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Review

Petroleum Discovery, Utilization and Processing in the World and Nigeria: A Comprehensive Literature Review

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Abstract: While the discovery of petroleum has brought numerous benefits to society, it has also created significant challenges, including environmental degradation and geopolitical conflicts. This review provides an overview of the history of petroleum, starting from its early discovery and use to the modern era of oil exploration and production. It covers the characteristics of fossil fuels such as natural gas and crude oil, and their impact on the environment. The article further discusses the global distribution of petroleum and the factors that have influenced its production and consumption patterns over time. Finally, the review takes an in-depth look at the oil industry and its impact on the world economy, including a case study of the oil industry in Nigeria, and forecasts future demand based on the potential impacts of technological advancements and shifts in energy policies.

***Keywords*:** petroleum, discovery, utilization, processing, Nigeria

Contents

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1. Introduction

Petroleum, derived from the Latin words petra meaning “rocks” and oleum meaning “oil”, is a naturally occurring fossil fuel. Its extraction has exerted a significant influence on the geological formations beneath the Earth's surface.[1] Petroleum originated from ancient marine organisms, including bacteria, algae, and plants that thrived in shallow seas millions of years ago.[2] These organisms' remains, upon death and deposition on the seafloor, mixed with other sediments and underwent burial, requiring considerable time, high pressure, and high temperature for their transformation into petroleum.[3] During the periods of 1858-1859, only minute quantities of petroleum were accessible due to natural seepage in various locations worldwide, this scarcity confined its use only to specialized and medical applications.[4] According to the Organization of Petroleum Exporting Countries (OPEC), Shell (Shell D'Arcy), owned by the British Empire and Europe, made the inaugural oil discovery in Nigeria's Oloibiri Bayelsa State within the Niger Delta Region after an extensive 50-year exploration.[5] Production commenced in 1956 following Shell D'Arcy's authorization to prospect for oil throughout Nigeria in 1938. Notably, Nigeria achieved recognition as an oil producer and became ranked accordingly. Additional significant oil wells, such as Afam and Bomu, were discovered during this period, with the first oil field yielding 5,100 pd (barrels per day) in 1958. Subsequently, exploration rights facilitated the export of 847,000 tons of crude oil from the Ogoni territory after 1960. Other foreign companies were invited to explore the Niger Delta in the nearby onshore and offshore areas, including:

1. Tenneco 1960.
2. Gulf oil and later chevron in 1961.
3. Azienda Generale Italiana Petroli (AGIP) in 1962 and Elf Petroleum Nigeria (EPN) in 1962.

In 1970, the end of the Biafra War conceded with the rise in world oil prices and Nigeria was able to reap profits from its oil production. In 1971 Nigeria collaborated with OPEC and established a National Petroleum Company (NNPC) in Nigeria. This review amongst other points earlier stated, takes an in-depth look into the oil industry and its impact on the world economy, including a case study of the oil industry in Nigeria forecasting future demand based on the potential impacts of technological advancements and shifts in energy policies.

2. Methodology

Scientific articles used for this review were retrieved from the following petroleum journals and databases: "OnePetro (https://onepetro.org), "SPIE Digital Library (https://www.spiedigitallibrary.org/), "AAPG Datapages (https://archives.datapages.com), Journal of Petroleum Science and Engineering (https://www.journals.elsevier.com), Petroleum Geoscience (https://pubs.geoscienceworld.org).

The keywords used in the searches were: "Petroleum discovery", "Petroleum exploration and uses", "petroleum refining", "chemical contaminants and direct effects", "Chemical contaminants and indirect effect", "Refining units", "Oil extraction", "Renewable and non-renewable energy", "Nigeria oil Industry" and "Petroleum barrels per day".

3. Petroleum discovery, processing and utilization in the world

3.1 *History of petroleum discovery in the world*

According to Herodotus, more than 4,000 years ago, natural asphalt was used to build the wells and towers of Babylon (450 BC). Today, enormous quantities of asphalt are discovered nearby, indicating that there was once a source of the substance.[6] The Western world until the end of the 20th century was known for killing whales to produce oil, which was very important due to its versatility.[7] When oil was needed to light lamps or for other purposes, the whales' lungs were heated. While petroleum also played a similar role, it was less understood and utilized than whale oil. Alexander the Great was recorded to have frightened his enemies with flaming torches made of petroleum products in 325 C.

James Young, a Scottish chemist, made a significant discovery in 1847 that marked the start of petroleum's modern era.[8] He observed the natural seepage of petroleum, both at the Riding coal mine and in other locations, which yielded light, thin oil suitable for lubrication. Building on these successful distillations, Young continued his experiments with coal and successfully produced various liquids, including an early form of petroleum. In 1850, he obtained patents for his coal-derived paraffin waxes and oils, establishing a partnership with geologist Edward William Binney later that year. The development of the first oil refinery and oil works was a direct outcome of these advancements. Around the world, local coal became a crucial source for producing oil and paraffin wax. Young however was not the sole scientist in the nineteenth century who made significant contributions to the understanding of coal, in 1846, Canadian geologist Abraham Pineo Gesner created a liquid from bitumen, oil shale, and coal that burned more effectively and more cleanly than other types of oils. In 1850, he founded the Kerosene Gas Light Company and named the substance "kerosene". The company utilized this oil to illuminate the streets of Halifax and later expanded to the United States. Young and Gesner's initial discoveries, which led to the establishment of businesses, sparked a growing interest in the coal industry to produce the oils they discovered. In 1852, Ignacy Łukasiewicz, a Polish engineer, simplified Gesner's method and opened the first rock oil mine in ORKA, Poland, in 1854. It is noteworthy that in 1859, particularly in Titusville, Pennsylvania, a man named Edwin Drake drilled the first successful well through a rock, leading to the production of what some referred to as the "Drake Folly" and marking the beginning of the modern petroleum industry.

3.2 *Petroleum processing and utilization in the world*

As earlier stated, petroleum is a liquid mixture of hydrocarbons that is found in specific rock strata and can be extracted and refined to produce fuels, such as gasoline, kerosene, diesel, etc. The processing of petroleum begins with the refinement of crude oil because it is a raw material and not particularly useful.[9]

3.2.1 *Refining*

Petroleum refining is an intricate process that relies on a range of refining units to unlock the full potential of crude oil and produce valuable refined products. Among these units, distillation towers, catalytic cracking units, and hydrotreating units play critical roles in the transformation and purification of crude oil. Distillation towers stand at the initial stage in the refining process, employing fractional distillation to separate crude oil into distinct fractions based on their varying boiling points. By carefully controlling temperature and pressure, these towers turn crude oil into lighter gasses like naphtha, kerosene and diesel as well as heavier residual products. Distillation towers lay the foundation for the subsequent processing of each fraction to yield specific refined products. Catalytic cracking units on the other hand are essential in maximizing the production of valuable refined products from the heavier fractions obtained through distillation. Within these units, high temperatures and catalysts facilitate the cracking of large hydrocarbon molecules into smaller, more desirable ones. This process, known as catalytic cracking, enables the production of lighter products like gasoline and light olefins from heavier and less valuable fractions. Catalytic cracking units optimize product yields and help meet the increasing demand for gasoline and other refined products. The Hydrotreating unit focuses on the purification and improvement of refined products. By employing hydrogen gas and catalysts, these units remove impurities and unwanted components from refined streams. Processes such as hydrodesulfurization (HDS), hydrodenitrogenation (HDN), and hydrodearomatization (HDA) help reduce sulfur, nitrogen, and aromatic content from fuels and other refined products. The Hydrotreating unit further plays a vital role in enhancing product quality, meeting regulatory standards, and ensuring the market acceptability of refined fuels.[10] Additional refining units, such as isomerization units, alkylation units, and reforming units, further contribute to the intricate web of processes involved in petroleum refining. The Isomerization unit converts straight-chain hydrocarbons into branched isomers, improving the octane rating of gasoline. The Alkylation unit combines light olefins with isobutane to produce high-octane blending components for gasoline.[11] At the Reforming unit catalysts and high temperatures are utilized to transform low-octane naphtha into high-octane gasoline components and aromatics. These refining units together, form a sophisticated network of processes that exemplify the ingenuity and expertise of the refining industry. Engineers and operators continuously strive to optimize the conversion of crude oil into a wide range of valuable refined products. Through the harmonious interplay of distillation towers, the catalytic cracking unit, the hydrotreating unit, and other refining processes, the industry meets the diverse energy demands of the modern world while pursuing efficiency, quality, and environmental stewardship.

3.2.2 *Analysis of refining units*

Refining units are the backbone of the petroleum industry, responsible for transforming crude oil into a range of valuable products. These units utilize various processes and technologies to break down complex hydrocarbon molecules and enhance the quality and functionality of petroleum products. An in-depth analysis of the three key refining units namely: distillation towers, catalytic cracking units, and hydrotreating units are given below.

3.2.2.1 *Distillation towers*

Distillation towers, also known as crude distillation units (CDUs), are the primary units in a refinery. They employ the process of distillation to separate crude oil into different fractions based on their boiling points.[12] Crude oil is heated in the tower, and as it vaporizes, it rises through a series of trays or packing materials. The tower is divided into sections, with each section operating at a specific temperature. Lighter hydrocarbons, such as gasoline and jet fuel, rise to the top of the tower and are collected, while heavier components, such as diesel and residual fuel oil, settle at the bottom. Distillation towers provide the initial separation of crude oil, forming the basis for further refining processes.

3.2.2.2 *Catalytic cracking units*

Catalytic cracking units, also known as fluid catalytic cracking (FCC) units, are vital for converting heavy hydrocarbon fractions into more valuable products (Figure 1). The process involves breaking down large hydrocarbon molecules into smaller, more useful molecules using a catalyst. The feedstock, typically heavy gas oils or residues, is mixed with a catalyst and introduced into the cracking reactor, where it undergoes thermal cracking in the presence of the catalyst. This process produces lighter hydrocarbons, such as gasoline, propylene, and other petrochemical feedstock. Catalytic cracking units are crucial for maximizing gasoline production and increasing the yield of high-value products from heavier crude oil fractions.

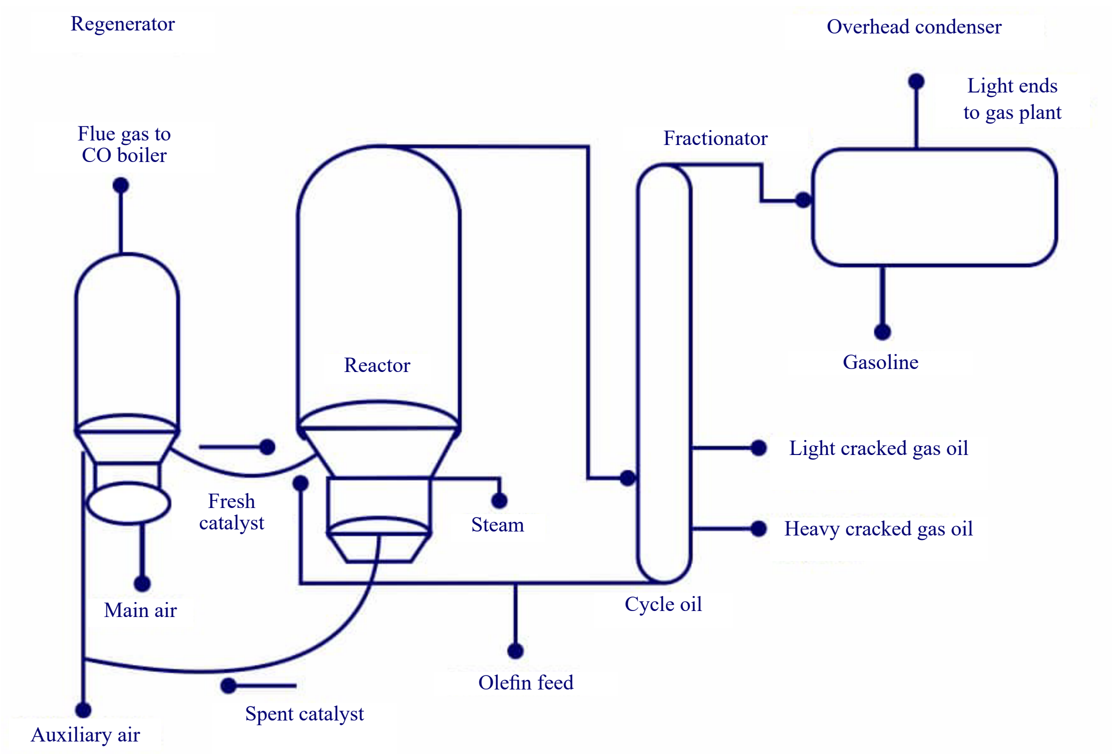

Figure 1. Diagram of a fluid catalytic cracking unit

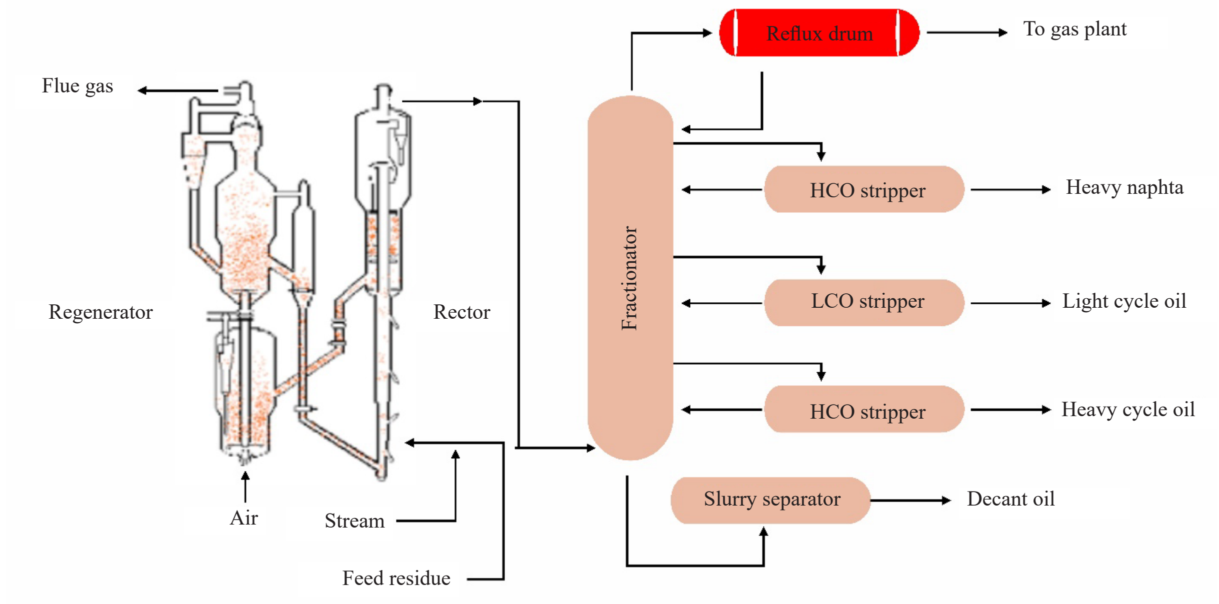

Figure 2. Typical PFD of a residue catalytic cracking unit

3.2.2.3 *Residue catalytic cracking unit*

Residue catalytic cracking is a highly efficient process employed in the petroleum refining industry to convert heavy, high-boiling petroleum residues into valuable lighter products (Figure 2). This intricate procedure relies on a catalyst to break down complex hydrocarbon molecules into smaller, more desirable fractions. At its core, residue catalytic cracking begins with the introduction of a viscous, low-value residue feedstock, which typically consists of the residual bottom fractions from crude oil distillation. This feedstock is characterized by its high boiling point and significant molecular weight. To transform this heavy residue into more valuable products, the process employs a catalyst, usually composed of zeolites or other porous materials with high surface area and acidity. The first step of the process involves the vaporization of the residue feedstock, achieved by heating it to extremely high temperatures. This creates a vapor phase, allowing for improved contact between the feedstock and the catalyst. Once the feedstock is vaporized, it enters a specialized reactor where it comes into contact with the catalyst, initiating a series of complex chemical reactions. The catalyst, acting as a molecular surgeon, cleaves the large and complex hydrocarbon molecules present in the feedstock. These molecules are broken down into smaller fragments through a process known as cracking. This cracking reaction occurs due to the acidic nature of the catalyst, which facilitates the weakening of chemical bonds within the feedstock molecules. As a result, the heavy residue molecules are converted into lighter hydrocarbon compounds, such as gasoline, diesel, and other valuable petrochemicals. To sustain the cracking process, the catalyst needs to be constantly regenerated. This is achieved by removing the carbonaceous deposits that accumulate on the catalyst surface during the cracking reactions. The catalyst is sent to a regeneration unit where it undergoes a high-temperature treatment, typically involving combustion, to burn off these deposits and restore its catalytic activity. The cracked products, along with any unconverted residue, are separated from the catalyst and further processed to obtain the desired fractions. The lighter hydrocarbon products are typically sent to various refining units for additional treatment and purification, while any unconverted residue may undergo further cracking cycles or be utilized for other purposes. Residue catalytic cracking plays a crucial role in the petroleum refining industry, enabling the conversion of heavy, less valuable feedstock into more valuable and desirable products. Its efficiency and effectiveness contribute significantly to the production of transportation fuels and other essential petrochemicals, ultimately meeting the energy demands of our modern society.[13]

3.2.2.4 *Hydrotreating units*

The Hydrotreating unit plays a critical role in refining by removing impurities and improving the quality of petroleum products. The hydrotreating process involves subjecting feedstocks, such as naphtha, diesel, or gas oil, to high temperatures and pressure in the presence of hydrogen and a catalyst (Figure 3). This process removes sulfur, nitrogen, and other contaminants from the feedstock, enhancing the quality and environmental friendliness of the end products. Hydrotreating units are essential for meeting regulatory requirements regarding sulfur content in fuels and ensuring the production of cleaner-burning transportation fuels.[14]

These refining units, along with other auxiliary units like reforming units, alkylation units, and isomerization units, work in concert to optimize the refining process and produce a diverse range of valuable petroleum products. The combination of distillation towers, catalytic cracking units, and hydrotreating units enables the refinery to maximize the production of high-value products, meet stringent product specifications, and respond to market demands. The continuous development and optimization of refining technologies and processes ensure the efficient utilization of crude oil and the production of essential energy sources and feedstock for various industries.

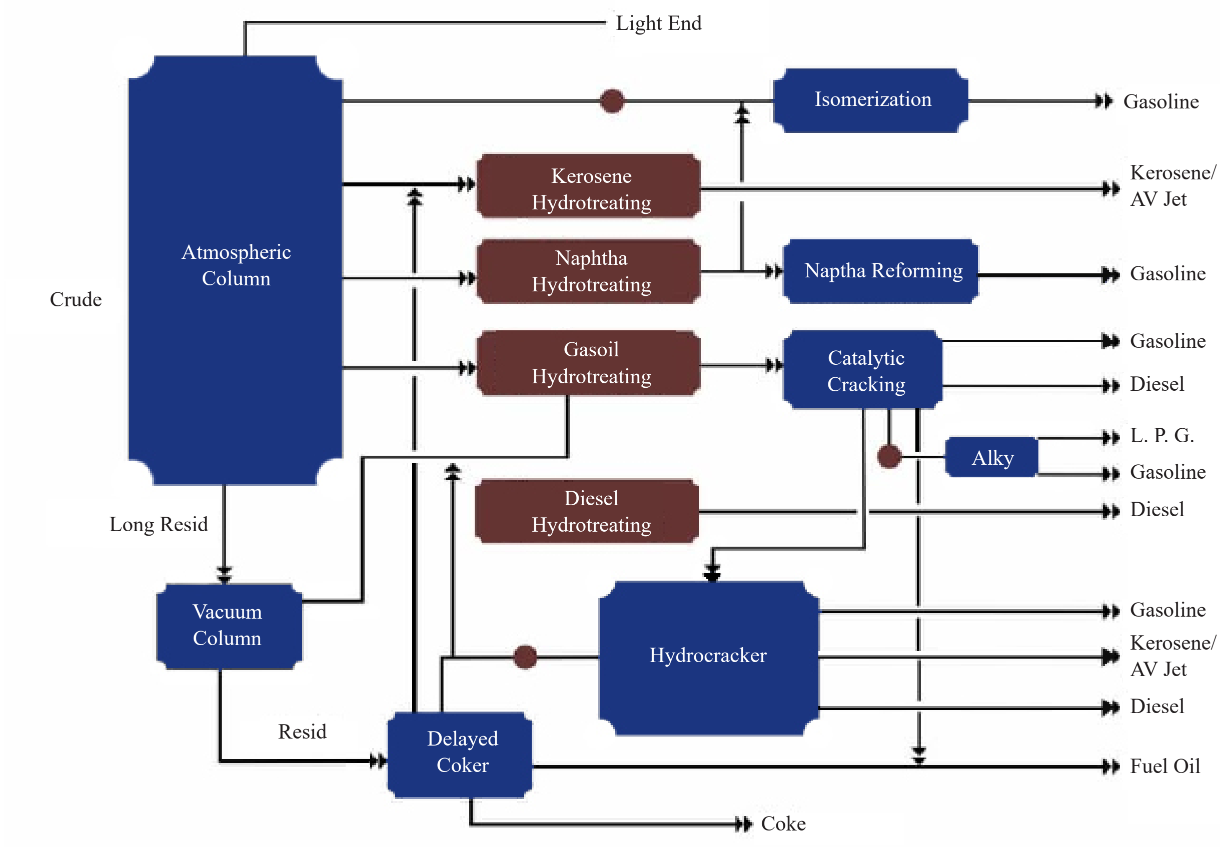

Figure 3. Process area block flow diagram of hydrotreaters

3.2.3 *Conditions for the formation of petroleum*

An oxygen-depleted environment is vital for the preservation of organic matter and the subsequent transformation into petroleum.[15] The rapid burial facilitated by sedimentation processes ensures that the organic material is effectively isolated from aerobic bacteria, which may prevent its decomposition thus maintaining its potential for conversion.

Heat and pressure, acting as the geological alchemists, orchestrate the transformative processes within the depths of the Earth. As sediment layers continue to accumulate, the immense weight of overlying materials exerts substantial pressure upon the buried organic matter. Simultaneously, the Earth's internal heat adds its influence to the equation.[16] These forces in harmony, initiate a chemical metamorphosis that spans millions of years. Complex organic molecules undergo a process of thermal maturation, breaking down, rearranging and reassembling into hydrocarbons; the fundamental constituents of petroleum. Within this geological saga, certain rocks play a pivotal role in the formation and retention of petroleum. Known as source rocks, these sedimentary formations possess high organic content, serving as abundant reservoirs of potential hydrocarbons.[17] Fine-grained shale formations, with their characteristic low permeability, exhibit a remarkable capacity for the generation and retention of petroleum, holding within their layers the building blocks of our energy infrastructure.[18] The narrative of petroleum formation continues as the hydrocarbons seek pathways for migration. Pressure differentials concealed within the Earth's subsurface propel the hydrocarbons towards reservoir rocks, capable of storing and facilitating their flow. Porous and permeable formations, such as sandstone and limestone, provide conduits through which the hydrocarbons traverse, driven by the forces that shaped their creation. Yet, the quest for petroleum is not without obstacles. Traps, strategically positioned within the geological landscape, present challenges for the hydrocarbons' migration and accumulation. Structural traps, formed by tectonic forces, create impermeable barriers that halt the upward escape of hydrocarbons. Stratigraphic traps, sculpted by variations in rock types, impede their progress, constraining the hydrocarbons within geological pockets. These traps, acting as reservoirs, harbor the accumulations of commercial quantities of petroleum, forming the foundations of oil and gas fields. Organic matter accumulation, preservation in oxygen-depleted environments, the alchemical interplay of heat and pressure, the significance of source rocks, the journey of migration, and the presence of traps all converge to shape the creation of this invaluable energy resource. Appreciating these conditions not only deepens our understanding of Earth's geological intricacies but also guides our efforts in sustainable resource management and the pursuit of cleaner energy alternatives.

3.2.4 *Utilization of petroleum in the world*

Petroleum products are refined from crude oil and other unique liquids made from fossil fuels and are used by people for a variety of things. Historically, the primary source of required electricity for the entire annual U.S. power consumption has been petroleum. Products made from petroleum are used to power vehicles, heat buildings, and generate electricity. The petrochemical industry utilizes raw materials (feedstock) in the industrial sector to produce goods like plastics, solvents, and numerous other intermediate and end-user products or goods.[19] The average daily consumption of petroleum in the United States in 2021 was 19.78 million barrels, including a million barrels per day of biofuels. Overall, the United States' total petroleum consumption was about 8% higher in 2021 than it was in 2020 as the country's economy recovered from the COVID-19 pandemic-related effects.[20] Moreover, the majority of petroleum products were also consumed more in 2021 than in 2020. The petroleum product gasoline was the fastest consumed product while distilled oil was consumed an average of 8.8 million barrels per day as of 2021.[21] Below (in Table 1) is a list of the top oil-consuming nations along with their percentage of global petroleum consumption as of 2019.

Table 1. Biggest petroleum countries and their share of world petroleum in 2019

Countries	percent %
United States	20.5%
China	14.0%
India	4.9%
Japan	3.7%
Russia	3.7%

3.3 *Oil and natural gas*

As the world's main fuel source and two of the largest industries in the energy sector,[21] oil and natural gas also have a significant impact on the global economy.[22] Oil and gas production and distribution processes and systems are highly complex,[23] capital-intensive, and dependent on cutting-edge technology.[24] Natural gas has historically been associated with oil,[25] primarily due to the upstream or production phase of the industry.[26] The downstream, midstream, and upstream segments of the industry are frequently separated (Table 2).

Table 2. Production process of crude oil

Production process	Description
Upstream	The business of oil and gas exploration and production
Midstream	Deals with transportation and storage
Downstream	This involves refining and marketing

Petroleum, also known as crude oil, is a naturally occurring liquid that can be refined into fuel[27] and is found beneath the surface of the earth.[28] Petroleum, a fossil fuel, is produced over time when organic matter breaks down and is used to power machines, vehicles, and heaters.[29] It can also be used to make plastic. Additionally, a variety of different hydrocarbons (Figure 4) are comprised of petroleum.

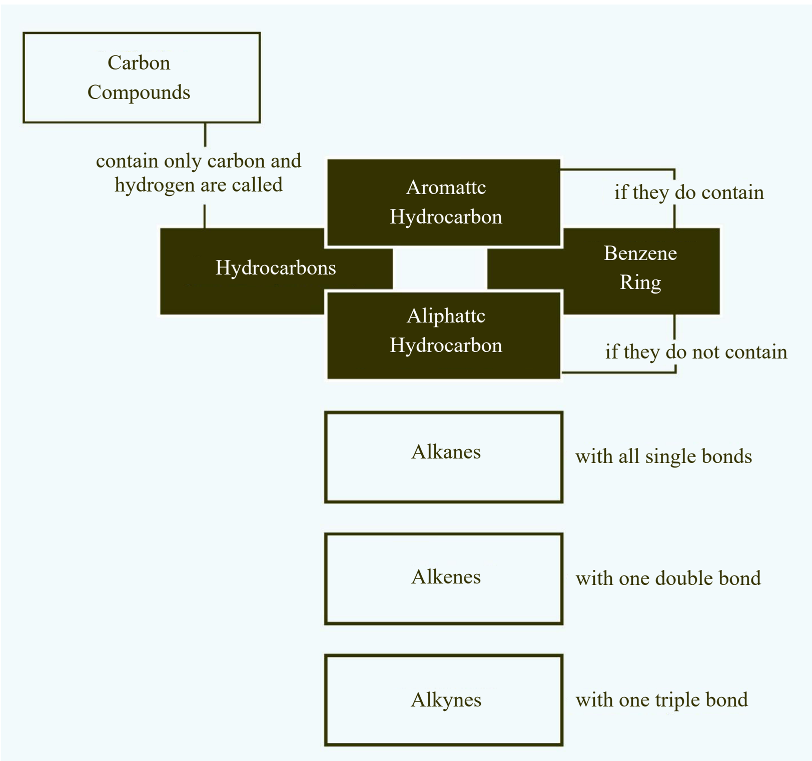

Figure 4. Hydrocarbons in petroleum

Barrels are crucial and significant in the production of oil because they are used to measure the volume of crude oil in liters, or 42 US gallons, per day. One barrel of crude oil is equal to 159 liters, and barrels are denoted by the symbol bbl. Because it involves relatively different roles in the marketing sector of the oil company involving production, processing, circulation, distribution, and sale, respectively, the demand and supply of oil in the petroleum industry are significant.[30]

3.3.1 *Natural gas*

The odorless and highly combustible gaseous hydrocarbon known as natural gas, often referred to as methane gas or natural methane gas, primarily consists of methane and ethane with traces of other substances (Table 3). It is commonly found in association with crude oil as a type of petroleum. Natural gas, being a fossil fuel, serves multiple purposes including electricity generation, heating of homes, fueling certain vehicles, and powering kitchen appliances.[31] It also plays a critical role as a chemical feedstock for the production of plastics and is utilized in the manufacturing of various chemical products such as fertilizers and dyes.[32] In many cases, natural gas is dissolved in oil when found in underground reservoirs under high pressure. It can also exist above the oil as a gas cap. The pressure exerted by natural gas in the subsurface reservoir often leads to the upward movement of oil to the surface. This type of natural gas, commonly known as "associated gas", is considered the gaseous phase of crude oil and may contain light liquids like propane and butane. As a result, associated gas is sometimes referred to as "wet gas" due to the presence of these light liquids.

Table 3. Crude oil composition

Compounds	Molecular Composition	Formular
Methane	CH_4	65-90%
Ethane	C_2H_6	0-25%
Propane	C_3H_8	1-2%
Butane	C_4H_{10}	> 1%
Carbon Dioxide	CO_2	1-2%
Oxygen	O_2	> 1%
Nitrogen	N_2	> 1%
Hydrogen Sulphide	H_2S	> 1%
Rare Gases	Ar, He, Ne, Xe	Traces

3.3.2 *Fossil fuels*

Coal can be burned to generate electricity and is a nonrenewable fossil fuel that is hazardous to the environment and miners. Although it is dangerous, coal accounts for roughly 50% of electricity generation in the US. Coal is a sedimentary rock that is black or brownish-black, mostly composed of carbon and hydrocarbons. It is the largest source of energy for generating electricity globally and the most abundant fossil fuel in the US.

Fossil fuels, including coal, are formed from the remains of ancient life and are considered nonrenewable resources due to their limited supply. The formation of coal began during the Carboniferous period approximately 300 million years ago when the Earth was covered by vast shallow waters and dense forests. Occasionally, these forests were flooded by the oceans, leading to the trapping of vegetation and algae in marshy wetlands.[33] Over time, the plants were gradually covered and compressed by layers of leaves and organic material, primarily consisting of mosses and algae.

This slow decomposition process preserved the carbon content of the plant matter, which serves as an energy source.[34] The submerged plant material forms peat bogs, which contain significant amounts of stored carbon. In countries like Scotland, Ireland, and Russia, peat is an important source of thermal energy and can be used as fuel.[35] Under specific conditions, peat can undergo a process called carbonization, transforming into coal. Carbonization requires extremely high pressures and temperatures. Over time, approximately 3 meters (10 feet) of layered vegetation can ultimately produce a foot of coal (or about a third of a meter).[36] Coal is typically found in underground formations known as "coal seams" or "coal beds". These seams can span vast distances, reaching up to 1,500 kilometers (920 miles) in length, with a thickness of 30 feet and a height of 90 feet.

3.3.3 *Crude oil*

Crude oil, is found in porous rock formations within the Earth's crust and is utilized as fuel or processed into chemicals. Its underground presence and pressure vary depending on the depth, often containing significant amounts of natural gas kept in solution by the pressure. During extraction, oil wells may also bring in water along with the gas and liquid crude, which is then separated from the surface fluids using specialized machinery.[37] The clean crude oil is typically stored above the ground in large steel cylinders, known as tanks, with diameters up to 30 meters (100 feet) and heights of 10 meters (33 feet), at a pressure close to atmospheric. Transportation of crude oil from production sites to treatment facilities is commonly done through pipelines, particularly for overland transport. Tank trucks are utilized to collect crude oil from remote wells and transport it to pipeline terminals.[38] In certain cases, specially designed railroad cars are also used for transportation. International transportation of crude oil is carried out using tanker ships with specific designs having capacities ranging from less than 100,000 barrels to over 3,000,000 barrels. Following extraction, the majority of crude oil is transported to refineries, where it undergoes various processes.[39] These processes include fractional distillation, which separates the different hydrocarbon components of crude oil into fractions with similar properties. The separated hydrocarbons are then subjected to chemical conversions to produce more desirable reaction products. Additionally, purification techniques are employed to remove impurities and unwanted substances from the final products. Fractional distillation is a key method used to separate the hydrocarbon components of crude oil, and the resulting fractions undergo further processing to produce a wide range of products (R). These products include heating oil, asphalt, gasoline, and diesel fuel. The proportions of these products obtained through distillation vary depending on the crude oil's properties, as illustrated in the figure, which showcases the ratios of products derived from five typical crude oils, ranging from heavy Boscan oil from Venezuela to light Bass Strait oil from Australia. The market value of crude oil often increases with higher yields of light products, aligning with the demand pattern, where transportation fuels like gasoline are in high demand.

3.4 *The oil industry*

The petroleum industry, commonly known as the oil industry or the oil patch, encompasses the global processes involved in the exploration, extraction, refining, transportation (usually via oil tankers and pipelines), and marketing of petroleum products. The industry's main volume products include fuel oil and gasoline. Additionally, petroleum is a significant component in various chemical items such as plastics, fertilizers, insecticides, solvents, medications, and synthetic fragrances. Challenges related to refining crude oil into different end products and addressing the infrastructure age are also prevalent in the industry.[40] Petroleum holds immense importance for many countries as it is crucial to numerous industries and plays a vital role in maintaining the current form of industrial civilization. Oil consumption constitutes a substantial portion of global energy consumption, with the Middle East utilizing 53% of it, while Europe and Asia consume as little as 32%.[41] Consumption patterns in other geographic regions are as follows: Africa (41%), North America (40%), South and Central America (44%).[42] On an annual basis, approximately 36 billion barrels (5.8 km^3) of oil are consumed worldwide, with developed countries being the highest consumers. In 2015, the United States alone consumed 18% of the oil produced. The production, distribution, refining, and retailing of petroleum comprise the world's largest industry in terms of dollar value. However, compared to several other industries, the oil and gas sector allocates the least amount of its net sales, only 0.4%, to research and development.[43] Governments, such as the United States, provide significant public subsidies to petroleum companies in the form of tax breaks at various stages of the oil exploration and extraction process, including oil field leases and drilling equipment.[43] Enhanced oil recovery techniques, notably multi-stage drilling and hydraulic fracturing ("fracking"), have gained prominence in the industry in recent years as they play a crucial yet contentious role in new methods of oil extraction.[44] The oil industry is typically divided into three sectors: upstream, midstream, and downstream.

3.4.1 *Upstream sectors*

The upstream sector of the petroleum industry encompasses various aspects, including exploration, land management, drilling, completion, and well stimulation, production, and work-over intervention. It involves the search for potential natural gas and crude oil fields both on land and under the sea, drilling exploratory wells, and subsequently operating the wells to recover and bring the raw gas and crude oil to the surface. The upstream industry has historically witnessed significant merger, acquisition, and divestiture activities (M & A).[45] In 2012 alone, there were 679 deals in the upstream oil and gas sector, with a total value of $254 billion. The unconventional/shale boom, particularly in the United States, followed by Russia and Canada, played a major role in driving these M & A activities, accounting for 33% of the total in 2012. In the third quarter of 2013, the total value of upstream exploration and production (E & P) assets up for sale, known as "Deals in Play", exceeded the previous high of $135 billion. Between 2009 and 2010, the value of Deals in Play doubled, rising from $46 billion to $90 billion.[46] Although the level remained relatively stable at $85 billion in December 2012 due to ongoing M & A activities, the first half of 2013 saw a net influx of new assets worth $48 billion entering the market.[46]

3.4.2 *Midstream sector*

The midstream industry plays a crucial role in the transportation, storage, and exchange of crude oil, natural gas, and refined products. In the case of unrefined crude oil, pipelines are the primary mode of transportation for the majority of the journey, while tankers navigate interregional waterways. Once the oil has been extracted and separated from the gas, pipelines transport the crude oil to another carrier or directly to a refinery.[47] From the refinery, petroleum products are transported to the market using various methods such as tankers, trucks, railroad cars, or additional pipelines. Tankers specifically transport both crude oil and refined goods from one nation to another to fulfill the petroleum needs of different regions.[48]

3.4.3 *Downstream sector*

The downstream sector of the petroleum industry encompasses various activities including the processing and purification of raw natural gas, the refining of petroleum crude oil, and the marketing and distribution of products derived from crude oil and natural gas. This sector offers a wide range of goods to consumers, including gasoline, kerosene, jet fuel, diesel, heating oil, fuel oils, lubricants, waxes, asphalt, natural gas, liquefied petroleum gas (LPG), as well as naphtha and numerous petrochemicals. These products are sold to end-users and consumers through various channels.[49] It is worth noting that midstream operations are often considered part of the downstream sector and are closely associated with downstream activities.

3.5 *Nonrenewable energy sources*

Natural resources that do not replenish as quickly as they are used up are referred to as nonrenewable resources. A Nonrenewable resource is therefore a finite resource. While the creation of new supplies takes eons, humans constantly draw from the reserves of these substances. Coal, natural gas, and other fossil fuels are examples of nonrenewable resources. A renewable resource is the opposite of a nonrenewable resource. These resources can be sustained or replenished naturally.

3.6 *Oil price analysis: The impact of supply and demand*

Oil is indeed the most valuable commodity, with its applications ranging from plastics and asphalt to fuel. The oil industry serves as a significant economic driver, and various stakeholders, including governments, corporations, investors, and traders, closely monitor fluctuations in oil prices.[50] The price of oil is highly influential and can cause shocks to the global economy. Supply and consumption patterns play a crucial role in determining oil prices. Unlike luxury items that have limited utility and can be lived without, oil is a vital resource with widespread applications and high demand.[51] It is abundant and essential for various industries, making market forces the primary determinant of its price. The interaction of supply and demand, as guided by market forces, is a fundamental economic principle that affects oil prices. When the supply of oil increases, prices tend to decrease, while an increase in demand generally leads to price increases. Understanding the factors that influence the supply and demand of oil is vital for comprehending its price dynamics. Various factors can impact the supply of oil, such as geopolitical events, natural disasters, changes in production levels, and decisions by oil-producing countries. Additionally, technological advancements in extraction techniques, exploration efforts, and the availability of infrastructure for transportation also influence supply. On the demand side, economic growth, industrial activities, transportation needs, and population growth are among the factors driving oil demand. Additionally, government policies, environmental regulations, and advancements in alternative energy sources can affect the demand for oil. The interplay between these factors creates a dynamic environment in which the supply and demand of oil continuously evolve, ultimately influencing its price.[52]

3.6.1 *Supply and demand*

Hundreds of millions of people and various businesses jointly influence the price of oil through their use. Oil output also affects oil prices, especially in nations with substantial crude oil production. As of 2021, the United States produced more oil than Saudi Arabia, which most people consider to be the top producer in the world. In 2018 also, the United States overtook Saudi Arabia as the top oil producer.[53] Shale fracturing in Texas and North Dakota were the culprits. Due to attacks on its oil fields that halted production, Saudi Arabia's oil production for the year 2019 was also lower than usual. The United States produced about 18.9 million barrels of oil per day in 2021. About 10.8 million were produced in Saudi Arabia and 10.8 million in Russia. With 5.5 million barrels produced per day, Canada came in fourth.

3.6.2 *Capacity and reserves*

It may be surprising knowledge that the nations with the largest oil reserves are not always the ones with the highest oil output. The disparity between reserves and production can be significant. Venezuela holds the top position in terms of oil reserves, with estimated reserves of 303.8 billion barrels.[54] However, accessing and extracting their oil reserves can be challenging due to offshore and underground locations. Moreover, the oil in Venezuela is dense, requiring additional effort in the refining process to convert it into usable products like gasoline. Saudi Arabia ranks second in terms of oil reserves, with 297.5 billion barrels. The country has been able to maintain a high level of oil output relative to its reserves. In contrast, the United States while a significant oil producer, has proven reserves that are less remarkable compared to its current production capacity.[55] As of the end of 2020, the United States had 68 billion barrels in reserve. These variations in reserves and output highlight the complexities of the global oil market, where factors such as geological conditions, technological capabilities, infrastructure, and government policies all play a role in determining a nation's oil reserves and its ability to extract and produce oil.

3.6.3 *Oil extraction*

Technology developments have also affected oil drilling costs and production. The amount of oil produced in North America has substantially expanded, with fields in North Dakota and Alberta generating more oil than ever. Shale fracking innovations have also produced new sources of supply. Hydraulic fracturing, sometimes referred to as "fracking", is the practice of injecting fluid into fissures in rock formations to force them to open up. Therefore, petroleum or natural gas can be extracted using these subterranean wells.

3.6.4 *Refining and distribution*

Despite the increase in oil production, crude oil prices have remained volatile and often high. One of the contributing factors to this situation is the mismatch between production and the distribution and improvement of goods and services, which highlights a flaw in the basic supply and demand concept.[56] The construction of refineries has significantly declined over the years. In the 1970s, construction of new refineries came to a halt, and in the subsequent decades, only a small number of refineries were built, and those that were constructed were not designed for high capacity.[57] In fact, the number of refineries in the United States has decreased over time. As of January 2022, there were only about 130 functioning refineries in the United States. This limited number of refineries poses a constraint on the amount of crude oil that can be processed and sold, despite the overall large quantity of oil available. This combination of factors contributes to the limited availability of oil and impacts the processing and sale of crude oil, ultimately influencing the dynamics of crude oil prices in the market.

3.6.5 *OPEC and oil prices*

The issue of cartels is indeed a concern in the oil industry, with Organization of the Petroleum Exporting Countries (OPEC) being a prominent example. Established in the 1960s, OPEC has the ability to influence oil prices, even though its charter does not explicitly mention price-fixing. By collectively limiting production, OPEC can create artificial scarcity, which in turn drives up oil prices and allows its member nations to earn higher profits compared to selling at the prevailing market rates individually.[58] This strategy of limiting production to control prices was a significant factor in the oil market during the majority of the 1970s and 1980s, although it has evolved over time. The U.S. Energy Information Administration (EIA) has reported instances where OPEC members exceed their legally permitted production levels, knowing that enforcement agencies may not be able to effectively prevent such actions. The actions of OPEC and the influence of cartels in the oil industry have been a subject of debate, as they can significantly impact global oil prices and market dynamics. These practices have implications for both oil-producing countries and oil-consuming nations, affecting economic stability and energy security.

3.6.6 *Geopolitical tensions and oil prices*

The oil industry is a global game and what happens in the world impacts the price of oil, especially since a large proportion of the world's biggest oil producers are in unstable areas.

3.6.7 *Regions susceptible to tensions*

Many oil-producing nations, especially those in the Middle East, are frequently linked to geopolitical crises. These regions include Saudi Arabia, Iraq, Iran, Kuwait, and Libya. Thus, the supply of oil is now even more unpredictable, which has an effect on pricing from other nations. For instance, Russia has played a negative role in world affairs and has been subject to sanctions as a result. Attacks by terrorists, sanctions, and other regional issues affect how these nations deliver oil, which in turn affects how oil prices fluctuate. Oil prices will therefore increase when these nations are unable to produce oil due to the mentioned obstacles and the demand for oil does not change.

Russia and ukraine tensions that began in late 2021 and intensified in early 2022 had a significant impact on the price of West Texas Intermediate (WTI) oil.[59] Russian officials issued warnings regarding Ukraine's potential admission to the alliance and called for the withdrawal of NATO forces from Eastern Europe by mid-December 2021, which heightened tensions in the energy markets.[60] In early 2022, Russia initiated military operations in Ukraine, focusing on separatist regions in the east and other targets within the country. These developments led to a notable increase in WTI oil prices, with prices climbing from $74.32 on December 15, 2021, to $100 in early 2022. Brent crude prices also experienced a surge, surpassing $105 in intraday trade. Geopolitical consequences, such as economic sanctions, can further contribute to unpredictable behavior in energy markets. On February 22, 2022, U.S. President Joe Biden announced sanctions against Russia, including prohibitions on two state-owned Russian banks that provided financial support to the Russian military. The sanctions also prohibited the purchase of Russian sovereign debt in the U.S. and targeted Russian officials and their families. On February 24, 2022, Sberbank and VTB Bank, the two largest Russian banks, were added to the list of entities subject to sanctions, preventing them from accessing the American financial system. Additionally, regulations restricted Americans from purchasing both new and old Russian government debt on the secondary market. Financial attacks were carried out against Russian elites and their families, and export restrictions were implemented. These measures and the overall geopolitical situation significantly impacted the energy markets and had implications for oil prices and market stability. The evolving geopolitical landscape and the implementation of sanctions will continue to shape the dynamics of the energy markets in unpredictable ways.

3.7 *Oil production worldwide*

For nations with abundant oil reserves and the capability to produce more oil than they consume, oil serves as a significant source of revenue.[37] These countries often rely on oil exports to generate income and support their national budgets. On the other hand, nations whose economies heavily depend on oil imports need to factor in oil costs when planning their national budgets. The oil industry is susceptible to various factors that can significantly impact its dynamics, as expected.[61] Unrest in oil-producing regions, the discovery of new oil fields, and advancements in extraction technologies all play a crucial role in shaping the oil industry.[37] Top oil-producing countries often generate substantial profits from their oil production. According to the US Energy Information Administration (EIA), the average daily output of oil and other petroleum liquids was 95.6 million barrels in 2021. OPEC was the leading group of oil-producing nations, with a daily production of 31.7 million barrels, followed by the Organisation for Economic Co-operation and Development (OECD) with 31.0 million barrels. These production levels highlight the significant role that oil plays in the global economy and the financial impact it has on oil-producing nations. Understanding the production capacities and market dynamics of these countries is essential for assessing their economic stability and the overall state of the oil industry (Table 4).

Table 4. 2021 top 10 countries with the highest oil production (barrels per day)

Countries	Barrels per day
United States	11,567,000
Russia	10,503,000
Saudi Arabia	10,225,000
Canada	4,656,000
Iraq	4,260,000
China	3,969,000
United Arab Emirates	2,954,000
Brasil	2,852,000
Kuwait	2,610,000
Iran	2,546,000

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3.7.1 *Saudi Arabia*

In 2021, Saudi Arabia produced 10.8 million barrels per day (b/d) of petroleum liquids, which accounted for approximately 11% of the global total. The country holds significant oil reserves, with 15% of the world's proven oil reserves as of 2020, making it a dominant player in the crude export market. As the largest member of the Organization of the Petroleum Exporting Countries (OPEC), Saudi Arabia has a significant influence on global oil markets. The petroleum industry plays a crucial role in the Saudi Arabian economy, contributing approximately 42% to its GDP, 87% to its budgetary revenues, and 90% to its export revenues, according to the CIA World Factbook.[64] Several major oil fields in Saudi Arabia, including Ghawar, Safaniya, Khurais, Manifa, Shaybah, Qatif, Khursaniyah, Zuluf, and Abqaiq, are of utmost importance in the country's oil production. Projections indicate that Saudi Arabia's crude oil production, including lease and plant condensate, is expected to increase from 76.1 million b/d in 2020 to 99.3 million b/d in 2050. Moreover, the output of total petroleum liquids is anticipated to rise from 94 million b/d to 125.9 million b/d during the same period. These figures demonstrate the significant role that Saudi Arabia plays in global oil production and its importance as a major player in the petroleum industry.

3.7.2 *Russia*

In 2021, Russia was one of the major oil producers, contributing 11% of the world's total output, or 10.8 million b/d, on average. Western Siberia, the Urals-Volga, Eastern Siberia, and the Far East are the principal oil-producing regions of Russia. The Volga-Urals and West Siberian regions, particularly the Priobskoye and Samotlor Koye fields in Western Siberia, hold the bulk of the production. After the Soviet Union fell, Russia's oil industry was privatized, but the state forced a consolidation and reform in 2001. The top three oil and gas producers in Russia are Gazprom, Rosneft, and Lukoil.

3.7.3 *Canada*

Canada was the fourth-largest producer of petroleum liquids in the world in 2021 with 5.5 million b/d, contributing 6% to total production. The EIA estimates that the nation's production of crude oil and condensate, which was 4.2 million barrels per day (b/d) in 2020, might increase to 6.9 million b/d by 2050, primarily because of the development of oil sands. Canada's main oil-producing regions are the Western Canada Sedimentary Basin, the Atlantic offshore areas, and Alberta's oil sands.

3.7.4 *China*

In 2021, China produced 5.0 million b/d of petroleum liquids, approximately 5% of global production. In 2017, China overtook the United States to become the largest oil importer in the world. After the United States, China was the second-largest oil consumer in the world in 2019 with a consumption rate of 14.0 million b/d. The majority of domestic production is produced in the nation's northeast and north-central areas. Since the 1960s, mature oil fields like Daqing have seen extensive drilling for oil. To offset some of the production decreases, businesses are increasingly investing in enhanced oil recovery (EOR) methods including polymer and stream flooding and water injection.

4. Petroleum industry in Nigeria

The second-largest producer of oil and gas in Africa is Nigeria with oil wells in several States of the Country (Table 5). Crude oil from the Niger Delta basin is available in two weight ranges: light (around 36 gravity) and relatively heavy (20-25 gravity). Both are low in sulfur and paraffinic. Since 1960, income and revenues from the petroleum industry have largely supported Nigeria's economy and budget. According to statistics from February 2021, the oil industry in Nigeria is responsible for 9% of the country's total GDP. Nigeria is the continent's top producer of oil and gas and a significant exporter of petroleum products to the United States of America. In 2010, Nigeria exported over one million barrels per day to the United States, representing 9% of the U.S. total crude oil and petroleum products imports and over 40% of Nigeria's exports.

Table 5. Oil producing states in Nigeria and their qualities

States	Qualities of oil produce
Akwa Ibom	The oil wells in Akwa Ibom are more important to Nigeria's oil exports, making this region the country's biggest oil producer. One of the major investment options in the state is oil and gas. Adua, Etim, Eket, Enang, Utue, Ata, Ekim, Udar, Ibibio, Etebi and Ubium, Akam, Adanda, and Ebughu are only a few of the state's oil fields.
Rivers	Before Akwa Ibom overtook Rivers as the top oil-producing state in Nigeria, Rivers was second. In addition to making significant financial contributions to Nigeria, Rivers is home to other natural resources like glass and silica sand. Additionally, the state boasts an airport, a seaport, and extensive natural gas reserves.
Delta	One of the states that contributes significantly to oil exports and maintains Nigeria's annual budget is Delta. With nine oil fields that have been producing for decades, OML 30 is one of the biggest onshore blocks. Warri, the state's capital, is home to one of Nigeria's "ineffective" refineries.
Bayelsa	The first oil field to be discovered in Nigeria was in Oloibiri, in what is now the state of Bayelsa. Bayelsa made up between 30 and 40 percent of Nigeria's main oil exports as of 2015. It also possesses 18 trillion cubic feet of gas reserves, which is the greatest in Nigeria. By total area, Bayelsa is one of the tiniest states in Nigeria.
Ondo	It is called the Sunshine State, Ondo state is another oil-producing state in Nigeria and it houses 4 billion barrels combined of oil reserves.
Edo	Apart from being an oil-producing state, Edo state also houses large reserves of other mineral resources like quarry and limestone.
Imo	Apart from contributing largely to Nigeria's exports, Imo state also houses other investment opportunities.
Abia	With over 100 oil wells in Abia, the state also houses installed flow stations and an associated gas plant. Most of the oil wells in Abia are managed by Shell. Oil wells can be found in Imoturu and Isimili.
Lagos	The two states in the southwest that contribute to Nigeria's oil exports are Lagos and Ondo. Lagos, Nigeria's economic hub, used to be the richest state until the Yinka Folawiyo Company Limited discovered and began exploring for oil in 2016.
Anambra	Anambra state is the newest state to join the list of oil-producing areas in Nigeria as a result of the Revenue Mobilization Allocation and Fiscal Commission (RMAFC) attributing 11 oil wells to the state in its letter to the National Assembly dated August 24, 2021 with reference number RMC/O & G/48/VOL/I/55. Anambra is now qualified to receive the allotment of 13% of derivation money as a result of the declaration. Anambra River 1, 2, and 3 oil well attribution will be split equally amongst the state on a 50-50 basis.

4.1 *Benefits of being an oil producing state*

According to section 162, sub-section 2 of the Nigerian Constitution, when oil is discovered in a state and it starts to contribute to Nigeria's oil exports, that state automatically qualifies for the 13 percent derivation revenue set aside by the federal government to assist the oil-producing communities in developing infrastructure in their domains and communities.

4.2 *Trending issues in the petroleum industry of Nigeria*

4.2.1 *Oil spills in Niger delta*

Reports on the size and frequency of oil spills in Nigeria vary, but they highlight the significant environmental and economic impact of these incidents. According to the Department of Petroleum Resources, between 1976 and 1996, an estimated 1.89 million barrels (220,000 cubic meters) of oil were spilled into the Niger Delta in 4,835 incidents.[65] Another report from the UNDP indicates that between 1976 and 2001, there were 6,817 oil spills, resulting in a loss of three million barrels of oil, with over 70% of the spilled oil remaining unrecovered.[66] The causes of oil spills in Nigeria are multifaceted. Pipeline and tanker accidents account for approximately 50% of spills, while sabotage is responsible for 28%. Oil production activities contribute to around 21% of spills, and inadequate or malfunctioning production equipment accounts for 1%. Additionally, the aging infrastructure and lack of regular inspection and maintenance contribute to pipeline and tanker corrosion, leading to ruptures and leaks. The consequences of these spills are significant, with impacts on local ecosystems, communities, and livelihoods. Efforts to prevent and mitigate oil spills in Nigeria remain ongoing, with various stakeholders working towards better environmental management and enforcement of regulations in the oil industry.

4.2.2 *Pipeline vandalism*

Pipeline vandalism in the Nigerian oil and gas sector has far-reaching impacts, including significant financial losses. It involves the deliberate destruction or damage to petroleum pipelines with the sole aim of stealing crude oil and related products. The financial repercussions of pipeline vandalism are substantial, as the shutdown of pipelines and plants leads to revenue loss for the oil and gas industry. The costs associated with repairing the damaged pipelines and addressing the environmental damage further contribute to the financial burden. Environmental contamination is a grave consequence of pipeline vandalism, as oil spills contaminate water sources, farmlands, and natural habitats.[67] This contamination disrupts ecosystems, negatively affects biodiversity, and poses long-term risks to communities dependent on these resources. Furthermore, pipeline vandalism increases the risk of fire outbreaks, endangering lives and causing damage to infrastructure.[68] These fires can result in fatalities, injuries, and further economic losses. The impact of pipeline vandalism extends beyond the oil and gas sector, affecting various industries that rely on petroleum products. Shortages and scarcity of these resources can disrupt operations and hinder economic activities. Additionally, the decline in electricity production due to pipeline damage has adverse effects on households, businesses, and overall productivity. To address pipeline vandalism, the Nigerian government and oil companies are implementing security measures, engaging with local communities, and collaborating with law enforcement agencies. These efforts aim to deter vandalism, protect infrastructure, and mitigate the negative impacts on the oil and gas sector and society at large.[69]

4.2.3 *Crude oil theft*

Nigeria continues to suffer substantial losses due to corporate oil theft, with more than 1 million barrels per day being lost. A concerning discovery was made regarding the calculation of volume estimates by oil companies, as they used dipsticks to determine production figures, which could easily be manipulated by altering the physical properties of the oil at export terminals.[70] Estimates suggest that crude oil theft in Nigeria ranges from 200,000 to 1,200,000 barrels per day, highlighting the severity of the issue. In an effort to investigate this matter, a due diligence company called Molecular Power System was contracted to provide technical data, including records of crude oil and liquefied natural gas (LNG) lifting in Nigeria and landing certifications at international destinations. The findings of the investigation confirmed suspicions that the amount of crude oil declared as exported from Nigeria between January 2011 and December 2014 was lower than the amount declared as imported into the United States, a country with stricter compliance laws and detailed records. The consortium conducting the investigation estimated that 727,460 metric tonnes of LNG, valued at over $461 million, were not delivered to seven countries. This loss of income, which was later identified as undocumented goods, was associated with shipments from each port of entry at the destination countries. The investigation identified a total of 51 nations where Nigerian LNG was exported but not declared, with the United States being the largest recipient once again. These findings highlight the magnitude of the issue of oil theft and the need for stronger measures to combat this illegal activity. It underscores the importance of improving monitoring, compliance, and enforcement mechanisms to protect Nigeria’s valuable oil resources and ensure transparency in the oil trade.

4.2.4 *Pollution*

Pollution is the detrimental introduction of toxins into the environment, causing harm. In the case of Nigeria's Niger Delta, oil production has been gradually polluting the region's waters, leading to significant environmental damage.[71] Oil spills have had detrimental effects on the nation's forests and farmland, exacerbating the environmental challenges faced by the country. Unfortunately, the government and oil companies have not taken sufficient and effective measures to address the environmental issues associated with the industry. A report by the United Nations Development Programme (UNDP) revealed that a total of 6,817 oil spills occurred between 1976 and 2001 in Nigeria, resulting in a loss of three million barrels of oil, with over 70% of the spilled oil remaining unrecovered.[72] Of these spills, 69% occurred offshore, while 25% took place in marshes, further impacting the delicate ecosystems. The lack of effective action to tackle pollution and prevent oil spills in Nigeria underscores the urgent need for stronger environmental regulations, enforcement, and responsible practices within the oil industry. Efforts should be made to mitigate the environmental damage caused by oil production, safeguarding the Niger Delta's ecosystem and ensuring the well-being of local communities.

4.2.5 *Fuel pricing*

During a special session of the Nigeria International Petroleum Summit (NIPS) in Abuja, the state minister for petroleum resources highlighted the cost of petroleum products as one of Nigeria's key challenges. According to Kachikwu, simply fixing the existing refineries and attracting private investments to build new ones would not effectively address the country's downstream issues.[73] He emphasized the need to tackle the issue of appropriate pricing for gasoline and gas to achieve sustainable solutions in the downstream sector.

4.2.6 *Inadequate pipeline infrastructure*

Mordecai Laden, the head of the Department of Petroleum Resources, has identified the lack of sufficient gas pipeline infrastructure as the primary challenge in the domestic gas supply and market growth. He pointed out that the majority of Nigeria's gas infrastructure consists of the Escravos Lagos Pipeline System (ELPS), while other gas pipelines tend to be project-specific, point-to-point, and lacking flexibility. This limitation hinders the development and expansion of the domestic gas market.

5. Evolution of the petroleum industry

5.1 *Exploration and production advancements leading to the rise of the modern petroleum industry*

Exploration and production advancements have played a pivotal role in shaping the modern petroleum industry. Through significant technological breakthroughs, innovative techniques, and a deepened understanding of geology, the industry has made remarkable strides in extracting vast reserves of oil and gas resources. One of the most revolutionary advancements in oil and gas exploration is the use of seismic surveys and reservoir mapping. By emitting sound waves into the ground and analyzing their reflections, geologists can create detailed images of subsurface rock formations. This technique enables the identification of potential hydrocarbon reservoirs, estimation of their size and depth, and evaluation of their geological characteristics. Seismic surveys have significantly improved the success rate of exploration efforts, leading to the discovery of major oil and gas fields across the globe. Another critical advancement is directional drilling, which has expanded the reach and efficiency of petroleum extraction. By drilling at angles or curves instead of just vertically, companies can access reserves that were previously inaccessible due to geological obstacles.[74] Directional drilling has opened up new possibilities for reaching offshore deposits, extracting resources from unconventional reservoirs like shale formations, and maximizing production by accessing multiple layers of hydrocarbons from a single drilling site. Enhanced Oil Recovery (EOR) techniques have emerged as a vital tool in the petroleum industry. As oil fields mature, primary production methods become less effective at extracting the remaining oil. EOR techniques involve injecting fluids or gasses into reservoirs to enhance the flow of oil and increase overall recovery rates. Water flooding, gas injection (such as carbon dioxide or nitrogen), and thermal methods (like steam injection) are common EOR methods. These techniques have extended the life of many oil fields and unlocked previously untapped reserves.[75] The development of offshore drilling technology has been instrumental in the industry's growth. Offshore drilling platforms, such as fixed platforms, floating rigs, and subsea systems, have enabled the exploration and extraction of oil and gas resources beneath the seabed. Advancements in offshore technology, including dynamic positioning systems, advanced drilling techniques, and remote-operated vehicles, have made deepwater drilling economically viable and led to the discovery of substantial offshore reserves. Reservoir simulation and modeling have revolutionized the management of petroleum resources. Engineers and geologists construct mathematical models that simulate the behavior of oil and gas reservoirs, taking into account reservoir properties, fluid flow dynamics, and production techniques. Reservoir simulation allows for the optimization of production strategies, prediction of reservoir performance, and informed decision-making regarding field development plans. This technology has become an essential tool in efficiently managing petroleum resources, leading to higher recovery rates and improved overall production. These exploration and production advancements have propelled the modern petroleum industry to unprecedented levels of extraction, enabling the development of vast reserves and meeting the growing global energy demand. However, it is crucial to acknowledge the increasing focus on sustainability, environmental considerations, and the transition to cleaner energy sources in the industry's evolution. Despite these challenges, the exploration and production advancements that have shaped the petroleum industry continue to drive its growth and have a profound impact on the global energy landscape.

5.2 *Exploration of the impact of key events and discoveries in shaping the industry's trajectory*

The petroleum industry has undergone significant transformations due to a series of pivotal events and discoveries that have left an indelible mark on its path. These milestones have not only influenced the industry's expansion but also its technological advancements, global influence, and strategic decision-making. Let us delve into some of the notable events and discoveries that have molded the petroleum industry in a profound way.[76] The commencement of the modern petroleum industry can be traced back to the drilling of the first commercial oil well in Titusville, Pennsylvania, in 1859. Edwin Drake's pioneering feat demonstrated the feasibility of large-scale oil extraction, sparking rapid growth in the industry.[75] A monumental turning point occurred with the Spindletop oil discovery in Texas in 1901. This landmark event unleashed an immense oil gusher, igniting the Texas oil boom and propelling the United States to become the world's leading oil producer. The Spindletop discovery set the stage for the industry's substantial expansion throughout the 20th century.[77] The discovery of substantial oil reserves in the Middle East, particularly in nations like Saudi Arabia, Iraq, Iran, and Kuwait, reshaped the global oil industry. The abundance of easily accessible and inexpensive oil transformed the Middle East into a prominent player in the global energy market, leading to the ascendancy of national oil companies.[23] The formation of the Organization of the Petroleum Exporting Countries (OPEC) in 1960 brought about a significant shift in the industry's dynamics. OPEC's capacity to control production levels and influence oil prices became apparent during the oil price shocks of the 1970s. Events such as the Arab oil embargo and the Iranian Revolution led to substantial increases in oil prices, highlighting the geopolitical influence wielded by oil-producing nations Technological advancements have played a crucial role in shaping the petroleum industry. The introduction of seismic surveys in the early 20th century revolutionized exploration by enabling more accurate imaging of subsurface structures. Development in directional drilling techniques during the mid-20th century allowed access to previously inaccessible reserves. The progress in offshore drilling technology expanded the industry's horizons, unlocking vast offshore oil and gas resources. These advancements continuously push the boundaries of exploration and production techniques.[78] The development and commercialization of hydraulic fracturing (fracking) and horizontal drilling techniques in the late 20th century ushered in the shale revolution. This breakthrough, particularly prominent in the United States, unlocked significant unconventional oil and gas resources trapped in shale formations. The shale revolution reshaped global energy markets, leading to increased domestic production, reduced dependence on imports, and a restructuring of global supply dynamics. The global emphasis on sustainability and the transition to renewable energy sources is beginning to shape the trajectory of the petroleum industry. The growing adoption of renewable technologies, governmental policies promoting clean energy, and heightened public awareness of climate change have placed pressure on the industry to diversify and decrease its carbon footprint. This shift towards cleaner energy sources is influencing investment decisions, research and development endeavors, and long-term strategic planning within the petroleum industry. These pivotal events and discoveries have played an instrumental role in shaping the trajectory of the petroleum industry, impacting its growth, technological advancements, market dynamics, and environmental considerations. As the industry continues to evolve, future events and discoveries will undoubtedly continue to shape its trajectory, driving innovation, sustainability efforts, and the global energy transition.

5.3 *Forecasting future petroleum demand and prospect*

Nigeria's oil production has resulted in significant environmental damage, including contaminated water and fire outbreaks, leading to the loss of over 2,000 lives. The extent of the impact is challenging to determine accurately due to the ongoing instability. The decline in international air travel has also adversely affected the demand from the aviation sector. The oil market, which was already unstable, has become even more volatile due to the introduction of the coronavirus.[79] The short-term outlook for the oil market is currently the primary focus due to its volatility. However, it is crucial to consider both the present and future perspectives to understand the long-term effects of the global health crisis on economic activity. Factors such as higher-than-anticipated oil demand in China and the US, bottlenecks in refining and distribution, stricter product specifications, and the current geopolitical environment have raised concerns about potential future shortages of crude oil supplies. This has led to speculation in the futures markets and increased price pressure. Demand growth in 2019 was weaker than expected, and new vehicle efficiency rules have started to impact transportation fuel prices. Refining capacity has increased, surpassing demand growth, and creating a more competitive market. Global oil demand is projected to grow at an average annual pace of under 1 million barrels per day (mb/d) between 2019 and 2025, with petrochemicals driving a significant portion of this growth. World oil production capacity is expected to increase by 6.9 mb/d, with OPEC increasing its capacity by 2.4 mb/d and non-OPEC countries contributing 5.5 mb/d. However, this projection assumes no changes in the sanctions imposed on Venezuela or Iran.[80] The United States is leading in terms of new supply, with countries like Brazil, Guyana, the United Arab Emirates, Iraq, and others also contributing to increased production. The demand for gasoline and diesel is expected to slow as more people transition to electric vehicles and governments implement measures to improve efficiency and reduce CO_2 emissions. Despite this, refiners are continuing to expand their capacity beyond necessary levels to meet product demand. The impact of the switch to renewable energy on oil supplies is still uncertain. Oil companies are facing increasing pressure from investors and activists to prioritize sustainability and reduce CO_2 emissions. However, most companies have primarily focused on long-term objectives in their emission reduction plans.

The COVID-19 pandemic has had a profound impact on the world economy and oil markets, leading to a decline in demand and a surplus of oil. As countries focus on a sustainable recovery, the outlook for oil consumption has decreased, potentially accelerating the peak in oil demand if governments implement strong policies to transition to sustainable energy.[81] This presents a challenge for oil-producing countries and businesses, as they need to balance the need for investment and avoid future supply shortages. In addition to the pandemic, Nigeria's oil and gas industry has faced challenges from militant attacks on infrastructure and oil theft, resulting in significant financial losses for operating companies.[82] These issues are expected to hinder market expansion in the forecast term. However, the upstream segment is expected to grow rapidly due to increasing offshore exploration and production operations, driven by government initiatives to promote the country's hydrocarbon industry. The COVID-19 pandemic has also been classified as a "force majeure" by the Department of Petroleum Resources (DPR), leading to measures such as reducing the number of workers at project sites. These measures are necessary to mitigate the impact of the pandemic on the oil and gas sector. According to the recent study from Global Data titled "Africa Oil and Gas Projects Forecast to 2026", a significant number of oil and gas projects are expected to commence in Africa between 2022 and 2026. The study identifies a total of 447 projects that are anticipated to begin during this period. The majority of upcoming developments in Africa are categorized as new build projects, accounting for nearly 80% of all projects across the value chain on the continent. In particular, the midstream and petrochemical industries have a high proportion of new build projects, with over 90% falling into this category. In terms of geographical distribution, Nigeria and Egypt have the highest number of upcoming projects in Africa. Nigeria accounts for 24% of all projects, while Egypt follows closely with 19% of the projects scheduled to start up between 2022 and 2026. This anticipated increase in oil and gas projects reflects the ongoing investment and development activities in Africa's energy sector, highlighting the region's potential for growth and development in the industry.

6. Conclusion

In conclusion, this review article has provided a detailed overview of the history, distribution, production, and consumption of petroleum. It has also explored the impact of the oil industry on the global economy, society, and the environment. While the discovery of petroleum has brought numerous benefits to society, it has also created significant challenges, including environmental degradation and geopolitical conflicts. As we look to the future, it is important to consider the potential impacts of technological advancements and shifts in energy policies on the demand for petroleum and the global energy landscape. Ultimately, we must strive for a sustainable energy future that balances economic, social, and environmental considerations.

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Authors contribution

GE, PS, AJ, HE, UU, EO, OE, AE, IA, AO, KO, JO were responsible for the conception and design of the study; GE, PS, AJ performed data collection. GE, PS, AJ performed data analysis and drafted the article. GE supervised the study, contributed to data analysis, interpretation, and critical revisions. All authors approved the final manuscript.

Conflict of interest

The authors declare no conflict of interest.

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