# Sustainable Safety and Environmental Protection Technologies in Oil and Gas Industry

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## ABSTRACT

**Aim:** This paper examines the concepts of oil and gas production, effects of the operations on the environment and relevant environmental protection technologies to make the industry a sustainable one.

**Problem Statement**: Reports showenvironmental pollution and ecosystem disruption emanating from oil and gas operations which are majorly exploration, production and distribution to end-users. This makes the environment to be unhealthy for living and causes breakage in food chain.

**Significance of Study:**High relevance of oil and gas industry to the economic growth of a Nation has made it imperative to critically address the adverse effects attributed to the operations involved. Tackling the accorded problems via current environmental protection technologies will prevent operational accidents and minimize environmental pollution. With this, lives are protected, environment is kept safe, and the industry is enhanced for future sustainability.

**Discussions:** The upstream, midstream and downstream operations that make up the oil and gas value chain were discussed. The philosophy of sustainability and sustainable development as pertained to environmental pollution and disruption of ecosystem by the operations of oil and gas industries were discussed. Reasons why round table talk should be conducted from time to time by all stakeholders as related to environmental sustainability of Oil and Gas industries in years to come were discussed. The adopted technologies to ensure there is safety and environmental protections were stated within.

**Conclusion:** In conclusion, there is need for further research on effective technologies to improve the existing ones in terms of making safety and environmental protection from oil and gas industry a sustainable one.



*Keywords: Sustainability, Advanced safety, Environmental Protection, Technologies, Oil and Gas Industry*


## 1. INTRODUCTION

The role of oil and gas industries is highly significant in the development of a Nation. They are required to fulfil the energy requirements of a country and, their contribution towards the economic development of a Nation is inestimable. Thus, oil and gas industries play an immeasurable contribution towards the development of a Nation [1]. The major activities of oil and gas includes delivering the products to various locations for domestic usage by end users. This comes into play after adequate gathering of crude oil from various locations followed by their processing into various fractions and storing for onward transportation. The major components of a refinery are crude oil distillation column and handling infrastructure, hydrocracking units together with some other useful treatment units. There are also storage sections for both crude oil and refined fractions/products alongside distribution channels (ships, oil pipelines, vessels and so on) for the conveyance of the crude and products. The

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pipelines for the transportation of oil and gas may be located below or above the surface [2]. These can vary in diameter and length; and are used to deliver oil and gas to end users which could be power generation facility and petrochemical plant sited within or around the same location. To facilitate this, ancillary facilities such as pressure boosters, dispatch hub, auxiliary pumping stations and so on are coupled with the pipelines. At strategic distribution points, purpose-built sites are typically located to enhance the distribution of products to consumers.

For better understanding of sustainable advanced safety and environmental protection technologies in oil and gas industry, it is highly imperative to understand the structure and organogram of the industry. The oil and gas industries are usually categorized into Upstream, Midstream and Downstream as shown in Figure. These are the three major sectors involved. The upstream sector is also known as exploration and production sector which involves oil well exploration and production [3]. This may be further categorized based on the reservoir characteristics and field circumstances. In upstream, potential off-shore or on-shore crude oil is searched, and natural gas is performed. This is followed by the drilling of exploratory and appraisal wells. After drilling several development wells have been drilled and connected to the surface transportation facilities and production unit, commercial production then starts. The midstream and downstream sectors are the upstream supplements charged with the responsibilities of products delivery to the consumers. The midstream is comprised mainly of transportation routes from the well to both the processing facilities, and the refineries [1]. The oil and gas value chain are presented in Figure 1.

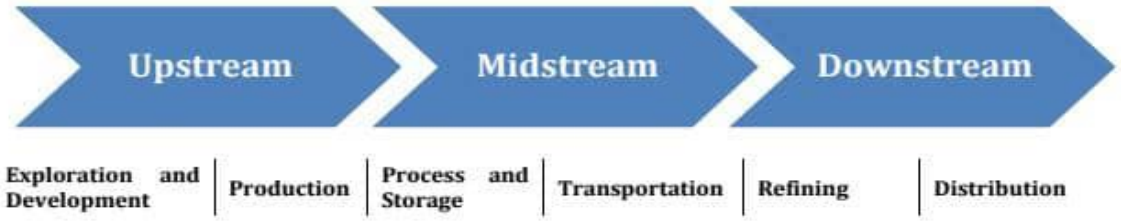


Figure 1: Oil and gas value chain

There are numerous intermediate terminals, in the midstream sector, which deliver wide services to distributors, producers, wholesalers, and a variety of consumers that include storage, delivery, stock management, blending and chemical injection services. Importantly, the midstream sector render services which expedite the process between raw upstream operations and refineries in a suitable manner. The downstream sector is comprised mainly of crude oil refining and natural gas processing. The products from this process include gasoline or petrol, diesel, kerosene, lubricant waxes, fuel or jet oil, asphalt and other petrochemicals. The downstream sector also covers the products delivery to the end users [4]. In the downstream, the quality and yield of various products are functions of crude oil properties, the process distillation parameters, and consumers' needs. Furthermore, heavier fractions are broken down into lighter fractions via secondary transformation techniques with aid of chemical catalysts, hydrogen and elevated temperatures purposely to customize their volume and composition. Considerable quantity of additives and chemical compounds are used in their production facilities purposely to treat and blend into the final products produced by petrochemical refineries. International oil companies (IOC) and national oil companies (NOC) are the major groups categorized as petroleum industry major developers. These companies frequently operate in an integrated way, covering both downstream and upstream making the elementary structure of this industry [5]. The block diagram presented as Figure 2 represents the three major components of oil and gas industry beginning from

exploration to the last stage of distribution. The blocks colored red, orange and green represent the upstream section, midstream components and downstream elements, respectively.

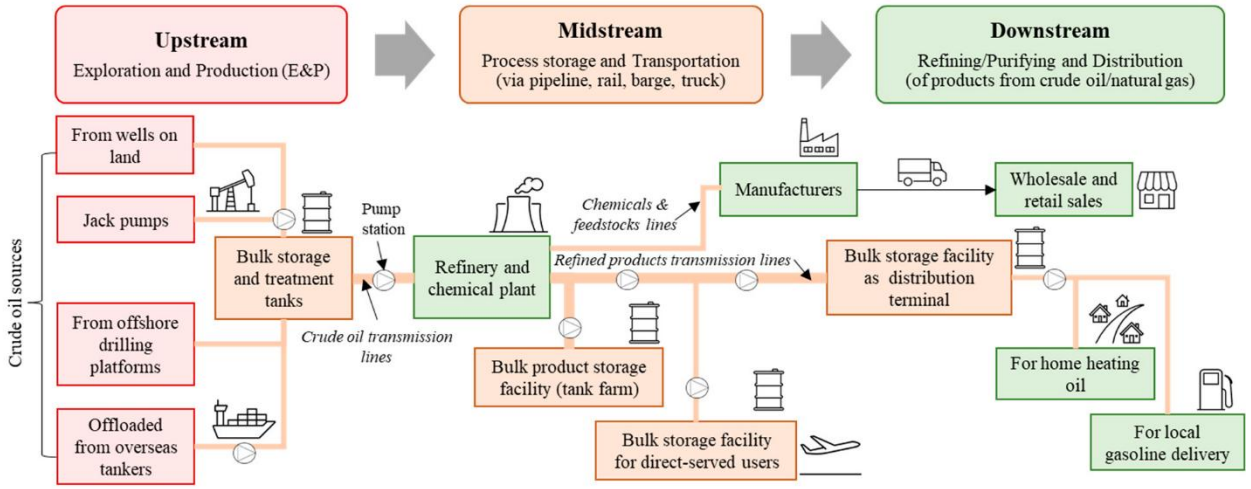


Figure 2: The three major components of oil and gas industry

Despite all the added advantages of oil and gas industries earlier stated, there is need to critically investigate the sustainability of these industries in terms of the evolving environmental pollution and hazard attached to the various operations being carried out. The word “sustainable development” is usually used interchangeably with the wider concept of “sustainability.” Sustainability is often referred to as a long-term goal while sustainable development is termed as the several pathways to becoming sustainable. Sustainability is usually identified as having three interrelated dimensions which include pillars, elements and facets. This covers economic, social and environmental factors which are goals and objectives. Figure 3a graphically represents the intersections of the three elements which are combined. Thus, the major focus of sustainable development should be on developing each of the earlier stated factors (economic, social and environmental) to ensure that the sustainability goal is realized [6].

As shown in Figure 3b, the impact or relationship on the other factors should be considered. Thus, sustainability should be at the fore-front and be identified as one of the main goals of the oil and gas industry. Making our Earth safe and habitable for future generations should be the main objectives of all oil and gas industries. The main causes of accidents and occupational injuries that have raised serious concerns in terms of the oil and gas industries sustainability have been known to come majorly from the exploitation of oil resources. Globally, the cost incurred on accidents and occupational injuries usually experienced on an annual basis by an employee is huge causing negative impacts on society, enterprise, employees and national economies. To curb this, it is imperative for oil and gas industries to put safety measures into places also there is need for better understanding and identification of the major causes of these occupational injuries and accidents [7].

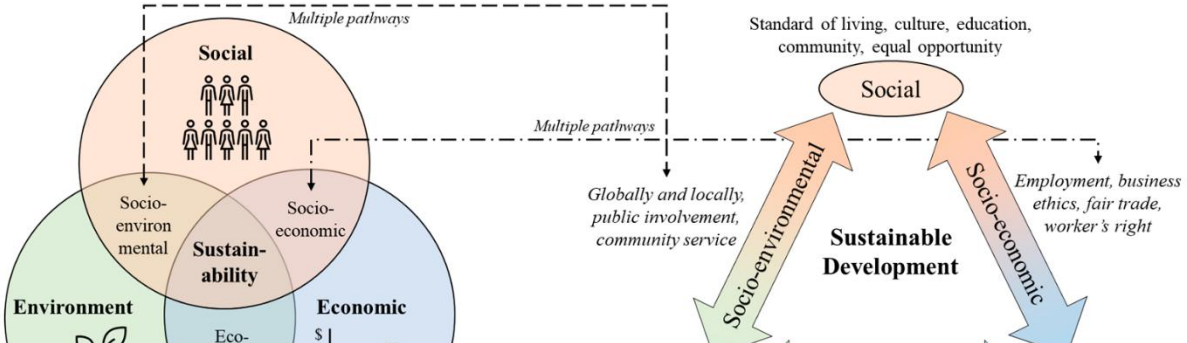

Figure 3: The graphical representation differentiating (a) sustainability from (b) sustainable development.

Asides the occupational injuries to employees during operations, worries have been recently noticed which has called for deliberation about protecting our environment from pollutions emanating from oil and gas operations. The brutality of environmental disasters and change in climatic emanated from oil and gas production has caused havoc for many societies. The disorderliness in global environmental issues around the globe have been affiliated to the major oil companies. They have received various kinds of accusations and have faced reliability issues by the public and policymakers from around the globe [8]. These environmental disasters have provoked the public into looking for both measurable development in performance and better transparency and operation in oil and gas industries as regards sustainability. Consequently, the oil and gas industries have restructured their business development strategy based on sustainable development. Therefore, to ascertain safety measures during exploration and production activities, supportive policies are being adopted by oil companies for environmental protection [3].

With this, sustainable development concept come into play in oil and gas industries. Oil companies are now presenting seminars and lectures on Sustainable Development, Green Economy, Risk Management and Social Responsibility. Nonetheless, innovations and smart solution implementations like Air Quality and Climate Change; Contaminated Site Management; and Performance Assurance and Operation Risk Management now become the subjects of discussion by the top management team of oil companies. In conclusion, studies have conducted in this regard revealing the difference between oil companies' declaration about sustainability and their performance measure. Though oil and gas companies still stand still as major causes of climate change and environmental degradation, they are now implementing decision-making levels that are in line with sustainable development and environmental protection [9].

Literatures have been presented on different measures of oil and gas sustainability and how processes of oil and gas production interfere with our environment causing pollution and disruption of ecosystem. The influence of oil and gas industry on the economic growth of a nation has also been discussed. However, knowledge about ways by which environmental sustainability can be ascertained via the utilization of some safety technologies is still minor. This paper critically discusses the major the concept of oil and gas operation; looking critically at reasons why call for sustainable advanced environmental safety in oil and gas industries is highly imperative and why some safety technologies are essential.

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## 2. CALL FOR SUSTAINABLE ADVANCED ENVIRONMENTAL SAFETY IN OIL AND GAS INDUSTRIES

It is of no doubt that operations in oil and gas industries ranging from exploration-drilling-refining-distribution are being executed round the year. By so doing, our ecosystems are disrupted causing serious havoc to the society because of these numerous activities from the oil and gas industry. Not only this, but records have also shown huge contributions of oil and gas operations to environmental destruction, accelerated climate change, destruction of green and recreational centers and lots more. These are essentials needed for good living and human survival [6]. To keep the environment safe, high emphases are laid by the government regarding preserving and balancing the environment with fossil fuels production without any form of hindrance or alteration. Governments in different Nations are encouraging oil and gas industries to curb environmental hazards via granting of financial incentives, tax incentives and having direct usage of government owned sites. To minimize the risks attached to environmental degradation from oil and gas industries, societies are diversifying and transiting from fossil fuels to sustainable renewable energy sources such as wind, solar, bioenergy green sources and lots more[10]. Major areas calling for sustainable advanced environmental safety in oi and gas industries are discussed further.

### 2.1 GAS EMISSIONS

The major emissions from oil and gas industries are methane emissions, the lightest carbon-carbon bond alkane compound. Environmental sustainability measures should be taken to reduce this emissionto minimize greenhouse gases emissions. Studies have shown oil and gas industries to be the major contributors of methane emission into the environment either by anthropogenic or natural sources. The major focus is on these industries and thus, methane emissions reduction in oil and gas industries can possibly be minimized via the enhancement of local air quality. While doing this, the targets of meeting customers demand should be accomplished concurrently [2]. Primarily, methane is the major component of natural gas which is odorless and invisible. Natural gas emissions are usually categorized as either vented emissions or fugitive emissions depending on the route via which they are discharged into the atmosphere. This classification was based on operational context and regulations. During normal oil and gas productions, hydrocarbons may be released knowingly by operators from a unit into the atmosphere while trying to control the operation. This is termed vented methane emissions. In contrary to fugitive emissions, methane emissions occur unintentionally form unusual sources (such as flanges, damaged valves, ineffective controllers) and are released into the environment. Therefore, on a temporal and spatial scale, emissions of natural gas are mostly highly unstable [11].

### 2.2 CLIMATE CHANGE

In the process of contributing hugely to humanity development and promoting economic growth by oil and gas industries, they equally contribute adversely to atmospheric pollution causing climate change due to the earlier discussed methane/hydrocarbon emissions into the atmosphere. This has resulted into global warming caused by increase in atmospheric temperature because of thorn in global greenhouse gas emissions. This has called for crucial discussion and of great concern among academia, researchers, industrialists, government and other stakeholders. This observation could be attributed to greenhouse gases being released into the atmosphere via exploration, refining, production and burning of fossil fuel [8]. This causes harsh weather condition when the heat is trapped in the atmosphere. The negative impacts of climate change on the environment are numerous. The most vulnerable and underprivileged may be targeted unfairly leading to hindrance of

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initiatives intended at attaining equality in gender, poverty elimination, and disparities minimization among nations. This can also adversely hinder the water reserve, disrupt the ecosystems and endanger biodiversity. All these can disconnect the food chain and therefore pose serious threat to food supplies. Nonetheless, the health of the public may be endangered via the alteration of the geographical distribution of contagious infections. With the aforementioned factors, environmental stability and human safety are at alarming risk. To curb climate change caused by operations in oil and gas industries, a sustainable approach should be adopted. Energy utilization can be increased via the implementation of carbon offset strategy. Other means include the development of conjunctive usage of hydrocarbon fuels with alternative renewable sources and encouraging the implementation of carbon sequestration and storage methods. This will equally boast their socio-economic benefits [7].

## 2.3 WATER MANAGEMENT AND RECLAMATION

Water is a major natural resource needed in oil and gas industries for operations such as drilling, exploration, extraction, production and so on. Thus, large volume of wastewater is generated in these processes with the utmost assurance of being polluted with toxic chemicals, radiation-emitting compounds, heavy metals and other environmental harmful substances. Intentionally and unknowingly, these wastewaters are discharged into oceans, seas, underground tanks, uncovered ponds and so on which can later leak into water bodies disrupting aquatic lives and make the water unsafe and useless for other domestic purposes [12]. These can pollute them with carcinogenic substances causing neurological impairments, congenital abnormalities and other related problems. Similarly, oil spillage and leakage accorded during fossil fuels distribution and production can threaten the freshwater health and marine ecosystems stability via poisoning and contamination. Contaminants have also been detected in fresh water supplies (for domestic purpose) resulting from the fracking process [4].

## 2.4 ECONOMIC IMPACT

The increase in the high demand for energy has led many Nations to focus majorly on fractions from fossil fuel as non-renewable energy sources to expand and boast their industrial growth. The influence of industrialization on the economic growth of a nation is inestimable. These two objectives have been a major consequence of increase in energy consumption causing high rate of discharge and toxic gases emissions. This causes degradation of the environment. Advancement in global economy cannot be discussed alone without addressing the energy consumptions by industries [7]. Thus, discussions on environment, natural resources and economy go alongside together. Eco-innovation strategies are being adopted by countries around the globe to adapt with the depleting environmental conditions. The term eco-innovation means the development of products and processes that encourage green consumption and production by applying commercial knowledge and technologies. From ecologically friendly technological progress to socially desirable innovation pathways for sustainability, this covers a wide array of related concepts, ideas, and knowledge. Records have revealed improvement in economic and environmental efficiencies of companies via adopting eco-innovation strategies. Countries can utilize cost-effective and eco-friendly green energy resulting from eco-innovation technologies. Nevertheless, sustainable patterns of consumption and production can be adopted. Lastly, adopting cleaner production technologies can facilitate the reduction of economic growth negative impacts on the environment [13].

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## 3. ENVIRONMENTAL PROTECTION TECHNOLOGIES TO IMPROVE SUSTAINABILITY IN OIL AND GAS INDUSTRY

It is an established fact that oil and gas industries take an inestimable role in terms of the global energy supply and thus, it is ascertained that their significance is everlasting. With this, it is highly imperative that forward-looking and reliable sustainability initiatives should be implemented by organizations. This is to ensure that there is a long term deal and resilience of this essential resource. Environmental considerations are becoming progressively issue of much concern. Numerous organizations are now working towards having a net-zero carbon emissions from various units of oil exploration, production and distribution and this forms a section of strategies of achieving sustainability in oil and gas industries [14]. Numerous technologies have now been put in place gradually to attain this goal and some of them are discussed here.

### 3.1 RESEARCH AND DEVELOPMENT OF CUTTING-EDGE TECHNOLOGY

Creative and innovative ideas are continual ways of detecting new things and solving previous challenges. To solve the environmental problems attached to oil and gas industries, companies are now investing more on research and development. With this, there is strong anticipation that improved sustainable solutions will be developed. Previously, the issue of carbon storage after capturing has been addressed via numerous feasible initiatives undertaken in different disciplines link to this task. Not only this, development of low-emission, carbon-free and environmentally friendly means of energy generation was also targeted [10]. Currently, many organizations are now targeting and advancing their efforts to renewable energy. This will drastically reduce the volume of emissions into the atmosphere asides the usual ones coming from oil and gas industries. Creative technologies are being adopted not only in the storage and management of liquefied renewable biofuels but also in the utilization of micro-grids and residential solar systems. For effective management of these strategies, digitization should be implemented for regularization. The new advent of developing cloud-based solutions has really materialized in utility and energy companies [15]. Many companies are using these techniques for their daily business running activities. The maximization and configuration of operational functions can be efficiently enhanced throughout the business due to the transition to the cloud. With this, alternative routes are created for the development of expanded product, enhancements, new innovations and an easier workflow. This allows business to grow in a better form. Many technologies are in place which can be adapted to improve business sustainability and efficiency in a numerous way. Such technologies include the Internet of Things, real time information analysis, machine learning, artificial intelligence tools and processes automation [6]. These advanced technological processes are sufficient to spot irregularities and bottlenecks to know inefficiencies, as well as how to tackle them. An improved information technology framework based on functionality plays a key role in ensuring the operation's sustainability and integrity.

### 3.2 STREAMLINED OPERATIONS

One of the major contributors to environmental hazards being caused by oil and gas industries is the volume of waste generated (majorly wastewater) and discharged into the surroundings or water bodies. Minimization of waste and subsequent process optimization should be adequately monitored in oil and gas operations to ensure their sustainability aftermath. To achieve this, organizations are utilizing predictive modeling methods and complex analytics. This enables them to identify efficiency gaps [2]. Also, IoT technologies are deployed to recognize workflows that can be streamlined. This causes wasted resources, fewer process delays and workplace accidents. It is essential that oil and gas operators investigate the internal structures of oil reservoirs using devices like 3D scanning.

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This gives them the opportunity of making better evaluations and judgments based on effective oil production and controlling/avoiding the risk. It is expected that there should be significant positive impact on an enterprise's performance via improvements of valves, upgrading obsolete equipment, instrumentation or overhauling obsolete machinery. This should be conducted alongside with energy resource demands and waste reduction. Additionally, oil and gas industries are now transferring thermal energy using better equipment put in place [9]. This gives room for energy consumption minimization and improvement in wastewater reprocessing purposely for fracking. Opportunities are now being sourced by oil and gas companies for the procurement of supplies from more local sources to assist in reducing their carbon footprint which is accorded with transportation [8].

## 3.3 REFINED REGULATORY FRAMEWORK

The government of different nations having oil and gas as their major source of income have set aside some regulatory bodies to be checkmating the activities of oil and gas industries in terms of environmental monitoring using the established guidelines. There are significant impacts of escalating environmental regulations. Oil and gas industries should strictly follow the evolving regulatory guidelines for sustainable development, adapt and adhere strictly to this. Creation of standard metrics was executed based on the feedback from experts, businesses and users. This enables the tracking and efficient recording of outputs from air emission levels, wastewater discharge, greenhouse gases and water consumption. Nonetheless, provisions are put in place for the reclamation of wastewater for re-use (either for industrial or domestic purposes). These provisions inspire businesses to reuse and recycle wastewater to reduce the usage of fresh water for production benefits. Additionally, self-regulatory standards and regulations are now being created and implemented by businesses as part of their operational processes [16].

## 3.4 IMPROVED INFORMATION ASSESSMENT

Numerous bodies were organized purposely to be keeping the track records of rates of emission and energy movements to identify the critical regions that need improvement and see how the problems can be tackled. Some independent organizations are also perfectly tracking their carbon footprints and establishing metrics to ensure sustainable development is attained. To identify the areas with serious challenges, critical assessment and evaluations of such areas should be executed by the concerned oil and gas companies. Better understanding of the source apportionment of different emissions can be achieved via a holistic technique of identifying emissions [17]. Reasons why production is needed are stated accordingly to reduce the emissions from the processes involved. Inexpensive devices with the potential of monitoring, identifying and notifying operations are placed within the pipelines. This will prevent pipeline ruptures from spreading across a wide area. Nonetheless, this will also prevent sudden occurrence of disaster. The advent of technology has given operators of oil and gas facilities to be alerted to warnings and respond quickly to them. Also, equipment is now kept in dependable working condition via improved maintenance planning. This prevents trivial issues from escalating into disastrous ones [13].

## 3.5 REDUCING CARBON EMISSIONS REDUCTIONS VIA DIVERSIFICATION AND IMPROVED TRANSPARENCY

The havoc caused by carbon emissions has motivated many companies to digress from describing their businesses as oil and gas firms. They had rather present themselves as energy producers, and in most cases as energy-focused commodities distributors. Investment in energy services via clean sources is now prevailing at high alarming rate among different companies nowadays [18]. This is purposely and basically to introduce the

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emissions of zero net carbon into the atmosphere. These include green hydrogen, renewable energy sources, and natural gas which possess less harmful attributes to the environment. Lastly, another valuable tool to ensure improved sustainability in oil and gas industry is attained is via improvement in transparency of operation. A major fundamental principle of sustainable development is to ensure that reliable sustainability assessments are provided in line with the objectives, benchmarks and targets set by international agencies. Nowadays, comprehensive and timely information regarding oil and gas assessments is provided by many companies. A significant shift towards sustainability is noticed and tagged as a top importance by companies, stressing their commitment to the issue [19].

## 4. CONCLUSION

This paper has discussed the concepts of processes involved during oil and gas operations. Focus was also on how the sale of products from these operations influence the economic growth of a Nation. Some disasters associated with the environmental pollution and disruption of ecosystem disruption were discussed. The philosophy of sustainability and sustainable development as pertained to environmental pollution and disruption of ecosystem by the operations of oil and gas industries were discussed. Reasons why round table talk should be conducted from time to time by all stakeholders as related to environmental sustainability of Oil and Gas industries in years to come were discussed. The identified key areas include gas emissions; climate change; water management and reclamation; and economic impact. The adopted technologies to ensure there is safety and environmental protections were also examined. In conclusion, further research on effective technologies to improve the existing ones is imperative to make the environment safe and protected from oil and gas industry.

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