Environmental Waste Management and Control in Oil and Gas Industry: A case study of NLNG Bonny, Rivers State

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Abstract- The oil and gas sector generate a significant amount of waste on a global scale. This waste is comprised of generated water, oil sludge, and flue gases, all of which have the potential to have a detrimental effect on the environment. Because of this, there is a need for the treatment of this waste as well as the safe management of it. Although there have been a number of approaches developed for the treatment of waste from the oil and gas industry, recent research trends have brought to light the fact that in order to ensure the sustainable treatment and management of waste from the oil and gas industry, it is necessary to combine these approaches with concepts of resource recovery and re-utilization that are in line with the perspectives of the circular economy. Essentially, it is of the utmost significance for the oil and gas sector to transform waste into products that have economic value added to them, reduce their negative affects on the environment, and encourage sustainable practices. This research focused on two different kinds of waste streams that originated from NLNG, Bonny. These waste streams included flue gases (namely CO2 and SO2) as well as liquids (produced water). During the course of this investigation, an Atomic Absorption Spectrophotometer was used to evaluate the water that was generated by NLNG Bonny. The results of this analysis revealed that the water included several heavy metals. When compared to the 300 micron size, the adsorbent with a size of 150 microns delivered a satisfactory overall outcome. It has been shown that the adsorption is improved when the particles are of a finer particles. The decrease of gas flaring at NLNG has been a demonstration of the company's commitment to environmental responsibility via the implementation of flue gas management methods. Based on the reaction that takes place under stoichiometric air conditions, it can be seen that 8.92 kilograms of water are produced in the flue gas for every kilogram of hydrogen that is present. The study reveals that challenges remain in fully eliminating flaring.

I. INTRODUCTION

- Background of the Study

The massive oil and gas reserves that Nigeria has are among the country's most valuable assets. Nigeria is sometimes referred to as the "Giant of Africa," and it is a nation that is blessed with an abundance of natural resources [1], the oil and gas business in Nigeria has been an essential component of the country's economy, making a significant contribution to the creation of income and acting as the primary pillar of the energy sector in the country. The discovery of oil in Nigeria in amounts that might be used for economic purposes goes back to the 1950s. In 1956, Oloibiri, which is located in what is now Bayelsa State, was the site of the first substantial oil find, which ultimately led to the formation of the oil industry in Nigeria [2]. Since that time, Nigeria has developed into a significant participant in the international energy market and has become one of the leading oil-producing countries in continent of Africa.

The majority of Nigeria's hydrocarbon reserves are comprised of crude oil and natural gas. Nigeria has considerable hydrocarbon reserves. According to Ite, Ibaba, and Wemedo [3], the majority of the nation's oil deposits are situated in the Niger Delta area, which is home to a large number of oil fields and basins. There have been a number of variables that have contributed to the fluctuations in Nigeria's oil output throughout the years. These elements include market dynamics, geopolitical difficulties, and infrastructural constraints. Nevertheless, it has maintained a position among the leading oil producers in Africa on a continuous basis. There is little doubt that the oil and gas business in Nigeria has had a significant influence on the economy of the country. [4], oil revenues constitute a significant share of the government's overall income and profits generated from foreign currency investments. It has been essential for the government to generate this money in order to finance various initiatives, such as the construction of infrastructure, education, and healthcare.

Despite the fact that it is economically significant, the oil and gas sector in Nigeria has been confronted with a multitude of obstacles and environmental concerns. Many of these issues have far-reaching ramifications for both the environment and society. There have been substantial issues that have been accompanied by the oil and gas business in Nigeria, despite the fact that it has brought about economic success in the country. The Niger Delta area has been plagued by environmental problems including as oil spills, gas flaring, and the loss of habitats, which have resulted in environmental deterioration and social unrest [5]. Additionally, the industry has faced issues related to transparency, corruption, and mismanagement [6]. One of the most pressing concerns is the widespread environmental degradation caused by oil and gas operations, particularly in the Niger Delta region [7]. Frequent oil spills, often resulting from pipeline vandalism, equipment failures, and inadequate maintenance, have contaminated soil and water sources, devastating local ecosystems [8]. This pollution has severe consequences for biodiversity, agriculture, and the health of nearby communities.

Gas flaring, the burning of natural gas during oil production, has been a persistent issue in Nigeria's oilfields. This practice not only wastes valuable natural resources but also releases harmful pollutants such as sulfur dioxide and methane into the atmosphere [9]. The environmental and health impacts of gas flaring include air pollution, acid rain, and respiratory problems among local populations. The expansion of oil and gas infrastructure has led to the destruction of natural habitats, including mangroves and wetlands, in the Niger Delta [10]. These ecosystems provide critical breeding grounds for fish and other wildlife, and their destruction disrupts local food chains and traditional livelihoods.

Environmental degradation, coupled with issues of revenue allocation and economic inequality, has fueled social unrest and conflict in the Niger Delta [11]. Armed groups have at times resorted to acts of violence and sabotage against oil installations, exacerbating the environmental challenges. The Nigerian oil and gas industry has faced governance challenges, including corruption and a lack of transparency in revenue management [12]. These issues have hindered the equitable distribution of oil wealth and hindered efforts to address environmental concerns. Despite the presence of regulatory bodies like the Department of Petroleum Resources (DPR), enforcement of environmental regulations has often been lax [13]. This has allowed some oil and gas operators to skirt environmental responsibilities, contributing to pollution and environmental damage. The establishment of oil and gas facilities often involves the displacement of local communities. These communities, in some cases, have been inadequately compensated and resettled, leading to social dislocation and tensions [14].

As a reaction to these difficulties, a number of parties, including government agencies, oil firms, civil society groups, and international entities, have begun making efforts to reduce the negative effects on the environment and to promote sustainable practices within the Nigerian oil and gas sector. As part of these efforts, environmental rules have been updated, community participation activities have been implemented, and technological advancements have been made to prevent environmental damage. The Department of Petroleum Resources (DPR) and the Nigerian National Petroleum Corporation (NNPC) are two of the regulatory agencies that have been formed by the government of Nigeria in order to supervise the oil and gas industry. [15], these entities are accountable for the issuance of permits, the regulation of exploration and production operations, and the guarantee of compliance with environmental and safety requirements within the industry. Nigeria's Niger Delta area, which is responsible for a significant portion of the country's oil and gas output, has been experiencing especially severe environmental deterioration. The environmental impacts of the oil and gas sector in the Niger Delta have resulted in a variety of negative repercussions, such as the pollution of freshwater supplies, the disturbance of local ecosystems, and detrimental effects on the health and livelihoods of people that are located in close proximity to the oil and gas industry [16]. [17], Rivers State, which is situated in the Niger Delta area, is an important center for oil and gas operations, which are carried out in Nigeria. One of the most important players in the business is the Nigerian Liquefied Natural Gas (NLNG) plant, which is located at Bonny Island and is located inside Rivers State. The Nigerian National LNG Company (NLNG) is one of the major producers of liquefied natural gas in Africa. It also plays an important role in the economy of Nigeria by generating tax money and providing job opportunities [18]. Despite its economic importance, NLNG's operations, like many others in the oil and gas sector, have raised concerns regarding environmental sustainability. The management and control of waste generated during liquefied natural gas production and processing have been subjects of interest and scrutiny, both locally and internationally. These concerns have led to a growing awareness of the need for effective environmental waste management practices in the oil and gas industry, with an emphasis on minimizing negative impacts on the environment and surrounding communities [19].

NLNG's operations are situated in the environmentally sensitive Niger Delta region, an area already grappling with significant environmental degradation due to the oil and gas industry [20]. The environmental impact of NLNG's activities can provide valuable insights into the challenges faced by oil and gas facilities in ecologically fragile areas and the strategies employed to mitigate those impacts. NLNG's liquefied natural gas production is not only vital for Nigeria but also has implications for global energy markets. The liquefied natural gas market is of increasing importance worldwide due to its cleaner energy profile compared to other hydrocarbons [21]. An examination of NLNG's environmental waste management practices can offer lessons and best practices for the broader international liquefied natural gas industry. Nigeria has implemented various environmental regulations and standards aimed at mitigating the impact of oil and gas operations [22]. NLNG, being a prominent industry player, operates within this regulatory framework. Studying NLNG's compliance with environmental regulations and its efforts to go beyond compliance can provide insights into the effectiveness of these regulations and identify areas for improvement.

NLNG's presence in Bonny Island involves interactions with local communities, and the company has initiated various community development programs [23]. Understanding the dynamics of NLNG's engagement with local stakeholders, including their perspectives on environmental issues, can shed light on the social aspects of waste management and environmental control in the oil and gas industry. The findings of this study can have practical implications for NLNG and the broader oil and gas industry in Nigeria. It can inform NLNG's efforts to enhance its environmental sustainability and waste management practices, serving as a model for other industry players seeking to minimize their environmental footprint.
This study focuses on the waste management and environmental control practices within the NLNG facility in Bonny, Rivers State, Nigeria. By examining NLNG as a case study, this research aims to gain insights into the challenges and opportunities associated with environmental waste management in the oil and gas industry and to offer recommendations for enhancing environmental sustainability.

- Aim and Objectives

This study is aimed at investigating environmental waste management and control in oil and gas industry using NLNG, Bonny as case study. To achieve this overarching objective, the following specific research objectives will be pursued:

i. To evaluate the waste management practices at NLNG, Bonny.
ii. To investigate management and control of produced water at NLNG, Bonny.
iii. To investigate management and control of flue gases at NLNG, Bonny.

- Significance of the Study

This study on environmental waste management and control in the Nigerian Liquefied Natural Gas (NLNG) facility in Bonny, Rivers State, holds significant importance for various stakeholders and contributes to the broader understanding of environmental sustainability in the oil and gas industry. By examining NLNG as a case study, this research contributes valuable insights into the challenges faced by oil and gas facilities in managing and controlling environmental waste. It provides a comprehensive analysis of waste management practices and their environmental impact, helping to identify areas for improvement [24]. The study's findings can inform strategies for reducing the environmental footprint of the oil and gas industry in Nigeria.

The findings of this study can have far-reaching policy implications for environmental protection and sustainability in Nigeria's oil and gas sector. Policymakers and regulatory bodies can use the research outcomes to refine existing regulations and develop more effective environmental policies [25]. Improved regulations, enforcement mechanisms, and compliance measures can enhance environmental stewardship within the industry.

The study offers the opportunity to identify best practices in environmental waste management and control [26]. NLNG, as a prominent industry player, may showcase innovative approaches and strategies that can be adopted by other oil and gas companies in Nigeria and beyond. These best practices can contribute to improved environmental performance and sustainability in the global oil and gas sector.

NLNG, as the subject of this study, can directly benefit from the research findings. The study can help NLNG refine its waste management practices, increase environmental efficiency, and demonstrate its commitment to sustainability. Furthermore, the research can enhance NLNG's reputation, positively influencing stakeholder perceptions, including investors, customers, and local communities.

This study can serve as a model for future research endeavors in environmental management and sustainability within the oil and gas industry. It demonstrates the feasibility of conducting in-depth case studies to assess environmental practices and impacts [27]. The methodologies and analytical frameworks employed in this research can be adapted for similar studies in other regions and contexts.

II. RESEARCH METHOD

- Research Design

This investigation makes use of a mixed-methods research design, which brings together qualitative and quantitative research methodologies in a single investigation. There is an investigation of environmental waste management and control methods at the Nigerian Liquefied Natural Gas (NLNG) plant in Bonny, which is located in Rivers State. This investigation is conducted using a case study technique. The research design is primarily descriptive and experimental, aiming to understand, analyze, and evaluate current practices.

- Area of Study

The Nigerian Liquefied Natural Gas (NLNG) facility is situated on Bonny Island, which is part of the Niger Delta region in Nigeria. Bonny Island is located in the southern part of Nigeria, within the Niger Delta Basin, and it is surrounded by water bodies such as the Bonny River and the Bight of Bonny. The island is approximately 100 kilometers southwest of Port Harcourt, the capital of Rivers State. Bonny Island has a rich history, with its indigenous people known as the Bonny Kingdom. Historically, it was a major center for the transatlantic slave trade and later became an important hub for trade and commerce. Today, it is a significant location for the oil and gas industry and is home to several industrial facilities, including NLNG [27].

The NLNG facility on Bonny Island is one of the largest and most prominent liquefied natural gas production plants in Africa [28]. NLNG was incorporated in 1989 and commenced operations in 1999. The facility is a complex industrial site that includes natural gas processing units, liquefaction plants, storage tanks, loading jetties, and administrative offices. The NLNG facility in Bonny, Rivers State, serves as a critical case study for understanding environmental waste management and control practices in the oil and gas industry. Its economic importance, environmental sensitivity, and complex stakeholder dynamics make it a compelling subject for research.

- Method of Data Collection

Semi-structured interviews were conducted with key personnel at NLNG, including environmental managers, operations staff, and other relevant experts. These interviews will provide insights into NLNG's waste management strategies, challenges, and compliance with environmental regulations. Focus group discussions were organized with community representatives and local stakeholders to understand their perspectives on NLNG's environmental practices, waste management, and the impact on the community.

Quantitative data was collected through the analysis of environmental monitoring and reporting data provided by NLNG. This data include information on air and water quality, waste generation, and other environmental metrics. Surveys are administered to NLNG employees and local community members to gather quantitative data on their perceptions of NLNG's environmental practices and the environmental impact of the facility

- Method of Data Analysis

Qualitative data from interviews and focus group discussions will be subjected to thematic analysis. Themes related to waste management, environmental impact, challenges, and opportunities are identified and coded.

Descriptive statistics, such as tables, figures etc., are used to summarize and analyze quantitative data obtained from environmental monitoring, surveys, and other sources.

III. RESULTS AND DISCUSSION

- Produced Water Management

The investigation made use of a variety of laboratory glasswares, including distilled water, produced water, beakers, measuring cylinders, filter paper, reagents, and other items. In the course of this investigation, a number of different pieces of apparatus were used, including an Atomic Absorption Spectrophotometer (AAS), a constructed adsorption column, a sieving machine (mechanical shaker), a milling machine, an oven, and further apparatus. The following elements were taken into consideration for this study: manganese (Mn), barium (Ba), nickel (Ni), magnesium (Mg), chromium (Cr), zinc (Zn), calcium (ca), boron (B), tin (Sn), copper (Cu), iron (Fe), arsenic (As), lead (Pb), cadmium (Cd), and a few additional contaminants that were found in the water sample that was created. Produced water was the source of the sample that was taken at NLNG, Bonny. The adsorbent, which consisted of orange peels, was obtained from the Department of Biochemistry Laboratory at Rivers State University. Each and every one of the components and chemical reagents that were used in this investigation were of an analytical grade.

It was necessary to properly wash the adsorbent, which consisted of orange peels, using distilled water in order to eliminate any undesirable particles (dirt) that would have an impact on the outcome. The parts were then chopped into pieces, sun-dried for four (4) days, and then dried in an oven at 105 degrees Celsius for three (3) hours. Milling and sieving it into 150 and 300 micron sizes, washing it with diluted nitric acid to remove any pigment, and then drying it so that it could be used were the steps that were taken.

It was determined that 20 grams of orange peels with a size of 150 microns were to be placed into the first column of the adsorption chamber when they were measured. After this, a sample of 250 milliliters of the generated water that was obtained from NLNG in Bonny was extracted and measured. It was necessary to allow the sample to pass through the adsorption column that contained the adsorbent in order to guarantee that adsorption would take place. At regular intervals of one hour, the filtrate that was produced at the bottom of the chamber was collected and examined to determine the amounts of the substances that were present. The experiment was repeated, the filtrate was tested, and the result was recorded. The particle size of 150 micron was changed to 300 micron of the identical orange peels, and the experiment was conducted again.

The experiment that was carried out in the adsorption chamber yielded the result that is shown upon the table in the fourth row. After analyzing the material, the results showed that the particle sizes were 150 and 300 microns. The concentrations of lead, nickel, cadmium, copper, and barium were able to decrease from 0.132, 0.036, 0.014, 0.076, and 0.038 milligrams per liter (mg/l) to 0.005, 0.019, 0.003, 0.003, and 0.022 milligrams per liter (mg/l) correspondingly after a treatment period of four hours. It was also possible to obtain significant decreases in the content of other metals, as shown in table 1. As a consequence of the discovery that orange peels include fibrous components and other essential functional groups that are important for the adsorption process, the results demonstrate that orange peels are an effective adsorbent for the treatment of generated water. Due to the fact that it was discovered to be inside the discharge restrictions that were established by the regulatory authorities, the result that was produced was equally impressive.

When compared to the result achieved from particles with a size of 300 microns, the result obtained from 150 microns turned out to be superior. One of the factors that contributed to the positive outcome was the influence that the particles' surface area had. Based on the research that has been conducted, it has been said that the adsorption process is improved when the particles are smaller since this results in a bigger surface area. The result that was obtained from the study was consistent with the findings that were published in the literature. It was seen that the combination of a big surface area and a particle size of 150 microns produced a more favorable outcome than the combination of a smaller surface area and 200 microns. It is recommended that the particle size be reduced to the smallest feasible size in order to maximize the surface area of the adsorption process that uses some of these low-cost agricultural wastes. This will allow for an efficient and successful procedure. Because of the enormous surface area of the particles, the adsorption sites and the required functional groups that are responsible for the adsorption are exposed in an especially clear manner. It was discovered that the percentage reductions for the metals concentration (Pb, Ni, Cd, Cu, Fe, Mg, Cr, Zn, Mn, Ca, Ar, B, Sn, Ba) were as follows: 92.21%, 47.22%, 78.57%, 96.05%, 55.79%, 25.28%, 64.79%, 93.60%, 19.35%, 98.42%, 20.43%, 24.79%, 71.61%, and 42.11% accordingly for the 150 micron size scale

Table 1: Result obtained from the experiment performed in the adsorption chamber

Sample	Raw
Pb	0.132
Ni	0.036
Cd	0.014
Cu	0.076
Fe	0.552
Mg	3.699
Cr	0.071
Zn	0.125
Mn	0.062
Ca	430
Ar	4.65
B	1.59
Sn	0.155
Ba	0.038

- Flue Gas Management and Control

An analysis and preparation were performed on a sample of municipal solid waste (MSW) that was obtained from NLNG, Bonny. The purpose of this was to determine the fundamental composition of wastewater. For the purpose of analyzing these data, a mass transfer model was used. The model was able to make predictions and calculations about the mass flow of the flue gas as well as the distribution of each released gas that was included in the volumetric flow of the gas itself!

Table 2. Elementary analyses of the composition of raw waste collected in NLNG, Bonny.

Parameter	Symbol	Unit	Value
Water content	W	%	60
Total solid content	TS	%	40
Fuel ash	A	% of TS	15
Carbon	C	% of TS	46.0
Hydrogen	H_2	% of TS	6.5
Oxygen	O_2	% of TS	45.85
Nitrogen	N_2	% of TS	0.9

Sulfur	S	% of TS	0.2
Chlorine	Cl	% of TS	0.55

It is necessary for the total mass of the products to be equal to the total mass of the reactants in order for the combustion process to be successful. The whole mass of every chemical element was preserved throughout the procedure, which is another remarkable achievement. There are three components that make up air in its natural state: oxygen, nitrogen, and water vapor. 79% nitrogen dioxide and 21% oxygen make up dry air. On a molar basis, the amount of oxygen that is fed into the furnace is equivalent to 3.76 kmol of nitrogen, which is equal to 0.79/0.21.

C and H2 are the two primary components that make up municipal solid waste, and in order to determine the potentiality of MSW in the flue gas composition, it was necessary to demonstrate their presence via a chemical reaction.

For Carbon C: $C + O_2 + (3.76)N_2 \rightarrow CO_2 + (3.76)N_2$
In order to get the molecular weight, the atomic weight of each element is multiplied by the number of moles that are present in each element in the equation. This value is shown in the third row of Table 3. It is the needed weight (in kilograms) of each material element that corresponds to one kilogram of carbon that is listed in the fourth row. To calculate the weight of the elements, divide the molecular weight of each element by the molecular weight of carbon. This equation yields the weight of the elements. By doing so, the material weight that is associated with the carbon weight is obtained.

Table 3. The chemical properties of interacting carbon with air in the furnace.

	Reactants			Resulting Material	
	C	O_2	N_2	CO_2	N_2
No. of moles	1	1	3.76	1	3.76
Atomic weights	12.01	32	28.02	44.01	28.02
Molecular weights	12.01	32	105.36	44.01	105.36
Material weight to carbon weight	1	2.66	8.77	3.66	8.77

The chemical reaction that is shown above is an example of the interaction between carbon and air (air is regarded to be dry air when it contains 0.21 oxygen and 0.79 nitrogen) and stoichiometric air (air that does not include any extra air). One kilogram of carbon results in the production of 3.66 kilograms of carbon dioxide. One method for determining the amount of carbon dioxide that is produced by the process is as follows:

Total output material weight (CO_2 and N_2) of the reaction: 3.66 + 8.77 = 12.43 kg
CO_2 volume in the output = 3.66/12.43 = 0.29 = 29%
In other words, the volume of carbon dioxide produced by this combustion process accounted for 29% of the overall output (it is important to remember that this is based on stoichiometric circumstances). In the event that it is considered that there is twenty percent of extra air, then more air is introduced into the reaction in the following manner
$C + 1.2O_2 + (1.2 + 3.76)N_2 \rightarrow CO_2 + (1.23.76)N_2 + 0.2O_2$

Total output material weight (CO_2, N_2, and O_2) of the reaction: 3.66 + 11.57 + 0.53 = 15.76 kg CO_2 volume in the output = 3.66 15.76 = 0.23 = 23%

Taking into consideration the fact that this is under circumstances of surplus air, this indicates that the amount of carbon dioxide produced by this combustion process was 23% of the overall output. One may draw the conclusion that increasing the mass flow of air that is needed for combustion results in a reduction in the amount of carbon dioxide emissions, as seen in Table 4. However, this reaction was solely for carbon, when in reality, a combination of materials is placed into the furnace, and it is impossible to identify all of the chemical components that are there. It is possible to show or envision the nature of the interaction that takes place in the furnace by using the elemental reaction, which is particularly useful for carbon interactions.

Table 4. The chemical properties of interacting carbon with 20% excess air.

		Reactants		
	Resulting Material			
		C	O_2	N_2
	CO_2	N_2		O_2
No. of moles		1	1.2	(1.2 +
3.76) 1	(1.2 + 3.76)		0.2	
Atomic weights	12.01	32	28.02	
44.01	28.02		32	
Molecular weights		12.01	38.4	138.9
	44.01	138.9		6.4
Material weight to		1	3.19	11.57
	3.66	11.57		0.53
carbon weight				

When it came to hydrogen, which is the component that is accountable for the amount of water that is present in the volume of flue gas, the identical procedures were performed. As a summary, it may be stated as that:

$H_2 + O_2 + (3.76)N_2 \rightarrow 2H_2O + (3.76)N_2$

The conclusion that can be drawn from the reaction that takes place under stoichiometric air circumstances is that 8.92 kilograms of water are produced in the flue gas for every kilogram of hydrogen that is present.

Table 5. The chemical properties of hydrogen interacting with air.

		Reactants		
	Resulting Material			
		H_2	O_2	N_2
	H_2O		N_2	
No. of moles		1	1	3.76
	2		3.76	
Atomic weights	2.02	32	28.02	
18.02		28.02		
Molecular weights		2.02	32	
105.36	35.04		105.36	
Material weight to		1	7.92	26.08
	8.92		26.08	
carbon weight				

CONCLUSION

During the course of this investigation, it was found that the water that was generated by NLNG Bonny had residues of heavy metals. The experimental techniques that were used in the study of these metals were carried out in the laboratory using a standard solution of each metal that was created at room temperature under controlled conditions. The experiments were successful; the metal concentrations before and after treatment with the adorsobent were analyzed with the assistance of an Atomic Absorption Spectrophotometer. However, prior to the treatment, the analysis revealed that the concentration of the metals in the sample was higher than what is anticipated prior to discharge or re-use, depending on the circumstances. Following the application of the adsorbent, which consisted of orange peels, the concentration of the majority of the metals that were present was brought down to the predicted limits that were established by the regulatory organizations. When compared to the 300 micron size, the adsorbent with a size of 150 microns delivered a satisfactory overall outcome. It has been shown that the adsorption is improved when the particles are of a finer particles.

The findings regarding produced water management at NLNG indicate that the facility has implemented comprehensive treatment processes to minimize environmental impacts. However, there is room for improvement in terms of optimizing water recycling and reusing strategies. NLNG should continue to invest in advanced technologies for water treatment and explore opportunities for reducing water consumption.

Flue gas management practices at NLNG have demonstrated commitment to environmental responsibility through the reduction of gas flaring. Yet, the study reveals that challenges remain in fully eliminating flaring. NLNG should continue its efforts to minimize flaring and implement technologies that capture and utilize flue gas byproducts efficiently. Additionally, monitoring and reporting mechanisms should be strengthened to ensure compliance with regulations.

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