrol as a basis:

$$C_8H_{18} + 12.5O_2 \rightarrow 8CO_2 + 9H_2O \quad (1)$$

This yield atomic numbers of 96 and 18 for carbon and hydrogen respectively.

$$\text{Carbon percentage of petrol} = (96/(96+18)) * 100 = 84\% \quad (2)$$

$$\text{Carbon mass of petrol per liter} = 0.84 * 0.74 = 0.625\ kg \quad (3)$$

Based on 12 g/mole of Carbon and 44g/mole of Carbon dioxide,

$$\text{1 liter of gasoline produces} \rightarrow (44 * 0.625)/12 = 2.29\ kg \text{ of } CO_2 \quad (4)$$

For Diesel:

1 liter of petrol is 0.84 kg on average. Therefore, using one mole of diesel as a basis:

$$C_{12}H_{23} + 35.5O_2 \rightarrow 24CO_2 + 23H_2O \quad (5)$$

This yield atomic numbers of 144 and 23 for carbon and hydrogen respectively.

$$\text{Carbon percentage of diesel} = (144/(144+23)) * 100 = 86.2\% \quad (6)$$

$$\text{Carbon mass of diesel per liter} = 0.84 * 0.74 = 0.724\ kg \quad (7)$$

Based on 12 g/mole of Carbon and 44g/mole of Carbon dioxide,

$$\text{1 liter of diesel produces} \rightarrow (44 * 0.724)/12 = 2.66\ kg \text{ of } CO_2 \quad (8)$$

The total CO_2 emissions were calculated over a seven-month period including rig move, drilling and completions. A daily fuel consumption tracker built in MS Excel was used onsite from the following equipment:

- 4 Diesel generators for power generation
- 4 Hilux for personnel transport
- 2 Cranes and 1 Forklift for onsite material transport and handling vehicles.

By integrating quantitative data with qualitative insights, the research aims to uncover the underlying drivers of carbon emissions and propose actionable recommendations for sustainable development.

III. Results and Discussion

After a compilation of the data and subsequent analysis, inferences have been drawn from the fuel consumption and rig energy rating presented in this section.

The contribution of the diesel generators, cranes, forklift and the Hilux vehicles to the carbon footprint of the drilling project is shown in Table 1. The total mass of CO_2 emissions (kg) calculated was 103533.4 kg. We can easily identify which equipment is most responsible for emissions.

Table 1: Fuel Consumption

Contributors	Diesel Generators	Cranes	Forklift	Hilux
Mass of Emission (kg)	64445.6	19526.8	4017.4	15543.6

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Percentage (%)	62.2	18.9	3.9	15.0

Figure 1 portrays the emission distribution onsite the drilling project.

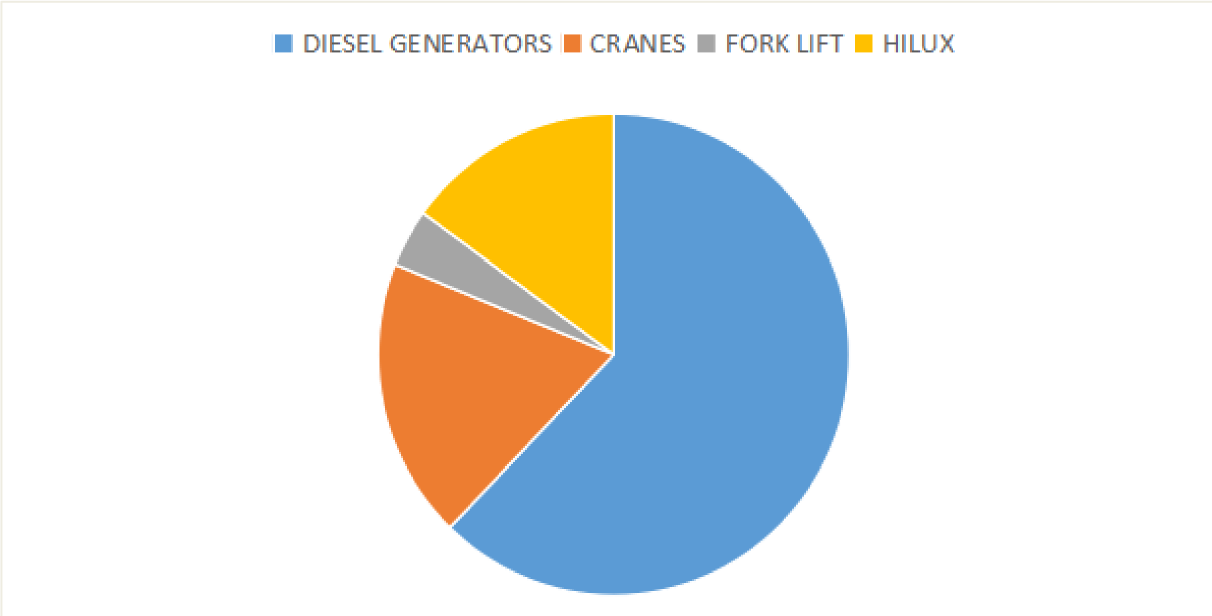

Figure 1: Emission spread by equipment

The source of CO_2 emissions in the drilling project is the fuel consumption by various machines for:

1. **Power Generation**:

Description: Generators are used to provide electricity for various operations on the drilling site. They typically run on diesel fuel and are often in continuous operation, leading to a significant amount of fuel consumption and, consequently, CO_2 emissions.

Emission Contribution: 64.4 metric tonnes of CO_2, representing 62.2% of the total emissions.

Analysis: Diesel generators are the primary source of CO_2 emissions in the project. Their significant contribution is due to their heavy reliance on diesel fuel for power generation and the fact that they were operational all through the duration of the project. This high percentage suggests that improving the efficiency of power generation or switching to alternative energy sources could substantially reduce overall emissions.

2. **Handling Vehicles:**

Description: These vehicles are used for transporting equipment and materials to, from, and on the drilling site. They are the cranes and forklifts that operate on diesel fuel. The frequent movement and heavy loads contribute to high fuel consumption and CO_2 emissions.

Emission Contribution: The cranes emitted 19.5 metric tonnes of CO_2, representing 18.9% of the total emissions, while the forklift emitted 4 metric tonnes of CO_2, representing 3.9% of the total emissions.

Analysis: Cranes are the second-largest contributor to CO_2 emissions. Their operations involve lifting and moving heavy equipment and materials, which requires considerable energy. The crane produced significantly high CO_2 but wasn't used all through the span of the project. Optimization of crane operations, such as reducing idle time, getting an efficient operator, and ensuring proper maintenance, could help lower emissions. Forklifts contribute a smaller but still notable portion of the emissions. These vehicles are used for handling and transporting materials on-site. Considering their lower contribution, efforts to reduce emissions here include using more efficient forklifts or optimizing their usage patterns.

3. **Personnel Transport Vehicles:**

Description: These vehicles are used for transporting people to and from the drilling site

Emission Contribution: 15.5 metric tonnes of CO_2, representing 15.0% of the total emissions.

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Analysis: Hilux vehicles are used primarily for personnel transport. Their significant contribution is due to high usage. They were used every day throughout the duration of the project. Strategies to reduce emissions could involve using more fuel-efficient vehicles such as buses, which have a size advantage and can transport more people with less fuel consumption, optimizing transport schedules, or carpooling to reduce the number of trips. There are also alternative choices of energy for personnel transport, such as electric vehicles, even though this is not very cost-efficient as of today.

Given that diesel generators are the largest contributor to emissions, implementing energy efficiency measures here could have the most significant impact. Options include upgrading to more efficient generators, using hybrid systems, or incorporating renewable energy sources like solar panels.

The more energy produced by the generators, the higher the emissions. However, from the Figure 2, we see a difference from the linear progression after a while. This is due to the increased workload on the generators during the drilling and completion phase. The higher the workload on the generators, the more energy is generated per liter of diesel used. It is therefore a good idea to carry out projects with high energy requirements using the generators in a hybrid system.

This analysis highlights the key contributors to CO_2 emissions in the drilling project. By focusing on the largest sources, particularly diesel generators and cranes, and implementing targeted strategies to improve efficiency and reduce fuel consumption, the project can significantly lower its overall carbon footprint.

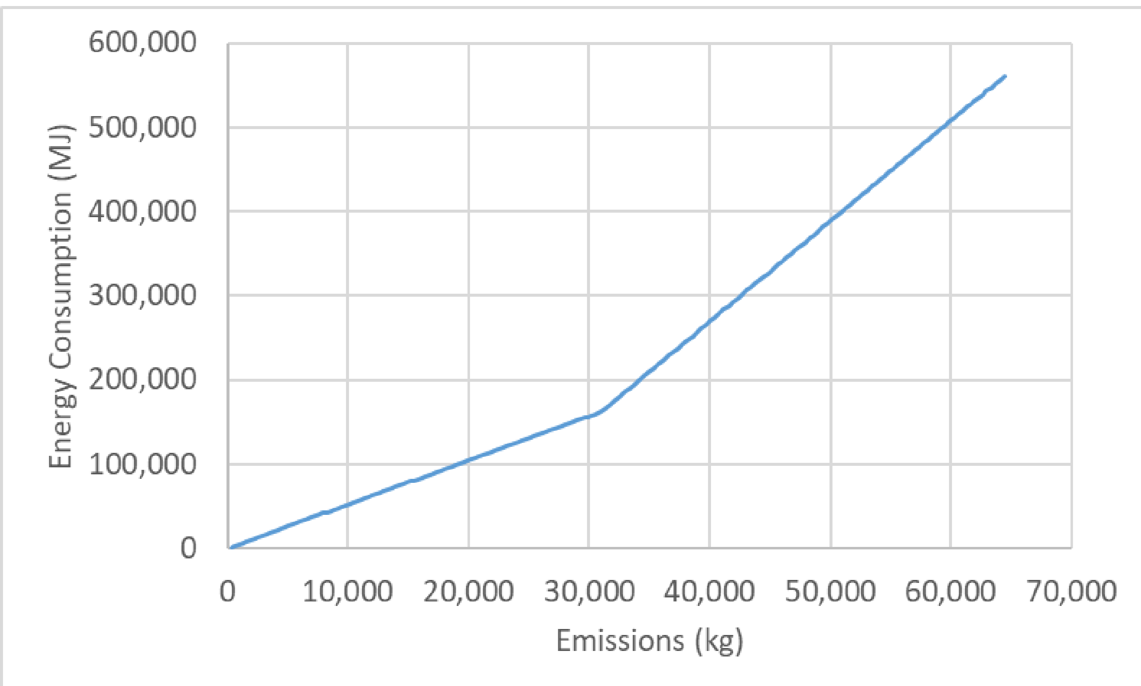

Figure 2: Energy consumption versus emissions

Energy Consumption

The CO_2 emissions from the drilling project is due to the fuel consumption by various systems involved in the drilling operations. These systems include hoisting, rotary, circulating, and well control. Table 2 summarizes the daily power consumption and the percentage contribution of each system to the total power consumption.

Table 2: Power Consumption

System	Hoisting	Rotary	Circulating	Well control
Total power consumption (MJ)	14496.4	11811.89	39569.82	3221.42
Percentage (%)	20.98	17.09	57.26	4.66

Figure 3 shows the contribution of the main drilling systems to power consumption during the drilling operation. On drilling rigs with three mud pumps due to the well depth, the power consumption is bound to increase.

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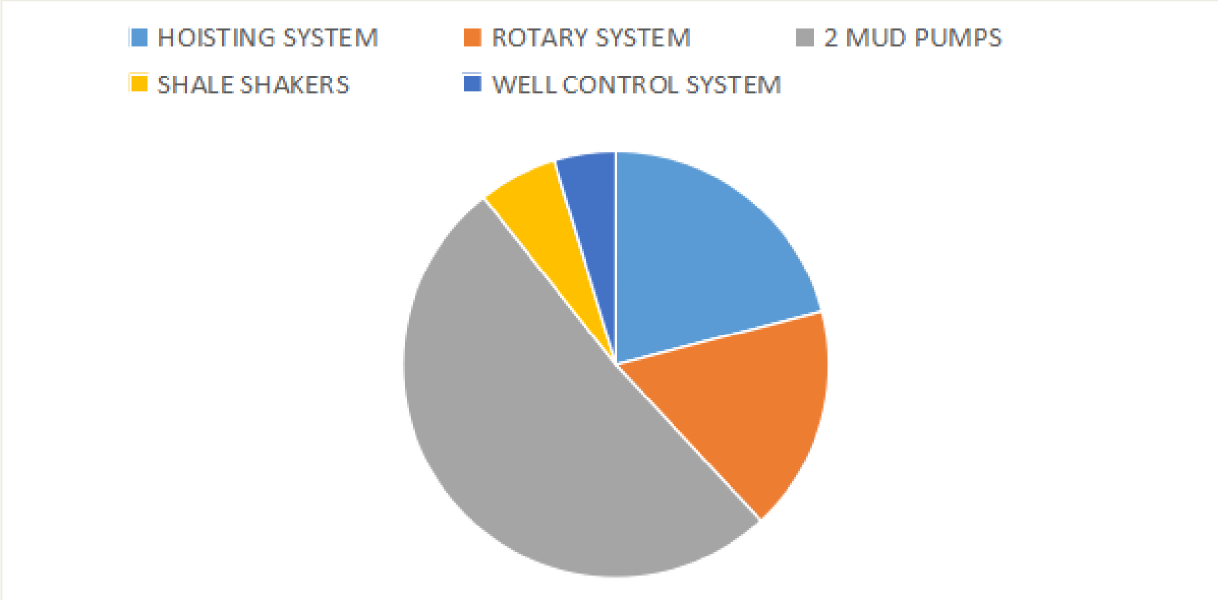

Figure 3: The contribution of different drilling systems to total power consumption

Circulating System:

- **Daily Power Consumption:** 39,569.82 MJ, representing 57.26% of the total power consumption.
- **Analysis:** The circulating system is the most significant consumer of power in the drilling project. This also means that, with regards to drilling, this system is most responsible for the carbon footprint and must be paid the most attention to when considering methods of optimization of the drilling rig. This system is responsible for circulating drilling fluids to cool the drill bit, remove cuttings, and maintain well pressure. The high energy consumption is primarily because it was operational for almost 24 hours daily. To reduce the overall energy consumption, strategies could include optimizing fluid properties, improving pump efficiency, and ensuring proper maintenance of the circulating system components.

Hoisting System:

- **Total Power Consumption:** 14,496.4 MJ, representing 20.98% of the total power consumption.
- **Analysis:** The hoisting system is the second-largest consumer of power. It is used for lifting and lowering the drill string, casing, and other equipment in and out of the wellbore. This system is very power-dependent, as heavy objects are moved through the wellbore. However, as it isn't operated for extended periods of time, its impact is not as high as the circulating system, even though the power rating for both the hoisting system and circulating system is close. The significant power consumption by the hoisting system suggests that optimizing the hoisting operations, such as reducing unnecessary lifts, using energy-efficient hoisting equipment, and implementing advanced control systems, could contribute to overall energy savings and reduced CO_2 emissions.

Rotary System:

- **Total Power Consumption:** 11,811.89 MJ, representing 17.09% of the total power consumption.
- **Analysis:** The rotary system is responsible for rotating the drill bit to cut through the earth. Its power consumption is crucial for the progress of the drilling operation. This is also operated for extended periods, sometimes up to 24 hours a day. Enhancements in drill bit design, rotary drive systems, and operational practices can help reduce the power demand of the rotary system and, by extension, the emission level.

Well Control System:

- **Total Power Consumption:** 3,221.42 MJ, representing 4.66% of the total power consumption.
- **Analysis:** The well control system has the lowest power consumption among the systems analyzed. Even though it is operated 24 hours per day all through the drilling process, the energy requirement is so low that the impact is so significant. It is essential for maintaining well integrity and preventing blowouts. Although its power consumption is relatively low, ensuring the efficiency and reliability of the well control system is critical for safe drilling operations. Regular maintenance and the use of advanced well control technologies can help maintain its energy efficiency.

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Given that the circulating system is the largest power consumer, improving its efficiency should be a priority. This could involve using more efficient pumps, optimizing fluid dynamics, and implementing real-time monitoring to adjust operations dynamically.

IV. Conclusion and Recommendations

The primary objective of this research was to quantify the CO_2 emissions associated with drilling operations, identify the major sources of these emissions, and develop strategies to reduce them effectively. The key results of this project were as follows:

- The primary source of CO_2 emissions is power generation, and this is where most mitigation strategies are required.
- The total carbon produced through the course of this drilling project is 103.5 metric tons.
- The most significant emissions were traced to the operation of mud pumps, which are essential for the circulation of drilling fluids.

Therefore, it was recommended as follows:

1. The use of Alternative Energy Sources. As previously concluded, energy generation is the primary source of CO_2 emissions. A source of energy that doesn't burn fossil fuels will make the process much cleaner. Kharwade et al. (2022) showed the possibility of solar-powered drilling using solar panels and batteries. If this can be fully or partially utilized (hybrid power generation), carbon emissions will be greatly mitigated.
2. Upgrade mud pumps to more energy-efficient models, implementing variable frequency drives (VFDs) to optimize pump speed and reduce energy consumption.
3. Develop and utilize drilling fluids that require less energy for circulation. Also, explore alternative fluids that have a lower environmental impact.
4. Install advanced monitoring systems to track fuel consumption and CO_2 emissions in real time, using data analytics to identify inefficiencies and areas for improvement.
5. Transportation also contributed significantly to CO_2 production. There are alternatives, such as the use of electric cars, even though, right now, the cost implications are too high.

On the Operational side,

1. Implement best practices for drilling operations, such as optimizing the rate of penetration (ROP) and minimizing non-productive time (NPT). Use automated drilling systems to enhance precision and reduce unnecessary energy use.
2. Conduct regular maintenance and inspections of all rig equipment to ensure optimal performance and fuel efficiency. Replace outdated or inefficient equipment with modern, energy-efficient alternatives.
3. Optimize the use of generator sets to match power output with demand, reducing idle running time and fuel waste. Implement load-sharing strategies to distribute power demand evenly across generators.

While on the policy side,

1. Advocate for stricter emission standards for drilling operations to ensure industry-wide adherence to best practices.
2. Promote policies that offer financial incentives for adopting energy-efficient technologies and renewable energy sources in drilling operations.
3. Implement regulations that require companies to monitor and report their CO_2 emissions, fostering transparency and accountability.
4. Encourage government and industry collaboration to fund research and development in low-emission drilling technologies and practices.
5. Develop training programs and certification requirements for drilling personnel on emission reduction techniques and sustainable practices.

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