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Petroleum: Market analysis and its importance in the Colombian economy

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ABSTRACT

The goal of this research is to monitor and examine how the global oil market operates, with a focus on how important it is to the Colombian economy. A theoretical framework that describes the history of oil, the properties of the substance, its derivative products, the stages of the production process, and its effects on the environment is presented as a means of generating precise comprehension. Later, the global market will be covered through a qualitative and quantitative analysis of the primary factors affecting the global market, as well as its key actors, using the databases provided by the Organization of Petroleum Exporting Countries (OPEC) and the Observatory of Economic Complexity (OEC). Next, the document focuses on the Colombian historical context, as well as its organizational and regulatory framework, and then, with a clear and concise idea of the functioning of oil in the world, it covers and analyzes the dynamics of the national market through the databases provided by the National Hydrocarbons Agency (ANH) and the National Administrative Department of Statistics (DANE). Finally, the multiple factors that make oil fundamentally important to Colombia are analyzed, both favorably and unfavorably, as well as a future projection of President of the Republic of Colombia Gustavo Petro's proposal aimed at decarbonizing the country's economy.

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CHAPTER 1

1 PETROLEUM

1.1 Origins: history, discovery and evolution

The word petroleum comes from the Latin "petroleum", which means "rock oil". It is a natural mineral oil, viscous, flammable, and liquid at normal temperature and pressure, consisting of a mixture of hydrocarbons and other elements, in smaller quantities, which is naturally found in certain geological formations.

In a general way, it can be defined as that dark and wonderful substance, whose origin lies in the depths of the Earth and that has been formed, initially and fundamentally by the increase of temperature from the decomposition of organic substances produced by the action of microorganisms, in other words, by the remains of organisms and beings that lived millions of years ago on the planet.

Its organic origins are primarily ***marine phytoplankton*** and ***zooplankton***, with modest contributions from plant and animal remains. All of these components were deposited on the seabed or, occasionally, the bottom of lakes over durations measured in millions of years. Rivers, wind, and tides carried successive layers of mud, sand, clay, and other sediments into place beside and on top of this organic material, so that later on, the massive amounts of organic matter that were deposited would begin to decompose due to the pressure and temperature inside the earth, over the course of millions of years, turning them into oil and gas inside the so-called "source rocks" through a complicated chemical-physical process. An overview of the general composition of petroleum is provided in Table 1. [1]

Table 1: Oil Composition

Element	**Weight %**
Carbon	84-87
Hydrogen	11-14
Sulfur	0-2
Nitrogen	0,2

In order to discuss the discovery of oil, it is crucial to look back in time and provide a brief overview of some facts related to civilizations [2]:

- The oil industry, according to history, first appears in archeological records close to Hit, on the banks of the Euphrates River, in what is now Iraq. There, asphalt was extracted 6,000 years ago for use as mortar between building stones and as waterproofing for baths, pottery, and ships thanks.
- In 4,000 BC, crude tar known as bitumen was employed in Mesopotamia for a variety of purposes, including caulking ships, mounting mosaics and jewelry, and adhering weapon grips.
- The famous pyramids and the walls of Babylon were kept together with it, and the Egyptians employed it also for embalming.
- Even Noah's Ark and Moises' basket are reported to have been coated with bitumen on both the interior and the outside.
- Around 500 BC, using bamboo reeds and bronze pipes, the Chinese began looking for oil underground with home and lighting purposes.
- By lighting the sea on fire and dumping oil into it, the Greeks annihilated enemy fleets.
- Last but not least, in pre-industrial times, stone oil was also used therapeutically, for embalming the dead, and as a home cure for burns, bruising, and rheumatism.

Although oil has been known and used since millennia, the history of oil as a vital element and strategic development factor is relatively recent, a little more than a century and a half.

In 1850, Samuel Kier, an apothecary in Pittsburgh, Pennsylvania (USA) marketed it for the first time under the name of "rock oil" or "petroleum". But it was William Drake, another American, who made the first commercial oil discovery, drilling a well in 1859 in Titusville, Pennsylvania. This finding triggered the "oil rush", which led to the production of 25,000 tons of oil a year later. The oil industry, formerly the world's most significant source of energy, had just emerged, and coal, which had previously dominated the energy landscape, was starting to decline. From that point on, the oil industry started to expand and a resource that has unquestionably improved society's quality of life started to be truly exploited.

Early societies used a variety of energy sources, but those that relied on solar radiation, water, and air currents stand out. The novelty of these energy sources was that they could be distributed among the various communities without needing to be obtained through a specific organization. However, as the use of fossil fuels spread throughout the community, a systematic shift in energy production and social organization occurred as a result of the need to address numerous organizational and technical challenges associated with resource extraction, transportation, and large-scale industrial applications. [3]

Since then, oil has shaped and molded the population by transforming ideas about social development, economics and technological innovation, and opening the doors to the possibilities of creating better living conditions. Basically, the great value of petroleum is due to its unique properties associated with its high energy capacity per unit weight and volume. Thanks to its ease of storage and transportation, once discovered, large volumes can be extracted.

Hydrocarbons are now widely accepted as a crucial component of everyday life. In fact, hydrocarbons account for a large portion of the energy used to power modern equipment, illuminate homes, run vehicles, and produce electricity. Similar to this, hydrocarbon-based fertilizers and pesticides are used in global food production, which is the main source of food for a significant portion of the world's population. It is also widely used in the plastic that is all around us and in countless other items that we use on a daily basis. In general, everyone requires oil. Every day of our lives, we use it in one of its various ways.

In general, the main uses obtained in the industry are specific fuels for transportation, industry, electricity generation and domestic use; Special products such as kerosene, lubricants, asphalt or products for industrial use; And raw materials for the petrochemical industry.

It can be said that everything that revolves around this element is influencing the political dynamics of the planet to the extent that the culture and economic systems associated with each population are dependent on energy consumption and to the extent that oil provides approximately 35% and 90% of the total energy consumed and the energy used in transportation, respectively.

1.2 Product Features

Starting with the fact that oil is one of the most demanded resources globally and currently serves as the basis for the largest number of products in existence. So much so, that it has become established as a key factor in the economic systems of each country and in the world economy. Therefore, determining the best type of oil for the needs of the market is crucial when it comes to commercializing these hydrocarbons.

It is important to mention that when it comes to product features, there are 3 types of petroleum classification to determine its value and quality. Classification based on its composition, API gravity and sulfur content.

1.2.1 Classification based on its Composition

At first, we are informed that they are chains, which can be simple or complex, based on the chemical components of carbon and hydrogen. It is important to note that different properties are obtained depending on the number of carbon atoms and the structure of the hydrocarbons that make up the oil, which characterize and determine their function, whether as fuel, lubricant, waxes, or solvents.

1.2.1.1 Paraffinic-base

Paraffinic crude oils are among the most valuable or those with the highest commercial worth on the market because of their capacity to be converted into a number of useful derivatives, such as gasoline, lubricants, and kerosene.

They are widely used in the cosmetic industry, due to their protective qualities, shine, and consistency, as well as in the manufacture of candles, textiles, inks, and food coatings, in addition to the uses associated with gasoline as a fuel and lubricants as a method of reducing friction and wear in machinery. However, due to the fact that its production and transportation process cannot be easily carried out, its commercialization is not very simple.

In terms of its composition, 75% of it, is constituted mainly of saturated or paraffinic hydrocarbons, which are ideal for producing paint solvents and gasoline due to their high freezing points and low sulfur content. They are also crucial as a base for large amounts of lubricating oil and naphtha due to their high kerosene production and low asphalt content during the distillation process. Its excellent fluidity, modest coloring,

and low specific gravity (approximately 0.85 kg/L) are some of its important characteristics. [4]

1.2.1.2 Naphthenic-Base

Naphthenic oils are obtained directly from the refining of crude oil, generally have a high asphaltene index and, compared to paraffinic-based hydrocarbons, are practically free of kerosenes, since saturated hydrocarbons make up approximately 45% of its composition.

These oils contain a relatively high proportion of volatile fractions, i.e., compounds whose interaction with the environment causes them to evaporate easily, and in some exceptional cases they are so light that they are almost pure naphtha. This type of base oil has a low sulfur content as well as much less wax than a comparable paraffinic base oil, which gives them much better low-temperature capabilities, which increases the lubricant compositions and makes it suitable for hydraulic and automatic transmission fluid formulation. [5]

It is also crucial to bear in mind that the production of this type of naphthenic base oils requires complex and costly physical and chemical processes, such as dewaxing, bleaching, sulfur removal, acid and solvent treatments, which ultimately results in an increase in the price of these oils.

Due to their high solvency, naphthenic oils also make good fuel for internal combustion engines and react favorably with antioxidants and additives. This type of naphthenic oil has a wide range of applications, including in printing inks, particularly for newspapers and magazines because of its nearly colorless nature and high viscosity. In addition, it is important to emphasize that white oils can be derived from naphthenic oil, whose application and use are focused on products that have direct and obligatory contact with human beings, so it must be non-toxic, non-staining and non-contaminating.

1.2.1.3 Asphaltene-Base

These oils contain a significant quantity of sulfur in addition to hydrogen and carbon and have a complex chemical structure that is not properly known. It produces a large amount of asphaltene residue when diluted, which can be used for roads or other productions. At the same time, asphalt-based crudes give us most of our heavy fuels.

In general, it is ideal for the creation of asphalt due to its composition, which contains high levels of residues such metals and sulfur as well as high viscosity. [5]

1.2.1.4 Mixed-Based

These are the ones that contain all known types of hydrocarbons, including paraffinic, naphthenic, aromatic, etc. Since no crude oil has a chemical composition that is totally naphthenic, paraffinic, or asphaltic, categorizing it as one of these categories would be inaccurate in some production locations where the oil is diverted in such equal amounts. This leads to the creation of the category known as mixed base crudes. This style of field predominates around the world. [5]

1.2.2 Classification based on its API gravity

The American Petroleum Institute, also known as API, is the main trade organization for the oil and natural gas sector in the United States. This organization aids in establishing guidelines for the extraction, processing, and distribution of petroleum products. The creation of a crude oil classification system, API gravity, that does not require knowledge of the precise composition of the crude oil, is one of the most significant standards that the API has established. In essence, this criterion is intended to assess how dense oil and petroleum liquids are in comparison to water. [6]

Gravity is measured in degrees API on the scale. Based on this norm, In the oil industry, crude oil is categorized as light, medium, heavy, or extra heavy. Most crude oils and petroleum liquids have an API gravity between 10 and 70 degrees. However, the ones having an index between 40 and 45 degrees typically commands higher prices.

While exploring for such a substance, it can be found in a liquid or gaseous state. The latter can be light, heavy, or extremely heavy. The amount of refinement needed to produce the most expensive products from an oil depends on how many API degrees it has. In other words, "light oil," which is less dense, is most desirable since it has a higher concentration of hydrocarbons that may be turned into gasoline and cause less pollution. [1]

In this way, API gravity is divided into three levels:

- Light crude oil (> 26): which has an API gravity value more than 26 and a low wax content in its composition. Easily poured, slightly more viscous than water, and easier to extract since they can flow through porous rock more freely.
- Intermediate crude oil (20-26): defined as having an API gravity that falls between 20 and 26. Easily poured, slightly more viscous than water, and easier to extract since they can flow through porous rock more freely.
- Heavy oil (< 20): with an API gravity below 20 degrees. This kind of oil does not flow easily. It is distinguished by having little to no natural gas liquids and a high concentration of heavy hydrocarbons, which gives it a denser structure with a greater molecular weight.

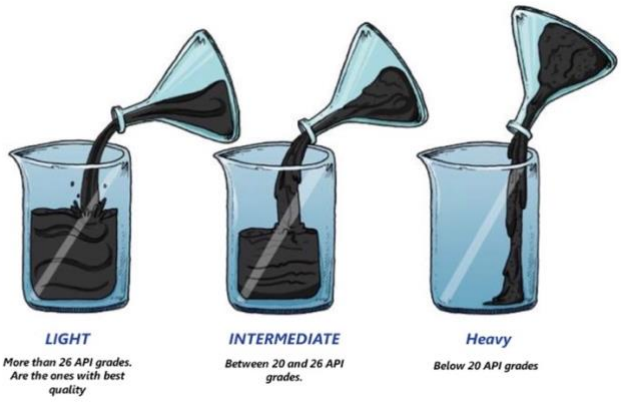

Figure 1. Oil based on its API gravity classification [1]

1.2.3 Classification based on Sulfur content

As was already established, oil contains a mixture of these saturated hydrocarbons, other hydrocarbons with differing properties, as well as smaller amounts of other metals and other compounds that are thought to be impurities, such as sulfur, nitrogen, and oxygen. As a result, it is crucial to note that sulfur is one of the most commonly mentioned pollutants in the sale of oil, and if it is present in large quantities, the oil will be referred to as ***Sour oil*** (more than 1.0%). Otherwise, it will be referred to as ***sweet oil*** if it is absent or present in low amounts (less than 0.5%).

1.3 Petroleum Products

As mentioned above, over the years, the use of petroleum has had considerable growth, where through different discoveries, research, and technologies, it has been possible to categorize the different types of petroleum and therefore, identify, determine, and classify petroleum products.

When we talk about petroleum products, we refer to those extremely complex chemical substances that are obtained during the refining process, requiring a considerable amount of effort to accurately and precisely characterize their chemical and physical properties (as will be explained later on). It includes a vast variety of chemical combinations with a wide range of properties, from gasses to liquids to solids, where depending on their composition, refineries can carry out the production of these different products

Basically, petroleum products are all the products derived from petroleum that can be obtained through the refining process, where the long list of products includes:

- **Gaseous fuels:** are all naturally occurring hydrocarbons that are produced exclusively to be used as fuels as well as those that are produced as a by-product in some industrial operations. One of these derivatives is propane.
- **Liquid fuels:** often known as gasolines, are a product of fractionating petroleum. It is primarily used as fuel for the majority of spark ignition internal combustion engines, as well as for lights, stoves, and various cleaning solutions. Kerosene, diesel oil, oxygenated compounds, etc. are a few of these items.
- **Lubricants:** Liquid materials that help extend the life of internal combustion engines and other machines with moving components. Some additives are added to these compounds to alter their viscosity and flash point. The primary goal is to prevent or reduce friction between moving metal parts of a machine or engine in order to prevent wear and damage. [7]
- **Kerosene waxes:** mineral oils that come in solid or liquid form and have a variety of uses in a wide range of industries, including the pharmaceutical and food fields. It serves as a starting point for the production of candles, floor waxes, matches, wax paper, petroleum jelly, pharmaceuticals, and other items including the packaging of frozen meals.
- **Asphalt:** Black, sticky material obtained through an industrial distillation process of crude oil. It represents more than 90% of total asphalt production. It is used as a binder in asphalt mixtures for the construction of roads, highways or freeways.

It is also used in waterproofing structures such as warehouses and roofs, as well as in the manufacture of tiles, roofing tiles and flooring. [8]

- **Petrochemicals:** which also includes certain aromatic compounds including olefin and its precursors. They are used for many different things. First, they are used to make monomers, which are then used to create polymers, which can be utilized to make plastics, synthetic fibers, gels, or lubricants. Secondly, they might be used as raw materials or as solvents in the production of the same. And ultimately, to create chemicals for items like cleaning agents and other things. [9]

In other words, the majority of crude oil is used as a starting point for the creation of energy. However, in addition to producing chemicals that can be used to make plastic and/or other useful materials like paints, varnishes, solvents, fertilizers and insecticides, artificial rubbers, polyester, detergents, etc., they also obtain significant amounts of sulfur as well as hydrogen, and coal in the form of petroleum coke. Furthermore, the fact that petroleum is a necessary component of the industry has allowed to develop many items that improve, extend, and generally make our lives easier. Sunglasses, cameras, cassettes, furniture, clothing, pacemakers, surgical equipment, credit cards and watches are just a few examples.

1.4 Production Process

The oil value chain refers to the entire series of tasks that must be completed from the supply sources to the commercial channels through which they are sold in the wholesale market. Stages like Upstream, Midstream, and Downstream can be found in this process.

In general, the Upstream stage, regarded as the riskiest stage in the industry, entails the search for potential oil reservoirs, the drilling of exploratory wells, and the development of the facilities surrounding those wells that produce commercial quantities; the Midstream stage entails storage and transportation through pipelines, either by sea, rail, or road; and the Downstream stage includes the refining of crude oil into petroleum products and its commercialization. [10]

The stages and substages of the value chain for these hydrocarbons are described in the sections that follow.

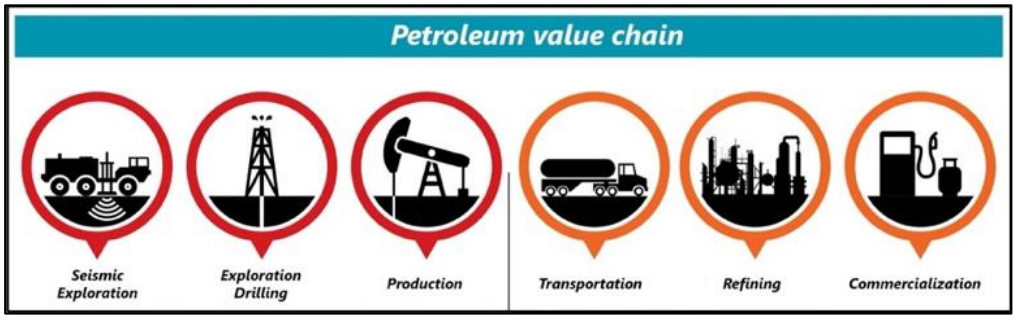

Figure 2. Decomposition of oil value chain. Adapted from [10]

1.4.1 Detection and Exploration

By means of research and operations based on geological, geophysical, geochemical, seismographic and drilling studies, a search and location of possible oil deposits or, in other words, the accumulations of hydrocarbons in commercial volumes existing in the subsoil is carried out. The above, in order to serve as a tool for specialists to select the most suitable place to drill such exploratory well, always within the framework of environmental and territorial laws designated by each country, to ensure respect for the environment and the planet.

Three basic phases normally consist petroleum exploration [11]:

- First Stage: This initial stage of the geological investigation process involves collecting rock and fluid samples in an area of interest while using aerial photographs, satellite images, and radar as support.
- Second Stage: The conditions of existence of a possible petroleum system are determined and areas of interest are identified.
    - Various types of maps are produced that identify characteristics of a given area, such as rock type, geological faults and other general data: vegetation, topography and water flows, among others.
    - Geologists analyze the data and determine whether or not there is a chance of discovering hydrocarbons, allowing for the advancement of exploration with more accurate techniques that demand larger investment, such as seismic.

- Third Stage: The drilling of an exploratory well will determine whether there are hydrocarbons in the subsoil that may be extracted for commercial purposes.

It is important to note that even though oil exploration is a costly and complex operation that must be carried out in the midst of difficulties with few guarantees of success, the execution of a ***seismic investigation*** can provide more certainty prior to drilling.

With the use of seismic data, it is possible to more precisely define the distribution of the various geological layers and structures as well as identify the presence of traps in the subsurface. Also, it gives the option of relating seismic data with rock properties, which enables finding the best regions for the accumulation of hydrocarbons.

Having said that, we must know that the seismic method consists as follows [1]: Initially, Artificial elastic sound waves are produced by means of vibrations induced by specialized vehicles on the surface, ships, or minor controlled explosions, with the intention of spreading them through the various subsoil layers and to propagate them down to the subsoil. As this happens, small echoes are produced in the layers of the earth, which can only be perceived by highly sensitive devices called geophones, which capture the information and direct it to the central recording unit. In the end, the interpretation of the seismic image is combined with all the data gathered during the exploratory phase to determine which areas may have hydrocarbon reserves, how potential those deposits are, and where exploratory wells should be drilled to confirm it.

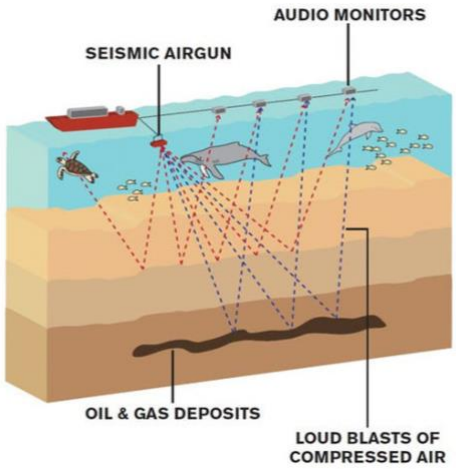

Figure 3. Seismic exploration at sea. Adapted from [12]

1.4.2 Drilling

Once the reservoirs or zones of interest have been located, drilling exploratory wells is the only certain approach to determine if there is oil onsite. Due to the extensive geological interpretation, skill, and time needed, as well as the operational risks associated with it, exploratory drilling is a very expensive and risky operation. Just three of every ten exploratory wells that are drilled worldwide, according to statistics, lead to the finding of a reservoir [11]. The fact that drilling is currently done underwater, whether in marshes, lakes or the sea, at depths greater than 3,200 meters, in addition to on land, must be mentioned.

Until the 1970s, the majority of oil wells were drilled using a method that involved drilling a straight line from the surface to the intended depth; the deeper the oil reservoir, the more control the drill bit's trajectory needed to maintain the hole's straightness. This process is referred to as vertical drilling, as shown below.

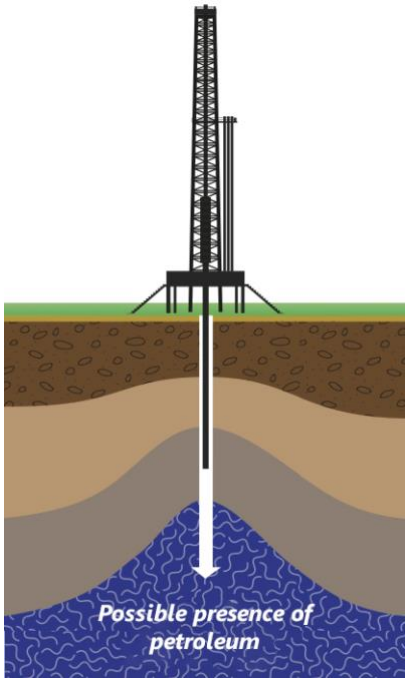

Figure 4. Illustration of a Vertical drilling. Adapted from [11]

However, due to the constant deviations in the progress of vertical drilling, associated with different geological and mechanical factors, the concept of drilling in a controlled manner while maintaining a desired degree of inclination, heading and lateral displacements towards a predetermined objective was developed. This innovative method has made it possible to access deposits kilometers away from the drilling site and to access hydrocarbon reservoirs just below the locations where it would be extremely challenging to set up a drilling platform, as well as underneath an environmentally sensitive, urbanized, or populated areas. [1]

Also, it is important to note that when a well is drilled in a geologically unexplored area, it is classified as "Well A3" and is called an "exploratory well". Subsequently, once oil is discovered or found, other wells are drilled around the exploratory well, called "Advanced A2", in order to delimit the true extent of the reservoir and to be able to adequately calculate the volume of hydrocarbons it may contain. As for drilling procedures in the marine subsoil, they are largely the same, except that drilling is done from huge platforms that float and remain stationary.

Once this process has been explained, it is important to make a brief explanation and description of the drilling equipment to obtain this substance. Based on the information published by the Colombian company Ecopetrol S.A., the main elements of a drilling rig will be explained:

- **Drilling tower:** Also called drill rig, it is a metallic structure in which the work of drilling the ground is mainly concentrated, generally between 800 and 6000 meters.

- **Drill pipe or "drill string":** steel conduit that joins with others as drilling progresses and that rotates on the axis of the drill and allows the liquid to be pumped through the drill bit and continue through the annular space.

- **Drill bit:** it is the one that drills the subsoil and allows the opening of the well.

- **Winch:** Unit that coils and uncoils the steel cable with which the drill string is lowered and raised.

- **Mud system:** Prepares, stores, pumps, injects, and continuously circulates a drilling mud inside the string to cool and lubricate the bit, support the walls of the borehole, and bring the rocky material being drilled to the surface.

- **Motors:** In charge of the driving force required by the entire drilling system.

- **Preventers:** a set of valves installed at the wellhead to prevent gas or oil from gushing out and endangering people, the environment and equipment.

1.4.3 Production

As the drilling process progresses, depending on the reservoir, it is determined what type of installation is necessary. The most popular technique is the "rocker arm" or "tap," which operates a pump at the bottom of the well that draws oil to the surface through constant rocking, if the well pressure is low. However, if the reservoir has its own energy, which is produced by the subway pressure and the substances that accompany the oil, it will emerge on its own. In this instance, the workers are in charge of constructing, in the top section of the well, an installation that has been called a "Christmas tree" in the dialect of oilmen. Basically, it consists of a set of combined valves, pipes and fittings that are controlled to regulate the pressure and flow of oil and gas.

The extracted oil, usually, is accompanied by sediments, water and natural gas, so it is necessary to previously build production, separation and storage facilities to bring the reserves into production, always using high safety and environmental standards. Also, it is important to mention that currently, at the time of extraction of this substance, the recovery factor is in a range between 15% to 50% and can reach up to 65% depending on the technology applied. However, it is important to clarify that it is never possible to obtain 100% of the oil available in a reservoir. As a result, "enhanced recovery" methods exist to maximize oil extraction in reservoirs without natural pressure or that have been producing for several years.

In the world we speak of primary recovery (natural energy), secondary recovery (such as water or gas injection) and tertiary recovery (on-site combustion, chemical or gas injection, among others), which require greater technologies as one moves from one to another [1]. However, it is expected that in the future we will be able to dedicate more exhaustive research on these techniques in order to carry out their respective analysis.

1.4.4 Transportation and Storage

Since oil wells are usually located in areas not close to the places of consumption, the transportation of crude oil becomes a fundamental aspect for the oil industry, in addition to requiring a significant investment in these networks.

The term "oil pipeline" will be utilized throughout this research, so it's critical to define it accurately. When we discuss oil pipelines, we refer to both the system of pipeline installations used to transport oil products as well as the infrastructure required to run the system, such as storage tanks, pumping stations, transmission network, connections and distributors, cleaning equipment, among others. [13]

After the hydrocarbons are extracted, they are moved through pipelines, above or below ground, to a facility on the surface where they will be kept in tanks for storage and subsequent import. As mentioned above, this method entails building a pipeline, where pumping stations are strategically placed to move the oil to the terminal station depending on the topography of the area.

The situation is different for offshore oil platforms. In this case, the crude is carried through oil tankers or submerged pipelines to the facilities for treatment, refining, or storage. Oil tankers are currently one of the main ways of transporting oil because they are considered the most cost-effective mode of transport for long distances, currently transporting more than one billion tons of crude oil per year worldwide.

The alleged carrying capacity of these so-called supertankers is approximately 500,000 tons, and it is said that around 250 million tons of crude oil can be carried aboard the tankers that are constantly cruising the seas and oceans of the planet, besides having a great flexibility of use, associated with the division of their interior space into individual tanks, which allows separating the different types of oil or its derivative products. [14]

Furthermore, it is important to keep in mind that certain nations depend heavily on oil imports, requiring the need for high-capacity pipelines, ports that can accommodate super tankers, in addition to outstanding, strong and effective transportation networks. However, self-supplying nations also require effective transportation networks because their most important oil fields are often thousands of kilometers away from centers of processing and consumption, as is the case in the United States, Saudi Arabia, Russia or Canada. [13]

Figure 5. Oil Pipe Line in Alaska. Taken from [13]

1.4.5 Refining

As the crude oil that comes out of the wells is practically useless, a treatment must be performed to extract the useful portion and to adapt its characteristics to the needs of society, in terms of finished products. This process is called refining. At first, it was believed that conducting the refining process close to the well would be the optimum course of action. After some time, it was proved that, because every country had different requirements, it was more profitable to refine it close to the major consumption centers.

Generally speaking, a refinery is a big facility where crude oil is put through several physical and chemical processes in order to extract a significant portion of the wide variety of components it contains. This industry has the ability to refine crude oil into more than 2,500 refined products, known as derivatives. These products include fuels (such as gasoline, diesel, kerosene, and fuel oils) as well as raw materials for the petrochemical industry (polyethylene, and cyclohexane, used in the manufacture of nylon, benzene and others).

The activities of oil refineries begin with the reception of crude oil for storage in the refinery, where the separation process begins with distillation. Using a physical operation in a cylinder more than 50 meters high (distillation tower) divided into different horizontal compartments, each of which has a different temperature, the crude oil preheated to temperatures as high as 400 degrees reaches the bottom of the tower as steam and rises through the compartments, where it is separated into its various components. Each vaporized component is collected by ducts attached to each compartment when it reaches its condensation temperature.

Subsequently, the compounds obtained are refined again in other process units such as conversion and treatment, where their molecular composition is modified and the derived products are stabilized and improved by separating them from the less desirable products and eliminating components that are harmful to health and the environment, in accordance with environmental standards. Thus, the desired products will be obtained in accordance with the technical and environmental requirements previously established and demanded by the market.

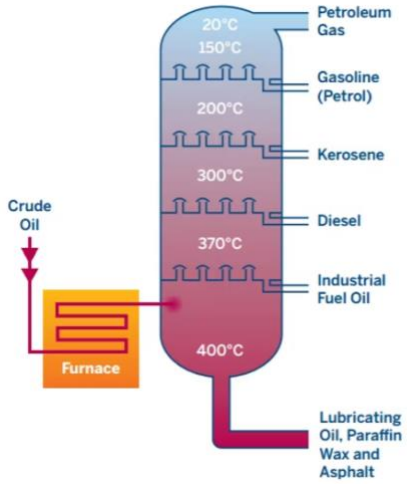

Figure 6. Refining process of crude oil. Adapted from [15]

1.5 Environmental Impact

As has been mentioned, oil is now a part of daily life in society since it provides energy and serves as the basis for the production of a wide range of goods for various industries. But so far, the extraction and management of oil results in serious environmental repercussions that have both immediate and long-term effects.

Currently, there are many factors that might lead to oil contamination, such as problems with the actual extraction process, problems caused by natural catastrophes, spills brought on by accidental errors, equipment and pipeline breakage caused by a lack of maintenance, etc. Nonetheless, in order to underline and properly study this issue, the most relevant effects will be covered.

1.5.1 Consequences on soils

When analyzing the impact of oil exploitation on soils, it is important to review the stages of the value chain of this product and delve a little deeper into the effects.

Starting with the seismic and drilling phase, in order to carry out the necessary studies, deforestation is carried out for the opening of the road and the construction of the required infrastructure, where up to 1000 km can be cut down, creating new access roads for colonization. In addition to the aforementioned deforestation and loss of biodiversity, there is also soil erosion, the generation of contaminating waste from cutting and drilling muds, and high noise pollution from the drilling platforms and the constant flow of vehicles and people in the area, which causes several animal species to flee, changes in their feeding and reproductive behavior, and even interference in the migratory routes of mammals, fish and birds.

Also, after the extraction process is finished, the crude oil is moved via pipes to a central infrastructure where it is treated before being moved to another central structure for export. Unfortunately, in addition to obstructing animal migration routes, these kinds of pipelines also contaminate the soils next to the flow lines, either by unintentional ruptures or regular leaks brought on by the pipeline's aging. In these situations, the solids and greases remain on the surface while the solvent components leak out, destroying the soil microorganisms and creating an overall ecological imbalance.

In general, the soil's microbiological, physical, and chemical properties are affected, the living organisms that are essential to the nutrient cycle are destroyed, fertility is lost, the fauna is impacted, the contamination of the soil with inorganic substances (sulfates and salts) and organic substances (especially hydrocarbons), and even effects that may have an impact on the local population's agricultural systems as well as the ecological balance of the area. [16]

Figure 7. Emergency in the Amazon due to terrible oil spill in 2019. Taken from [17]

1.5.2 Consequences on rivers and oceans

Currently, one of the most common cases associated with pollution in rivers and oceans is the oil spill. Oil spills can occur for a wide range of reasons, including accidents, corroded infrastructure, aging equipment, improper regular management that results in pipeline leaks, and, in severe cases, attacks against the infrastructure. It is important to note that the effects of oil spills might be stronger or less severe depending on the type of product transported, the size of the spill, the climatic conditions at the time and the surrounding ecosystems.

In the worst case, when the spilled substance enters a body of water, the heavier components have a tendency to sink into the sediments and, due to the difficulty of degradation, constantly contaminate the water body as well as the flora and fauna, with bottom-dwelling organisms being one of the most severely impacted. Moreover, the lighter substances that evaporate are a source of pollution that is spread through the air and deposited with rain, while those that remain on the surface form a thin film that blocks light from penetrating the lower strata, negatively affecting photosynthetic organisms, such as algae, and inevitably the entire food chain.

As far as the animal community is concerned, among the most vulnerable are all those species that feed by filtering the water, such as oysters; amphibians due to their sensitive cutaneous respiration mechanism; ecosystems that depend on algae and

plants; species that need to go to the surface of the water in order to breathe, such as turtles, dolphins and whales; Freshwater species, due to excessive salinity levels and the presence of other pollutants; birds, which when the substance impregnates their bodies, lose their thermal insulation capacity, find it difficult to fly and end up dying from hypothermia, or from ingestion when they try to clean themselves; and fish, which by force accumulate the contaminants in their fatty tissues and chronically poison communities that seek to supply themselves with the fish. Furthermore, morphological, coloring, and developmental changes frequently manifest later on in addition to changing fish communities. [18]

Figure 8. Pelican covered in oil due to the Deepwater Horizon Spill oil in the Gulf of Mexico 2010. Taken from Louisiana Governor's Office / Alamy Stock Photo

Figure 9. Deepwater Horizon Spill oil in the Gulf of Mexico 2010. Taken from Louisiana Governor's Office / Alamy Stock Photo

1.5.3 Consequences on the air

Before giving an overview of the negative impacts associated with oil and its production process, it is important to define the concept of the greenhouse effect. The greenhouse effect refers to the process whereby the heat radiation emitted by the surface of the planet is mainly absorbed by the greenhouse gasses present in the atmosphere, warming both the surface and the interior atmosphere.

Although the greenhouse effect is essential to life as it warms the planet, since the industrial revolution, man's influence on energy consumption and production systems has caused a steady increase in the emission of these gasses, raising their concentration in the atmosphere. As a result, more heat is trapped in the earth's atmosphere. Fundamentally, the burning of fossil fuels and the processes involved in their extraction are the main causes of global warming.

In this case, within the main causes of pollution associated with petroleum, the refining process takes on importance. Due to the plants' outdated technology and the refineries' proximity to populated areas, there is a latent danger of air pollution from these dangerous emissions. As was indicated in the previous section, in many oil fields, natural gas is also extracted in addition to crude oil. The same facilities either employ this gas as a source of energy, process it for later commercialization, or just flare it. However, the flaring associated with this natural gas has a negative impact by accelerating the global warming process and affecting biodiversity.

The main atmospheric emissions from gas flaring include carbon dioxide (CO2), methane, ethane, butane, propane, hydrogen, helium and argon, volatile aromatic hydrocarbons, nitrogen oxide, sulfur dioxide, ozone, carbon monoxide, halons and chlorofluorocarbons (CFCs).

Of all the greenhouse gasses, carbon dioxide is the biggest contributor to global warming and therefore public enemy number 1 when it comes to halting the climate crisis. However, compared to CO2, methane, the primary gaseous component of natural gas, ranks second. Since atmospheric methane has an 80 times greater ability to warm the world than carbon dioxide over a 20-year period, scientists estimate that it is now responsible for about 25% of global warming. [19]

Likewise, these gasses can become extremely toxic and have a significant negative impact on the local population and biodiversity. Among the different effects, there is a decrease in the insect population, since they are attracted by the luminosity

generated by burning gas every night and die incinerated by the heat. Also, the distribution pattern of populations of airborne microorganisms and birds that are directly affected by gas flaring are both affected. Even acid rains with a high hydrocarbon content are created in locations near refineries, which besides carrying carcinogenic substances, when they reach the soil, represent an important contamination to crops and other areas. [16]

Figure 10. Gas Flaring. Taken from iStock Photo

CHAPTER 2

2 INTERNATIONAL OIL MARKET

Oil is a non-renewable natural resource, considered the most important energy resource in the history of mankind, which provides the largest percentage of the total energy consumed in the world and has come to change the economic systems of the planet. As mentioned above, it is said that this substance was even used in the Bible and that it was an important resource in ancient times, in places such as the ancient Near East, Asian countries, ancient Greece, among others. However, it was in the present time, when thanks to different discoveries and technologies, it was possible to exploit this resource and open the way to what would be known today as the economic structure of the black gold market.

It is important to mention that in order to perform an accurate analysis, based on reliable statistics, it was used the Annual Statistical Bulletin released by OPEC[1] in 2022 (See attachment) as well as some data from the Observatory of Economic Complexity (OEC).

2.1 Supply Chain

Prior to discussing the global oil market, it is essential to understand the different processes used by the industries to subsequently carry out their proper commercialization. As is widely known, the various actors and phases comprise a crucial element within the set of activities, facilities, and distribution channels required to carry out the oil sales process. However, a general illustration of the oil supply chain will be provided since the composition and operation of this set of processes may be subject to distinct variances depending on the Country.

[1] OPEC currently comprises 14 countries: Saudi Arabia, Kuwait, Iran, Iraq, Venezuela, Algeria, Angola, Ecuador, Libya, Nigeria, Qatar, Gabon, Indonesia and the United Arab Emirates.

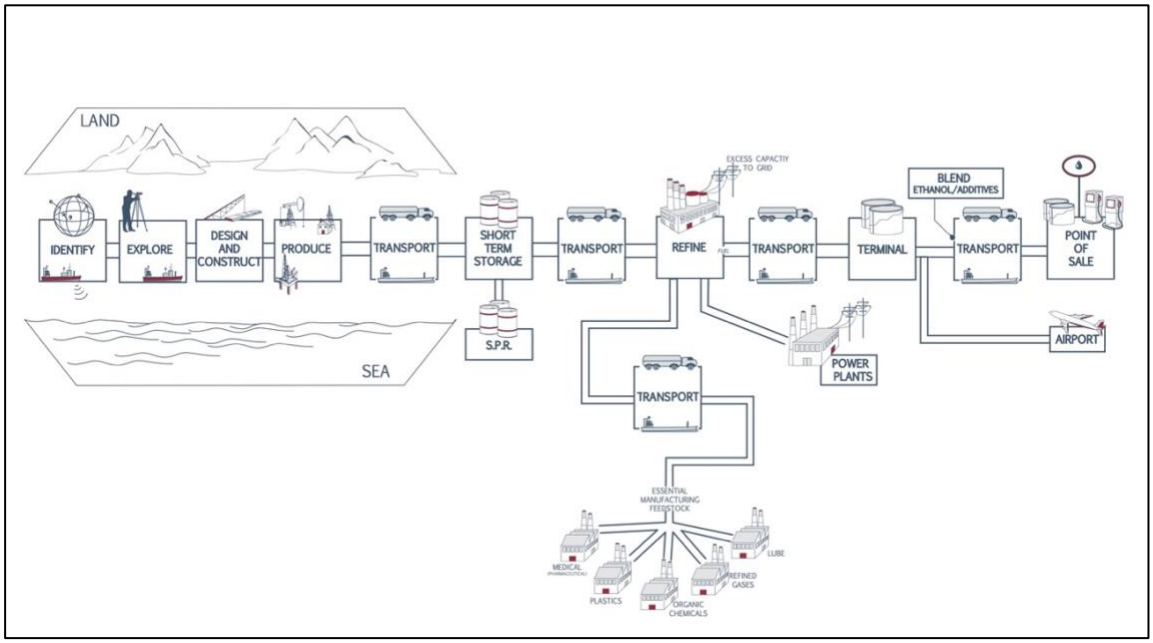

Figure 11. Oil supply chain. Adapted from [20]

The process starts with petroleum geologists examining the surface rocks and topography using satellite pictures, gravimeters, magnetometers, or seismology in an effort to find a signal informing them of the presence of oil. The exploration phase, a high-risk investment phase when risk assessment is crucial for success, then begins once the prospecting has been identified and assessed by an oil business. Here, a drilling well is used to clearly verify the presence of a source rock, a trap, a cap rock, or a reservoir from which oil can be extracted. Then, despite some variance, the goal of the design and construction phase is to ensure a perfect production of hydrocarbons while adhering to and preserving the requirements of safety and environmental regulations through the proper execution of the infrastructure.

After oil production is finished, it is transported to a facility for short-term storage, where its primary purpose is to act as a staging location for the distribution of crude oil and to adjust supply and demand along the remaining supply chain. There are times when an emergency supply of crude oil is kept in a strategic petroleum reserve (SPR), such as in the United States, to help with supply issues.

Following the storage facility, the crude oil is transported by trains, trucks, ships, or pipelines to the refineries, where it is turned through various chemical processes, such as distillation, into a variety of products that are used in a wide range of industries.

Both raw materials and finished goods are included among these products. In the first scenario, raw materials are shipped to manufacturing facilities where they serve as the basis of numerous supply chains, including those for lubricants, polymers, and various medical equipment. In the second scenario, the completed product is delivered to terminals where ethanol and other components are added before the fuel is delivered to the point of sale, where it will be spread across the nation by trucks, ships, and delivery lines.

It is also necessary to mention that within the global market, some industries decide to specialize in one segment of the supply chain, while others, given the high entry costs related to many of the operations of the oil industry, decide to appropriate the concept of vertical integration, where they basically have a presence in all phases of the oil activity, from exploration, production and refining, to the commercialization of oil derivatives, as is the case of many of the largest oil companies in the world, such as Chevron. Chevron Corporation, the second largest integrated energy company headquartered in the United States, produces crude oil, natural gas and other essential products through its subsidiaries and affiliates, with a combined capacity to process more than 1.0 million barrels of oil per day through its five U.S. refineries. [21]

2.2 Reserves

As mentioned above, oil is one of those commodities that can renew naturally, but not as quickly as human demands. For this reason, and because it is present in nature in limited quantities, it makes it a highly demanded product and gives certain economic advantages to countries whose lands are blessed with soils rich in oil reserves. (It is worth mentioning that having high oil reserves is not synonymous with a good national economy).

According to the Annual Statistical Bulletin released by OPEC in 2022, there are about 1,545 billion barrels of crude oil in the world, where the largest number of reserves are in the Middle East with 55%, headed by the Republic of Iran; about 22% in Latin America, where Venezuela contributes approximately 92% of the total; 7.8% in the African continent and 5.2% in Russia. However, assuming that the current production rate of 97 million barrels per day remains constant, it could be said that there would be oil for 47 years.

Table 2. Percentage Of Proven Crude Oil Reserves

	Percentage Crude Oil Reserves
Middle East	56.3%
Latin America	21.3%
Africa	7.8%
Russia	5.2%
OECD[2] Americas	3.2%
Other Eurasia	2.5%
China	1.7%
Other Asia	0.8%
OECD Europe	0.7%
India	0.2%
OECD Asia and Pacific	0.1%
Other Europe	0.1%

It is important to note that the limit of reserves could be closer than we think, as factors such as population growth and new technologies have a direct impact, even when taking into account various forecasting models based on the rising consumption in recent decades, and that the majority of the major global reserves have started to decline, with the Middle East's reserves being the only ones to continue to grow steadily.

From the 1960s to the most recent records associated with 2021, according to OPEC data and as shown in Figure 12, an exponential increase is observed where oilfield discoveries have multiplied by about five, where the Middle East has always been dominant, with significant growth in Latin America as well as in Asia and the Pacific; and a low variation in the behavior of the other countries or continents under study.

Likewise, from the analysis by country shown in Figure 13, it can be noted that Venezuela is the country that currently has the most oil reserves in the world, followed by the Middle Eastern countries (Saudi Arabia, Iran, Iraq, United Arab Emirates and Kuwait), which account for 20% and 54% of total world reserves, respectively.

[2] The Organization of Economic Cooperation and Development (OECD) consists of the United States, much of Europe, and other industrialized countries. (38 countries)

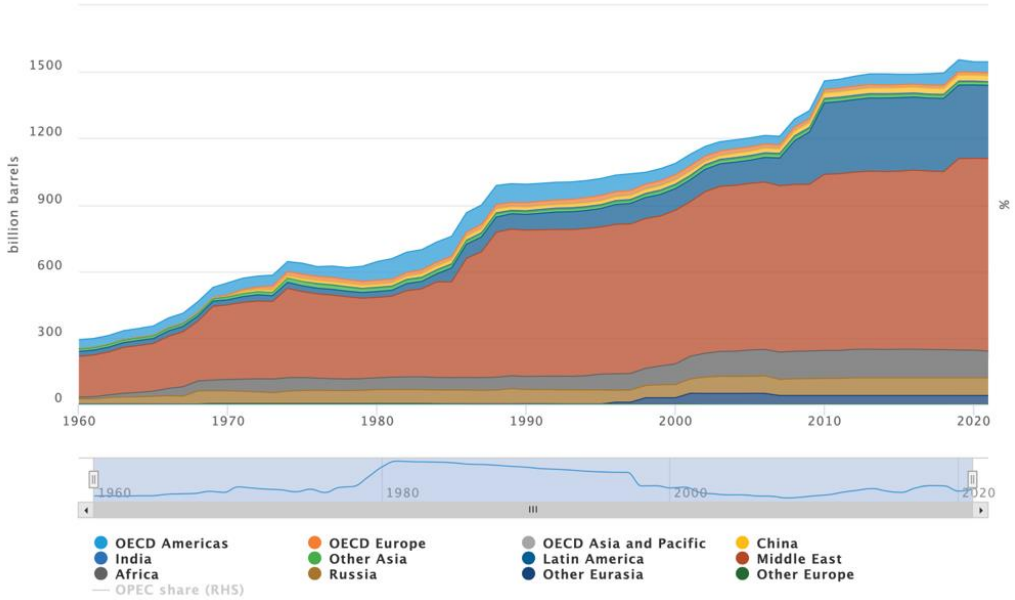

Figure 12. World Proven crude oil reserves. Taken from [22]

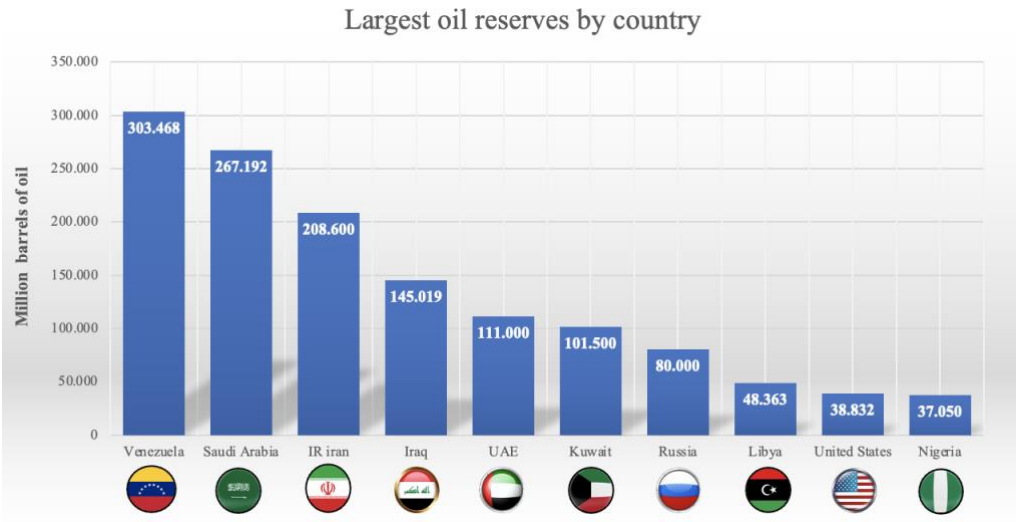

Figure 13. Top 10 countries with the largest oil reserves in 2021.

Although it is common that countries with greater reserves are associated with greater production capacity, it is necessary to clarify that this is not always a sign of wealth. One of the clearest examples is Venezuela, which, as was already said, is currently in

first place but is experiencing a severe economic crisis that has led up to 3.4 million Venezuelans to abandon their nation, according to the United Nations data. In this case, variables such as the weight of the oil are decisive, since the extraction process is more difficult and costly because it requires solvents to make it circulate, added to the economic sanctions of the United States that hardened the possibility of commercializing crude oil and reduced the buyers' network.

Another clear example is the case of Canada, which according to many information sources is in fourth place among the countries with the largest oil reserves in the world, however, the OPEC excluded oil sands from the database, since they are a combination of clay, sand, water and bitumen. For this reason, although Canada is a country with large oil sands reserves, the cost of extraction is relatively high due to the heavy nature of its crude oil. It is said that from 171 billion barrels of Canada's proven oil reserves, 97% corresponds to oil sands.

Generally speaking, the profitability and choice to produce black gold are directly influenced by the ease with which the oil extraction process is carried out, the nation's trade and foreign relations, as well as the policies associated with the regulations and measures that allow the state to obtain tax revenues.

2.3 Production

Oil production, as previously established, is the function of the industry in charge of the operations required to bring natural hydrocarbons to the surface, either by exploiting the natural energy of the reservoir or by alternative extraction methods. It should be emphasized that this activity includes the procedures involved in the extraction, managing, and treatment of hydrocarbons that will then be transported to storage facilities.

According to the Annual Statistical Bulletin , 69.6 million barrels per day are currently produced, with the United States, Russia and Saudi Arabia producing 16.1%, 13.8%, and 13.1% of the total global production, respectively, despite not having the greatest reserves.

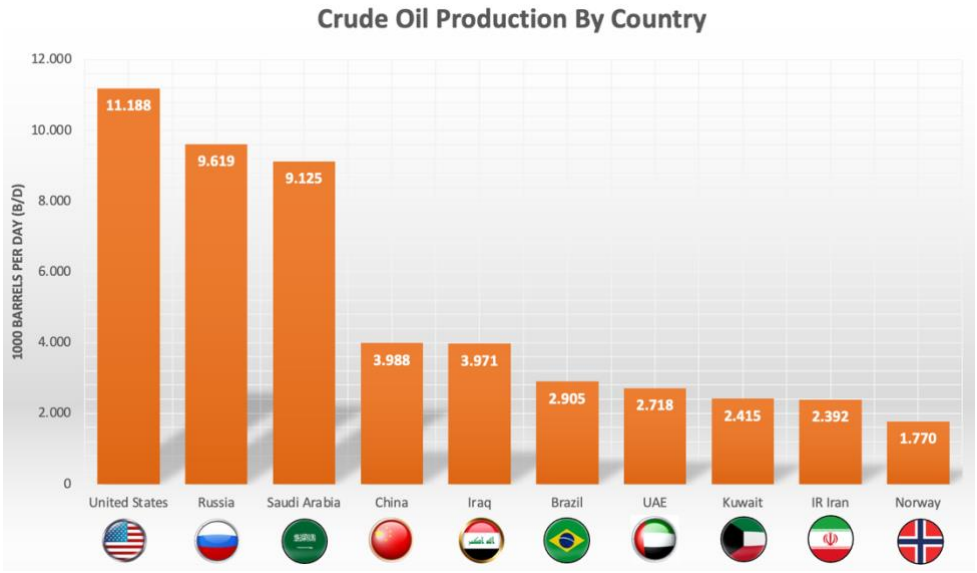

Figure 14. Top 10 countries with the largest crude oil production in 2021.

As regards the United States, more than 33,000 oil fields have been discovered, but only two supergiant oil fields —Prudhoe Bay in the North Slope region of Alaska and East Texas — account for the majority of these. With more than 800 operational oil wells, Prudhoe Bay is still the largest oil field in North America and remains among the twenty largest oil fields ever discovered globally after more than 40 years of production. [23] It's vital to note that at the start of the twenty-first century, innovations in the recovery of unconventional oil prompted production to rise, and in 2015, it was recognized as the world's top oil producer.

Russia, on the other hand, is the nation with the highest potential for new discoveries despite the two enormous oil reserves of Samotlor and Romashkino, discovered in 1964 and 1949, respectively. These two fields are among the largest sedimentary basins from which Russian oil is extracted [24]. Samotlor has been the largest oil field in Russia and one of the greatest in the world for decades since its oil potential was discovered in 18 productive reservoirs connected to the Jurassic and Cretaceous systems, located at depths between 1,600 and 2,500 meters. Although production from these fields is declining, production from new fields keeps overall Russian oil production stable.

Saudi Arabia, in addition to possessing the second largest confirmed oil reserves in the world, thanks to the discovery of the Al-Ghawar and Saffniyyah fields in the

Persian Gulf, in 1948 and 1951, respectively, managed to rise to the position of major oil producer. The former has established itself as the largest in the world since it began production in 1951, producing about 55 billion barrels after 60 years of operation. If water injection[3] is taken into account, according to the relevant authorities, this field contains recoverable reserves of more than 120 billion barrels. In a similar vein, the latter has a production capacity of more than 1.2 million barrels per day and has been ranked as the third-largest offshore oil field in the world. [24]

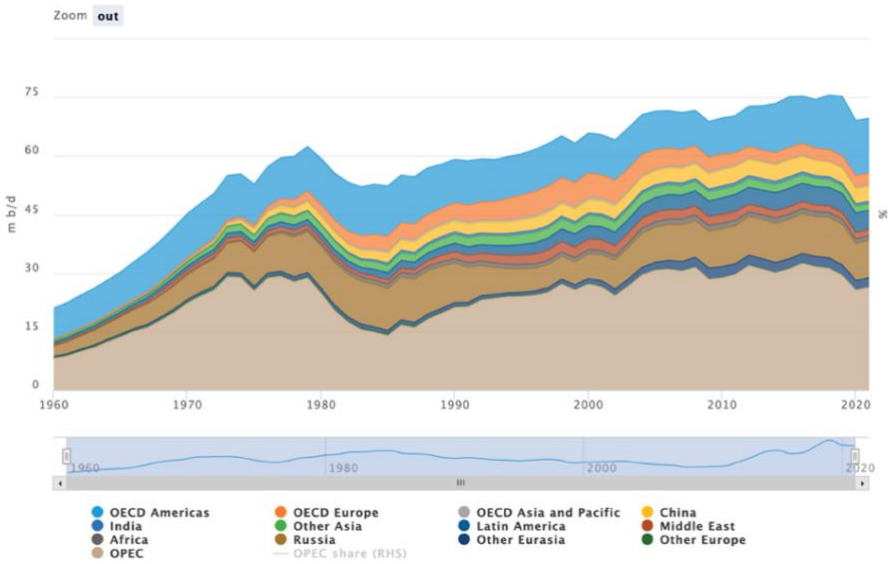

Figure 15 .World crude oil production. Taken from [22]

As can be seen in Figure 15 and as mentioned above, the largest oil production is attributed to OPEC member countries and OECD member countries in the Americas (Canada, Chile, Mexico, United States), with approximately 38% and 20% of total world production. Similarly, there has been significant growth in Russia, China and Latin America over this period of time.

2.4 Refining Capacity

Another important aspect to analyze, in addition to production, is refining capacity. Refining capacity is essentially the amount of crude oil that refineries are able to process in a single day. Recall that refining is the process by which crude oil and other

[3] (i.e., the injection of water that drives oil out of the reservoir)

raw materials are turned into products of greater quality and added value for their commercialization through various physical and chemical processes. Similar to oil production, North America, Europe, and Asia have the world's highest capacities for refining.

According to OPEC, in 2021, there are currently 680 refineries worldwide with a combined refining capacity of roughly 102 million barrels per day. As can be seen in Figure 16, among the countries with the largest refining capacity, the United States and China contributed close to 34% of total world capacity.

With close to 17.5% of the total world capacity and 130 oil refineries operating as of January 1, 2022, the United States is the nation with the most petrochemical complexes and the highest refining capacity. China, with 32 oil refineries, with a capacity very close to that of the U.S. at 16.2%, is in second place. Only slightly behind China, Russia and India, contributing approximately 7% and 5% of the total, are striving to increase their oil refining capacity to meet the country's growing demand for oil. Also, in comparison to world oil production, in addition to India, Figure 16 shows the entry of new countries such as South Korea and Japan, which, as we will see later, have a significant share in world oil consumption.

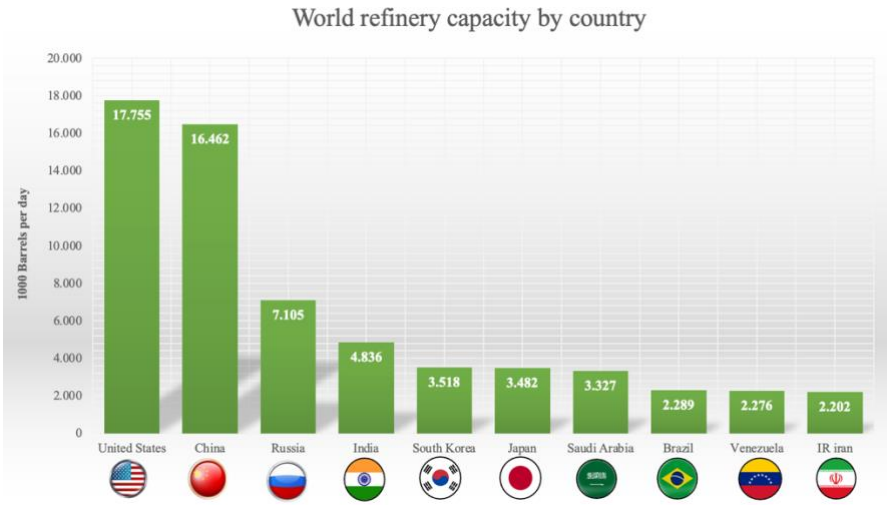

Figure 16. Top 10 countries with the highest refinery capacity

Although the United States is the country with the largest refining capacity, when it comes to refining size and capacity, Asia is the continent with the greatest number of

refineries in the top ten largest oil refineries in the world. The concentration of nearly 60% of the world's population on the Asian continent is certainly the explanation for this high degree of concentration of refining activity. Six of the ten largest refineries in the ranking are in Asia (As table 3 shows), with the largest, the Jamnagar industrial complex, having a refining capacity of 1.24 million barrels per day. Similarly, the other four are in the Americas, with three in the United States and one in Venezuela, where the Paraguana refinery complex, with 971,000 barrels per day, and the manufacturing unit at the Port Arthur refinery, with 630,000 barrels per day, stand out.

Table 3. World Biggest Oil Refineries

Top	Refinery	Location	Capacity (Barrels / Day)
1	Jamnagar (Reliance Industries)	Gujarat, India	1,240,000
2	Paraguana (PDVSA)	Falcón, Venezuela	971,000
3	Ruwais (Abu Dhabi National Oil Company)	Ruwais, UAE	922,000
4	SK Energy Ulsan (SK Energy)	Ulsan, South Korea	840,000
5	Yeosu (GS Caltex)	Yeosu, South Korea	800,000
6	Onsan (S-Oil)	Ulsan, South Korea	669,000
7	Port Arthur (Saudi Aramco)	Texas, United States	630,000
8	Garyville (Marathon Petroleum)	Louisiana, United States	596,000
9	Galveston Bay (Marathon Petroleum)	Texas, United States	593,000
10	Jurong Island (ExxonMobil)	Jurong Island, Singapore	592,000

It is vital to note that the capacity data was gathered from the websites of each of the corporations that own the aforementioned refineries in order to have a more recent analysis.

2.5 Demand

As has been highlighted throughout this research, crude oil is unquestionably the most significant natural resource for industrialized nations, since many of the components and goods that are used today are derived from this non-renewable resource. In fact, one of the most frequently asked issues concerning oil is whether or not humans could live without it. The world would almost come to a standstill if oil were to run out at

this point. Automatically, companies would cease operations, various means of transportation would become immobile, residences would be hit by winter, and even many of the items we use on a daily basis, such as fertilizer, medical supplies, cosmetics, etc., would experience difficulties with production. Basically, the usage of oil contributes significantly to human welfare and is one of the main drivers of economic development.

Over the years, as technology has advanced, the use of this resource has become stronger and more indispensable. Using 1960 as a baseline, global oil demand increased from 20 to roughly 100 million barrels per day in 2021. However, a pattern that has remained constant over time is the predominance of consumption in the OECD countries of America and Europe.

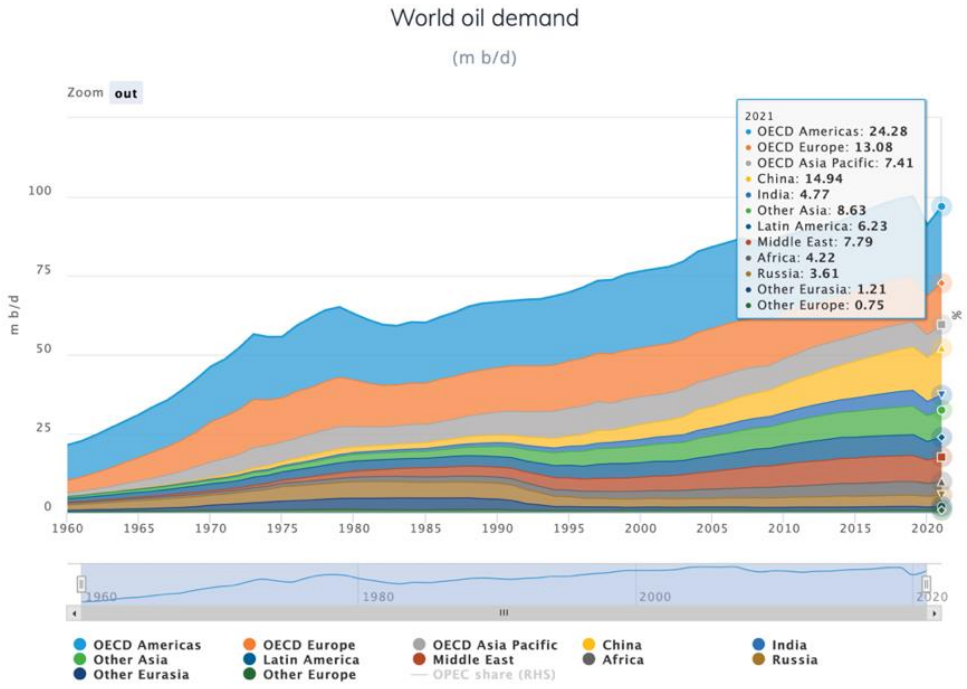

Figure 17. World oil demand in 1960-2021. Taken from [22]

In further detail, according to the OPEC bulletin, about 97 million barrels per day are consumed in the world, where about 62% of the total consumed corresponds to the 10 main countries illustrated in Figure 18; where the ones attributed the highest consumption of this substance are the United States and China with 20.6% and 15.4% of total world consumption, respectively.

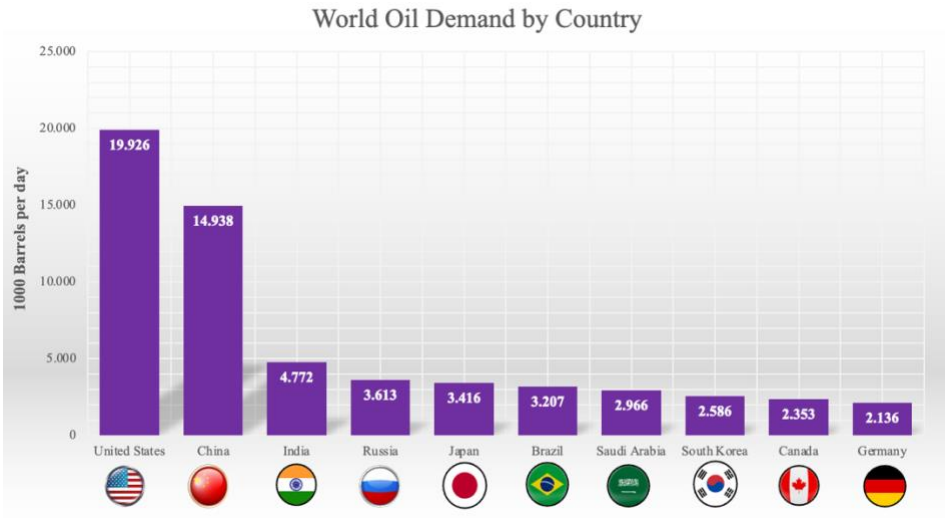

Figure 18. Top 10 countries with the highest oil consumption in 2021.

According to the U.S. Energy Information Administration [25], in 2022, in the United States, 66.6% of the total oil consumed was related to transportation, 27.5% to industry and the remaining related to residential, commercial and electric energy uses. Here, motor gasoline accounted for 43% of total consumption, distillate fuel oil (which includes heating oil and diesel fuel) for 20%, hydrocarbon gas liquids (such as propane, ethane, and butane) for 18%, and jet fuel for 8%. Remember that the U.S. economy is the largest in the world in terms of GDP, the most technologically advanced, and the top industrial manufacturer in the world.

On the Chinese side, diesel and gasoline were the most consumed goods, accounting for nearly fifty percent (50%) of total petroleum consumption. Let us not forget that it is the world's second-largest economy in terms of GDP, has a growing demand in the transportation sector with more than 250 million cars, is unquestionably the world's manufacturing center for all types of products, and is the world's largest industrial and merchandise exporter.

Also, when analyzing the causes of the high demand for oil in these nations, it's critical to keep in mind that these are nations that depend heavily on oil for their economies to work properly. It is crucial to note right away that the three nations with the highest oil consumption rates are also among the three with the highest populations. For this reason, and others associated with consumerism, these countries produce all kinds of materials for international trade and need the necessary energy to carry out their production.

2.6 Exports

As noted above, because of its range of uses and the steady rise in consumption by nations, the activity of buying or selling this service internationally plays an enormously significant role. In fact, according to the Observatory of Economic Complexity (OEC), a website that allows the visualization of international trade data, in 2021, within the top 5 of the most traded products worldwide, the number one position is held by crude oil ($951 billion / 41,227,000 b/d) and the number three position by refined oil ($746 billion / 29,370,000 b/d).

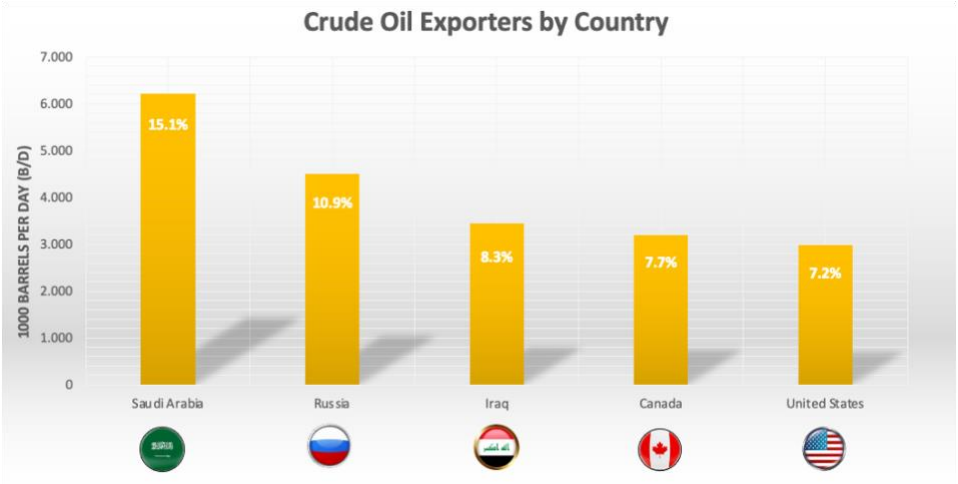

Figure 19. Top 10 Crude Oil Exporters.

According to the OEC, the number one exporter of ***crude oil*** in the world in 2021, Saudi Arabia, exported 6,23 million barrels per day, with the top five export destinations being China, Japan, South Korea, India, and the United States. In a similar vein, Russia sent 4.5 million barrels per day, ranking second in the world, with its primary markets being China, the Netherlands, Germany, Belarus, and South Korea. Followed by Iraq with 3.4, Canada with 3.2 and the United States with 2,98 million barrels per day.

Taking into account the above and according to data from the Organization of Petroleum Exporting Countries, in the world oil market, out of 195 countries, 10 export approximately 70% of the world's crude oil and if 25 are considered, 95% of the total crude oil exports of the planet are reached.

Among the top 25 we find the following:

- United Kingdom.
- Europe: Norway.
- Oceania: Australia.
- North America: Canada and United States.
- Eurasia: Azerbaijan, Kazakhstan and Russia.
- Africa: Algeria, Angola, Congo, Libya and Nigeria.
- Latin America: Brazil, Colombia, Ecuador, Mexico and Venezuela.
- Middle East: Iraq, Iran, Kuwait, Oman, Qatar, Saudi Arabia and United Arab Emirates.

Likewise, if we perform an analysis by zones, we can say that the countries of the Middle East are the ones with the highest level of oil crude exports worldwide, without forgetting that this area has the largest amount of oil reserves and has a significant share in world production. Followed by the countries belonging to the OECD of America (United States, Canada and Mexico), and Asia and the Pacific, where the largest percentage is contributed by Australia. On the other hand, looking at it in general terms, the 14 OPEC countries account for about 48% of total world crude oil exports and also play an important role in the import process.

On the other hand, analyzing the statistics related to ***refined oil***, provided by the OPEC, in 2021, the largest exporters of refined oil were the United States (5.65 million), Russia (2.38 million b/d), the Netherlands (2,26 million b/d), Singapore (1,43 million b/d) and Saudi Arabia (1,34 million b/d).

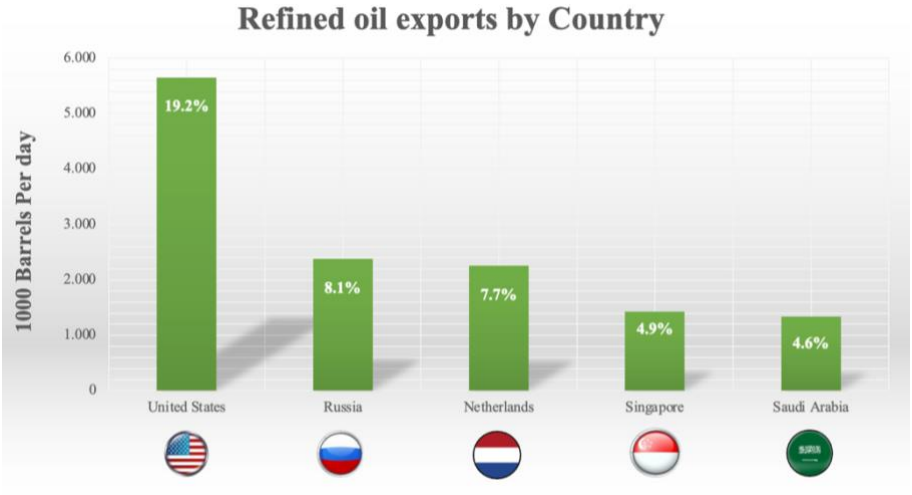

Figure 20. Top 5 countries with the highest refined oil exports in 2021

Partially, it was anticipated that the United States and Russia would be at the top of the list because, as was mentioned in earlier sections, they are among the ten nations with the largest oil reserves, the largest producers, the five largest consumers, and three of the nations with the most capacity for refining. In the United States, refined oil was the most exported good, with Mexico, Canada, Brazil, Chile, and Peru being the main destinations, while in Russia, refined oil was the second most exported good, with Netherlands, the United States, France, China, and Turkey being the main destinations.

One of the most notable nations on the list is the Singapore and the Netherlands, because it hardly stands out in the categories examined above. Singapore has developed into a significant energy trading and refining center in Asia thanks to its strong intercontinental business connections and strategic location at the confluence of the Indian and Pacific Oceans. On the other side, Netherlands with a vast network of ports, storage facilities, and pipeline connections, they nevertheless play a significant role as a major oil refining center in Europe and are essential to the supply and circulation of oil to the continent. Basically, the Neanderthal countries' success is due to the fact that regional suppliers send huge amounts of crude oil and petroleum products to the nation, where they will be exported to neighboring countries, taking advantage of the country's port and storage infrastructure. It is even said that currently, the volume of oil in transit is more than four times higher than the demand required by the country. [26]

2.7 Imports

On the other hand, as stated in the preceding sections on consumption and exports and being in line with the research done, the world's greatest importer of ***crude oil*** is anticipated to be a country from the Asian continent. In fact, the OEC reports that in 2021, China, an East Asian nation, topped the world in imports with about 10.3 million barrels per day translated into 208 billion dollars, mostly sourcing its goods from Saudi Arabia, Russia, Iraq, Oman, and Angola.

Similarly, as can be seen in Figure 21, the United States, which imported 6.1 million barrels per day ($120 billion in crude oil), or about 14% of all imports worldwide, was the second largest importer of this product, relying on Canada, Saudi Arabia, Mexico, Russia and Colombia as the main sources of supply. Only after the United States, we find India (4.2 million b/d), South Korea (2.6 million b/d) and Japan (2.49 million b/d).

Overall, it can be claimed that throughout the study period, crude oil was the most traded product in the world, with a total trading volume of 951,000 million USD and daily average export and import volumes of 41.2 and 42.7 million barrels of oil, respectively.

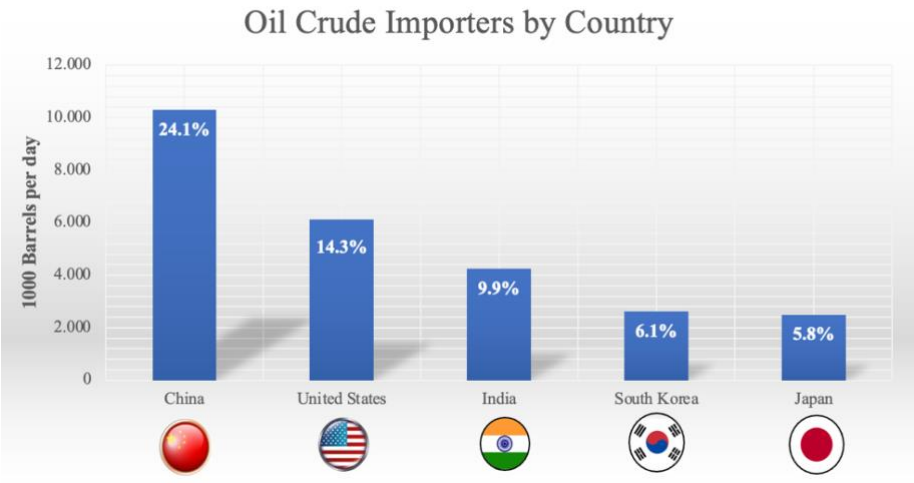

Figure 21.Top 5 countries with the highest Oil Crude Imports.

On the other hand, analyzing the statistics related to ***refined oil***, provided by the OEC, in 2021, were imported 27.8 million barrels per day, where the largest importers were the United States ($62.8B), Singapore ($50B), the Netherlands ($40B), Mexico ($27.3B) and South Korea ($24.3B).

Refined petroleum was the seventh most imported good in the US, where its main suppliers were Canada, South Korea, the Netherlands, and India. In Singapore, it was the second most imported good, with Malaysia, China, India, South Korea, and the United Arab Emirates serving as its primary suppliers.

On the other hand, the Latin American country, Mexico, stands out from the list because even though it produces most of the oil that is ideal for refining gasoline and diesel, the current economic situation makes it difficult for governments to make a decision regarding gasoline imports. Although refining locally rather than selling it is more attractive due to low international crude oil prices, the country's infrastructure blocks it from achieving high quality standards, and the region faces intense competition as a result of US production, which prompts the decision to keep importing. Nearly 90% of the refined oil that Mexico consumes is imported, and since

the United States has the largest refining capacity in the world, almost all of it comes from there. [27]

2.8 Price

Mentioned all of the above, the only section that remains to be covered is the price. Therefore, in order to reach a correct understanding, it is important to start with a general overview of the history of this pricing system.

We must know that a new chapter in the development of oil prices would begin between 1986 and 1988 as a result of many oil exporters implementing the market-related pricing structure. Basically, it signaled the change from a system where prices were originally regulated by the big multinational oil firms in the 1950s and 1960s and subsequently by OPEC between 1973 and 1988, to a system in which prices would be set by markets. [28]

The fact that oil is traded on the spot market or through long-term contracts must be mentioned. In the former, big cargoes or packages are traded in a single transaction for short-term delivery. Although this type of market accounts for a relatively small portion of the total transactions, it is crucial in determining pricing for the majority of the other transactions. [29] The latter refers to a contract in which the delivery of a certain amount of oil cargo over a specified period of time is determined by bilateral negotiations between buyers and sellers, where both the volumes of crude oil and the price have previously been established. In this situation, the contract requires both parties to carry out their respective obligations by the specified date.

2.8.1 Oil Price/Quality Relationship

Oil is currently known for its price volatility, which is heavily influenced by international relations, commercial interests, reliance on global demand for crude oil, economic factors, and political issues. However, in addition to the potential impact that these kinds of agents may have, oil quality has historically had an impact on price.

Since crude oil is primarily traded for the consumer-demanded final oil products, and because crude oil is not regarded as a homogeneous commodity, meaning that it has a variety of qualities and characteristics that enable the existence of various types of crude oil, the yield associated with refining will be directly impacted, which will lead to variations in the prices of each type of oil traded internationally. The two most

significant characteristics of crude oils are density and sulfur concentration, which will be used to categorize them as light or heavy and sour or sweet.

As was noted in the section concerning product features, light crudes are those whose density is low, the refining process is simple, and those that represent a greater proportion of the raw materials for the most valuable petroleum products, such as gasoline. On the other hand, heavy crudes have a low proportion of light hydrocarbons, require more refinement and upgrading, and have a higher production cost than light crudes. Similarly, sulfur is another component that has a significant impact on oil quality because it is an undesirable property that refineries must make considerable investments to remove.

Generally speaking, the differences in production costs and processing costs incurred to attain the standards of quality required for the crude oil to be traded worldwide are the key points of attention. As the oil's quality declines, more energy is required to transform it into goods with a higher market value. In this way, Crude oils that are light and sweet typically are more demanded and require less production cost than those that are heavy and sour.

2.8.2 Oil Pricing System

Due to the broad range of crude oils presented above, the price of a certain crude oil must be established as a benchmark for oil buyers and sellers in order to develop a price structure that encourages and ensures the producer's competitiveness versus its competitors in the destination zone. Currently, among the main reference points, the following stand out: the West Texas Intermediate ("WTI") for the American market; the Brent Blend for the European and occasionally African markets; and the DME Oman crude oil for the Asian and Pacific markets. [30]

***Table 4 characteristics of the main benchmarks. Adapted from** [30]*

Benchmark	Reference Zone	API	Sulfur %
WTI	US	39.6	0.24
Brent Blend	EU	38.3	0.37
DME Oman	Asia - Pacific	34	2.00

After mentioning this, it is possible to provide the formula used to set the price of oil in long-term contracts. The pricing formula can be stated as follows for crude oil of variety x:

$$P_x = P_R \pm D$$

where P_X is the price of crude oil x; P_R is the price of reference crude oil; and D is the value of the price differential. Regarding the reference price, because each transaction is distinct and depends on the time and place of its execution, and because the market does not directly provide a continuous price relationship that can be taken as a reference, the presence of information agencies like Platts and Argus is necessary. These agencies, through methodologies based on independent evaluations, determine the price relationships that will later be used as benchmarks. It is crucial to note that these organizations use various approaches when evaluating prices, therefore they do not always produce the same price for the same benchmarks.

This main Benchmarks (WTI, Brent, DME Oman), being a fundamental factor for this oil pricing system, are used by oil companies and traders to fix the price of cargoes under different contracts (long term or spot market); by future exchange markets and banks for the settlement of financial contracts and derivative instruments like swap contracts, respectively; and by governments for fiscal purposes. [28]

Regarding the price differential, it is set independently from a reference value by each of the oil-producing nations, and is often agreed upon at the time of finalizing the contract. It is regarded as any factor that might have an impact on the final selling price regardless of the benchmark price. It should be mentioned that because for many countries it is usually set in the month prior to the month of loading, the differential is established and made public in that month using the gross product worth (GPW) data and information that is currently accessible. Because of this, the price difference typically does not represent market circumstances at the time the cargo is loaded, and even less so by the time the cargo reaches its destination. [28]

Even more, oil exporters might have different pricing policies for different regions, which would add the cost of transportation as another component of the model given above. When determining the price of oil, some formulas take into account the possibility that freight costs may vary based on the export destination. Generally speaking, they comprise the difference between the transportation costs of the reference crude oil and crude oil x from its location to a given destination.

It's also crucial to note that while determining the differential, an exporting country must also take into account how its closest competitors are setting the differential in addition to the difference between its crude oil and the reference crude oil. In this way, globally, the competition among the exporters of crude oil of similar quality and with

the same destination has a tendency to negotiate with extremely small differentials. It is also important to highlight that the degree of competition among the many alternative sources of supply, as well as the factors connected to demand and supply between markets, directly influence the variability of the price differential.

The Middle Eastern nation of Saudi Arabia will be used as an example to further clarify what was previously stated. Within the U.S. market, this country faces a competition where the high competition and the large number of suppliers, including national ones, force it to establish a competitive price at destination, while within the Asian market there is a limited degree of competition and a high growth in demand, so it can lead to an "Asian premium[4] ". Because of this, even though it takes longer for the cargo to arrive in the United States, the price of a shipment delivered to the North American country may be lower than the FOB [5] Price in Asia.

2.8.3 Oil Prices Behavior

After providing a brief overview of the entire process that drives the price of oil, a table of the different prices associated with the annual average of the 1st, 6th and 12th month forward[6] ($) of the three main benchmarks within the period from 2017 to 2021 is presented, based on the annual statistical bulletin released by OPEC in 2022. As well as line charts for Brent and WTI benchmarks generated from the statistics site Trading Economics, with the aim of evaluating and determining striking behaviors in the price, in the period from 2018 to 2023.

[4] The term "Asian premium" refers to the high effective price that Asian nations like India and China pay to import crude oil from OPEC nations like Saudi Arabia and Iran.

[5] Is the price of goods at the frontier of the exporting country. Including, Value of the product at a basic price, transportation and distribution, taxes, etc.

[6] In a forward contract, two parties agree to acquire or sell an item at a fixed price at a future date.

Table 5. Annual average oil prices. Adapted from [22]

BENCHMARKS	Forward Month	2017	2018	2019	2020	2021
ICE Brent ($/b)	*1st*	54.74	71.69	64.16	42.31	70.95
	6th	55.08	70.66	62.32	45.15	68.26
	12th	54.88	68.94	61.19	46.2	65.88
NYMEX WTI ($/b)	*1st*	50.85	64.9	57.04	39.34	68.11
	6th	51.95	63.59	56.8	41.86	65.62
	12th	51.88	61.81	55.47	42.71	62.72
DME Oman ($/b)	*1st*	53.24	69.88	63.99	43.03	69.5
	6th	53.47	68.25	60.93	44.52	66.59
	12th	53.3	66.51	59.68	45.54	64.2

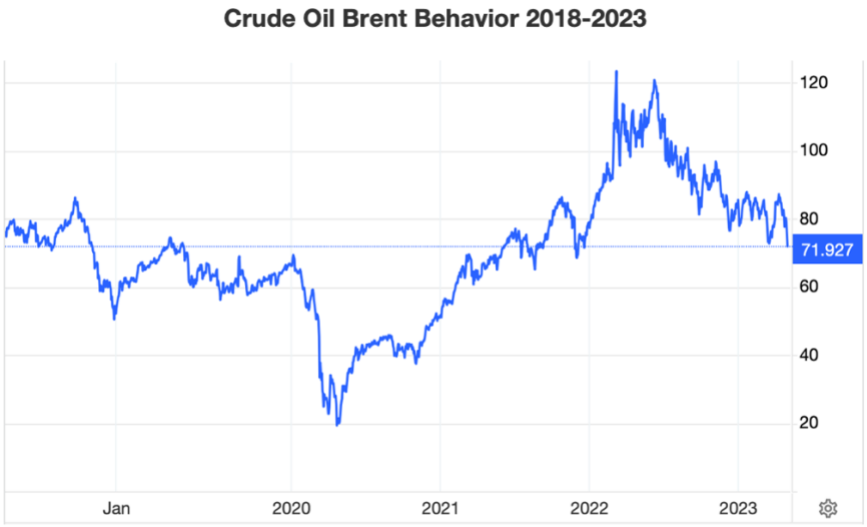

Figure 22. 2018-2023 Oil Brent Price Line Chart. Adapted from [31]

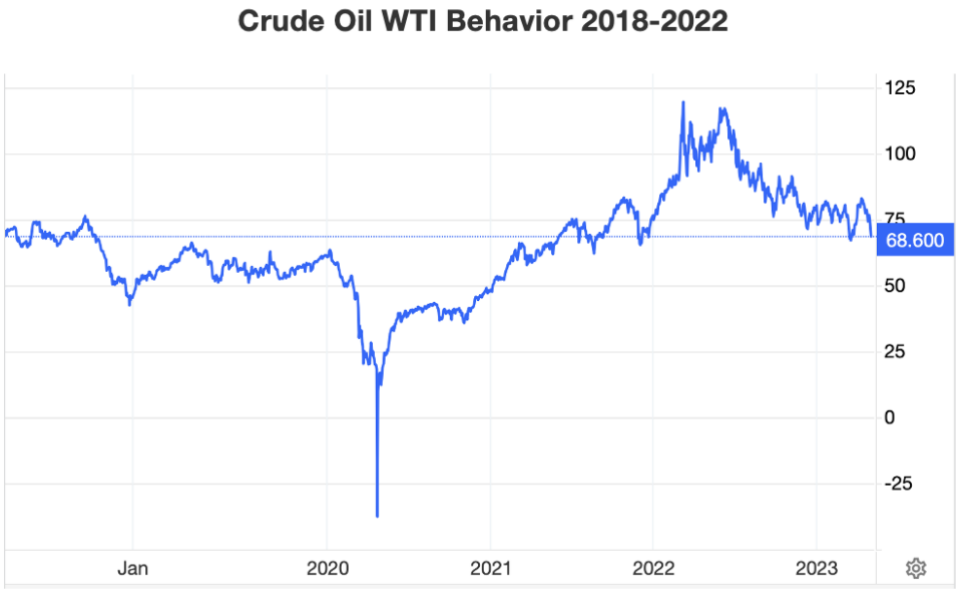

***Figure 23. 2018-2023 Crude Oil WTI Price Line Chart. Adapted from** [32]*

Beginning with what is presented in Table 6, in general, a rising pattern is noted between years, with ICE Brent and DME Oman prices increasing by more than 20% on average throughout the period 2017-2018, and NYMEX WTI prices increasing by nearly 19%. Following that, a sharp drop in price is observed during the 2018-2020 period, primarily due to the COVID-19 pandemic, with NYMEX WTI and DME Oman falling by more than 53% and ICE Brent falling by nearly 58%, even though remaining the benchmark with the highest value. Finally, an increase of between 34% and 37% is noted for the 2020-2021 timeframe, with DME Oman having the lowest growth and NYMEX WTI having the highest growth relative to the previous year's value.

Regarding the graph illustrating the daily price of Brent and WTI crude oil over this 5-year period, it is estimated that the average price has remained around $71.927 and $68.6 per barrel, respectively. However, the price of oil increased steadily at the start of 2018, until the beginning of October, when prices began to fall precipitously. Among the main causes was that at the beginning of this year, the government of President Trump stated that it would reduce Iranian oil exports to zero, which raised prices to a great extent, and then in mid-November granted temporary exemptions. Seeing this, Saudi Arabia, Russia, and the United States raised production, leaving the oil market with a potential surplus. The concern among oil traders was that the world

might not need all of the crudes coming onto the market, which drove Brent to fall to $50.47/b and WTI to $42.5/b.

Also, at the beginning of 2020, the oil price was around $68.9/b and $62.5/b for Brent and WTI respectively, and began an unbelievable decline, which by the end of April had reduced the price of Brent by more than 70% and dragged WTI down to -$37.63/b, a value never seen before. The cause? It was indeed entering the COVID-19 pandemic. In this case, the fall in energy demand was one of the main responsible, with the paralysis of the transport sector, which accounts for a large portion of global consumption, as well as the laws of confinement to roughly one-third of the world population, social alienation, reduced mobility, paralysis of factories and industries, collapsed the system, and even more when the oil supply was not reduced in the same proportion. Consequence? Oversupply and price decline.

Another important point to analyze and can be seen in Figures 22 and 23, is when Russia invaded Ukraine on February 25, 2022, at that time, the price of Brent oil was at $91.77/b and WTI at $89.89/b, but Russia being one of the largest oil producers in the world, the concern about energy supplies in the countries began to leave traces until March 8 of that year, when the price of oil rose to $123.48/b and $119.65/b for Brent and WTI, respectively. In addition to the fear in the countries, the non-purchase of their oil as part of the sanctions that the United States and European Union countries imposed on Russia, caused a decrease in supply in the face of high demand, which resulted in an increase in the price. As expected at that time, in order to balance the demand/supply balance, one of the main quick actions was that the United States released part of its oil reserves and some OPEC members agreed to increase production, which increased supply and lowered prices slightly.

In general, the key to understanding the price of oil is the relationship between supply and demand. Prices will increase in parallel with demand, assuming that supply remains static or decreases. On the other hand, prices will decrease as supply increases, assuming that demand remains static or decreases.

CHAPTER 3

3 COLOMBIA AND OIL RELATIONSHIP

In order to observe the close relationship between Colombia and oil and to generate a correct understanding of the research, a quick overview of Colombia as a nation will be provided, along with some information about its history, the issues associated with oil, the organizational structure of the sector, the regulatory framework and the most significant companies in the nation.

3.1 Quick Overview of Colombia

Colombia is a sovereign republic located in the northwestern region of South America. Covers an area of 1,141,748 km^2 and claims the area up to 928,660 km^2 as territorial sea, making it the world's twenty-sixth largest country and the Americas' seventh-largest. It has a population of more than 50 million people, making it the fourth most populous country in the Americas behind the United States, Brazil, and Mexico. It shares land borders with Venezuela, Brazil, Peru, Ecuador, and Panama, and as the only Latin American country with coasts on both the Atlantic and Pacific Oceans, it shares maritime boundaries with Costa Rica, Nicaragua, Honduras, Jamaica, Haiti, and the Dominican Republic.

It is a republic divided into 32 departments and 1120 municipalities, and it has indigenous territories established by mutual agreement between the government and indigenous communities, covering an area of approximately 30,845,231 km2, mostly in the departments of Amazonas, Cauca, La Guajira, Guaviare, and Vaupés (important factor in understanding the environmental conflict). Because it is crossed by the great Andean Mountain range, it offers a wide range of climates and ecosystems, with about 33% of Colombian territory distributed in mountainous reliefs.

Worldwide, Colombia is known for its production of coffee, flowers, emeralds, coal, and oil; for being the world's second most biodiverse nation, with 54,871 registered species; in addition to having the highest number of ecological confrontations between the local populace and multinational corporations in all of Latin America.

Figure 24. Colombian Flag. Source: Shutter stock

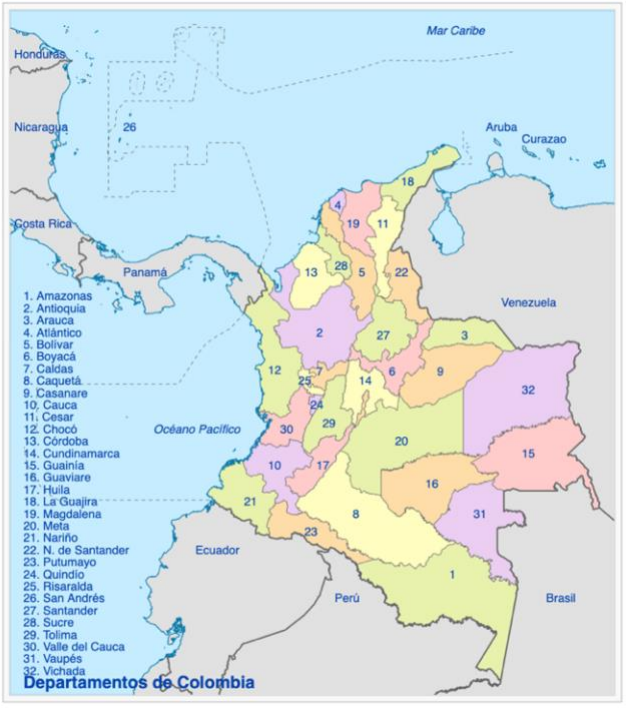

Figure 25. Colombian Flag. Source: Wikipedia

3.2 Oil's Historical Context

To talk about the history of oil in Colombia, it is necessary to go back to 1541, when the chronicles of Fernández de Oviedo mentioned the oil wells used by the Indians in Latora, near what is known today as Barrancabermeja.

The chronicler reported the narrative of Joan del Junco and Gomez del Corral, captains of Gonzalo Jimenez de Quesada's expedition down the Magdalena River in 1536. An expedition that established sovereignty over the country's interior and consecrated the Rio Grande de la Magdalena as the primary connection between the Atlantic coast and the central mountainous areas. The testimonies reported that: 'One day ahead of Latora (where the brigantines will disembark) there is a source of bitumen that is a well and that boils and runs off the land, and it is (located) entering the mountain (forest), at the foot of the mountain range, and it is a great quantity and thick liquor. And the Indians bring it to their houses and smear themselves with that bitumen because they find it good to remove fatigue and strengthen the legs; and with that black liquor and the smell of fish and worse, the Christians use it to brew their brigantines'. [33]

Although there are reports that in 1877, the writer and mining engineer Jorge Isaacs while looking for coal in the Atlantic coast, discovered oil manifestations in the eastern slope of the Gulf of Urabá, and in 1886 signed concession contracts to look for oil in the same place, it was already in the 20th century, when the greatest socio-economic impact in Colombia's history would begin to be generated.

The first oil well took place in Las Perdices, near Barranquilla, in 1907, where 11 dry wells were drilled over a period of four years in search of the desired black gold. In 1909, the Cartagena Oil Refining Company was inaugurated and began operations, with a capacity of 400 barrels per day and specializing in the refining of crude oil imported from North America in order to distribute its main product, kerosene, throughout the country. It was in operation until 1923.

On the other hand, in early 1903, José Joaquin Bohórquez arrived in Barrancabermeja with the intention of establishing a river transport company on the Opón, La Colorada, and Oponcito rivers to mobilize import and export cargoes for the commerce of southern Santander. However, due to a low demand in the transportation sector, at the end of 1904 he opted for the exploitation of products that were offered in abundance in those virgin forests. Near one of his camps, there was a place known as Las Infantas, where José Joaquín related:

"I found the first source of petroleum, whose knowledge gave me that it was this substance, the natural and proper smell of refined and having dipped in these liquid wicks of rag, giving these, after setting them on fire, a yellow-red light and a dark smoke that, when placed on top of an object, gave the same black smoke as that collected in the lanterns that I carried to light me in the forests, which were fed with refined oil.... In that same exploration I went as far as a pipe whose name was and is San Antonio, having found... other oil wells of different sizes, and almost the entire extension of the land being covered by a layer of compacted oil." [34]

It was at this time that Bohórquez began the process of marketing the substances he had discovered around the country, but he was only successful in Cartagena when he was offered the purchase of five-gallon cans for 50 cents (the price of oil imported from the Caribbean Island of Martinique). Soon after, in Barranquilla, he met Geologist Roberto De Mares, who joined him with the commitment to get a concession for the exploitation of oil deposits and to attract investors. (An important figure in the history of oil in the country.)

At the end of 1905, the concession was awarded in his name, where he was granted the privilege of exploiting the oil deposits of Las Infantas site, for a period of 30 years, committing with the Colombian state to deliver a 15% participation on the net product. The Mares Concession encompassed 512,000 hectares of land, including the Sogamoso, Magdalena, and Carare rivers, as well as the eastern mountain range's foothills. However, Despite the fact that De Mares was unable to successfully exploit these deposits, he was able to retain the concession and attract the attention of a group of North American businessmen who, surprised by the large amount of oil that gushed from the deposits, accepted the transfer of the concession in 1919 and established the Tropical Oil Company. Only one year later, Standard Oil of New Jersey acquired Tropical Oil Company (It is said that De Mares received USD 400,000 for ceding the rights and the Council of State granted Bohórquez a lifetime pension of $250 per month).

Because the refinery was a requirement at the time to legalize the start of De Mares Concession, and because of the difficulties in transporting materials and equipment through the Magdalena River to the Troco refinery under construction, they requested the Colombian Government to set August 25, 1921 as the start date. By 1922, The Troco refinery had a capacity of 1,500 barrels per day. (It currently has a capacity of 230,000 barrels per day).

In order to improve the connection between this deposit and Barrancabermeja, they undertook the project of a railroad, in which during its construction in 1924, Troco geologists discovered La Cira structure, which was considered worldwide as an important oilfield at the time. So much so that only a year later, the building of a 538-kilometer pipeline with ten pumping stations connecting it to the Caribbean coast was completed. So much progress was being made in the oil sector that in mid 1926 the first crude oil export to international markets took place, since the first ship left Cartagena with 88,172 barrels of crude oil for export to the United States. [35]

From then on, the period between 1921 and 1951, where important events such as the drilling of wells in 1924 by Richmond Petroleum Co. and Gulf Oil Co.; the acquisition of properties in Cundinamarca and Boyacá by Texaco in 1927, which were later recognized in 1939 and put into production in 1945; the concession developed in the Casabe area (Antioquia) by the Dutch company Shell (1938); the birth of the Ministry of Mines and Petroleum in 1940; and the ninth-place ranking in the world's oil production in 1949, marked the development of the oil industry in addition to new discoveries in the Middle Magdalena, Catatumbo and Lower Magdalena Valley.

***Figure 26. Constitution of ESSO Colombia in 1940. Taken from** [35]*

From this discovery in 1903, which gave rise to what is now known as the De Mares concession, to its reversion to the Colombian State in 1951, would take place the origin of the Colombian Petroleum Company, Ecopetrol.

Later on, by the 1970s and 1980s, the nation was already beginning to import oil, which had a significant impact on the country's economy and forced the government

to employ techniques like the association contract and an increase in exploratory activities to secure resources. Also, as part of an association contract, the second-largest oil field in Colombia, Caño Limon, with a reserve of about 1,250 million barrels was discovered in Arauca, which would enable the nation to regain its oil self-sufficiency. Two years later, the Caño Limon - Coveñas pipeline would be constructed and enable the country to begin exporting crude oil from this field to the international market. This would encourage an increase in production and exports, which would eventually lead to a decrease in the price of a barrel of oil.

By the 1990s, the third largest field in Colombia was discovered, the Cusiana field, with a reserve of almost 750 million barrels and the operation of the OCENSA pipeline, the largest in the country with 848 km of extension and 615,000 barrels of capacity, began. Finally, by the beginning of the 21st century, most of the control of oil in Colombia would fall on the state-owned company Ecopetrol, which would then manage the hydrocarbon resources in the hands of Standard Oil of New Jersey as a result of the reversion of the De Mares concession and would later become the largest oil company of Colombia and one of the most important in Latin America.

3.3 Armed Conflict and Its Impact on The Oil Industry

Something that is important to mention is that although there is currently a peace process, during the last seventy years, the history of Colombia has been marked by armed conflict, which has been reinforced over the years with the emergence of drug trafficking and narcoterrorism, in which armed groups have justified the use of violence as the only method to transform society. For this reason, and due to the fact that oil is one of the industries that contributes most economically to the country, its infrastructure has been attacked many times, generating great losses.

The beginning of this conflict dates back to the Colombian historical period known as La Violencia, between the 1920s and 1960s, when rebels from the Liberal party incensed by the murder of their leader Jorge Eliecer Gaitán on April 9, 1948, started a conflict known as "El Bogotazo" against the Conservative party.

While the Conservative and Liberal elites were confronting each other, an armed resistance of peasants organized to defend their lands was developing, which became officially recognized nationally in 1966 as the Revolutionary Armed Forces of Colombia (FARC), which was later joined by other guerrillas such as the National Liberation Army (ELN), and which grew stronger economically and militarily over

time. What began initially with a clear ideal ended up being influenced by the communist party and orthodox Marxist ideals to the point of declaring war on the Colombian government.

Simultaneously, Colombia's oil industry was undergoing a recognized boom, with several oilfields being discovered and pipelines being built; in short, the country was flourishing economically. However, in the 1980s, the FARC and the ELN opened a new front in their struggle against the government, taking advantage on the country's economic growth and the discovery of what was at the time Colombia's most important oilfield, Caño Limón. Thus, the pipeline (Caño Limón-Coveñas) connected to this oil field became one of their main targets.

According to reports, the rebels blew up the pipeline 460 times between 1985 and 1997. Furthermore, according to Ecopetrol, its five oil pipelines used to carry oil in the country have been blown up more than 1,010 times in the last decade, and the Caño Limón-Coveñas pipeline alone has been the target of more than 1,500 terrorist attacks in 33 years. As a result, over 3.7 million barrels of crude oil have been spilled in soils, streams, and rivers, endangering dozens of wildlife such as fish, mammals, amphibians, and reptiles, as well as the people, which are unable to obtain potable water. [36]

Figure 27. Terrorist attack against oil platform in Arauca by ELN, 25 July 2020. Taken from Ecopetrol Via Twitter

According to the Colombian Petroleum Association, attacks on oil infrastructure have resulted in the spilling of 4.1 million barrels of crude oil over the past three decades. Additionally, between 2002 and 2015, 9.3 million barrels were stolen from the country's pipelines, of which 6.5 million ended up spilling onto natural ecosystems. Even, according to data from Cenit, a company focused on the transportation and logistics of hydrocarbons, in only the first three months of the year 2023, about 44% of the attacks registered in the whole of 2022 have already been registered, mainly in Caño Limón–Coveñas.

3.4 Organizational structure in the oil sector

Before discussing the organizational structure that oversees the oil sector in Colombia, it is crucial to keep in mind that the principle of state ownership of oil dates back to 1886, when the political constitution, issued in that year, established the property of the state over the subsoil and, consequently, the non-renewable natural resources as a principle, leading to the payment of royalties by the exploiters of such resources. However, since the enactment of Law 110 in 1912, which allows for the possibility of temporary concessions for exploitation with prior approval from the Congress of the Republic, the law on oil would gradually start to be perfected.

By the beginning of the 21st century, in view of the international trend of change in oil companies in order to remain in the market, Colombia, following the example of Brazil and Norway, opted to separate the functions of state-owned companies through the creation of entities belonging to the government, without leaving aside the promotion of adequate conditions for proper business development. Additionally, as this industry is widely regarded as the nation's economic growth engine, a number of government organizations support it with technical, administrative, and public policy assistance to strengthen and accelerate the sector's expansion while adhering to the necessary technical, environmental, and social standards. [37]

3.4.1 Ministry of Mines and Energy

The Ministry of Mines and Energy is a national public entity at the central executive level, whose mission is to formulate and adopt policies aimed at the sustainable use of mining and energy resources in order to contribute to the economic and social development of the country.

This entity was created by Decree 968 of May 18, 1940, as a result of World War II, when the national government, faced with various international conflicts causing economic problems that ended up having a direct impact on the progress of Colombia, decided to design a plan for the defense and promotion of existing industries, in an effort to take advantage of natural resources and the development of other sources of production.

Figure 28. Ministry of Mines and Energy Logo. Source: Wikipedia

Among the main functions and duties of the Ministry of Mines and Energy, the following stand out [38]:

- Articulate the formulation, adoption and implementation of the public policy of the administrative sector of mines and energy.
- Formulate, adopt, direct and coordinate the national policy on exploration, exploitation, transportation, refining, processing, benefit, transformation and distribution of minerals, hydrocarbons and biofuels.
- Formulate, adopt, direct and coordinate policy on the rational use of energy and the development of alternative energy sources and to promote, organize and ensure the development of programs for the rational and efficient use of energy.
- Formulate policies aimed at ensuring that the activities carried out by companies in the mining and energy sector guarantee the sustainable development of non-renewable natural resources.
- Issue sector regulations for the exploration, exploitation, transportation, refining, distribution, processing, benefit, commercialization and export of non-renewable natural resources and biofuels.
- Issue regulations for the transportation of crude oil through pipelines.

3.4.2 Other governmental entities related to the hydrocarbons sector

The hydrocarbon industry is currently influenced by a large number of organizations in Colombia, but since the Ministry of Mines and Energy is the regulatory body in terms of direction and policies, there are a number of organizations attached to it that perform specific tasks and are crucial for the proper development of the industry. The National Environmental Licensing Authority is the only organization listed that is not a part of the Ministry of Mines and Energy, hence it is important to note.

3.4.2.1 National Hydrocarbons Agency (ANH)

The National Hydrocarbons Agency was established in 2003 as a result of the reform of the Colombian oil industry in response to the crisis that Colombia was facing as a result of a fall in its oil reserves. This restructuring included the decision of making Ecopetrol more competitive by separating its dual role as an oil company and a regulatory body, and putting it on an equal playing field with other businesses in the industry by having it focus solely on the oil business at all points in the supply chain.

In this way, the National Hydrocarbons Agency took on the responsibilities for administration and regulation, becoming an organization with administrative, technical, and financial independence, attached to the Ministry of Mines and Energy, in charge of the comprehensive management of Colombia's hydrocarbon production and reserves, putting all of its efforts into developing strategies that would boost the sector's competitiveness and reposition the nation on the global stage.

According to Article 3 of Decree 4137 of 2011, the objective of the National Hydrocarbons Agency is to comprehensively manage the hydrocarbon reserves and resources owned by the Nation; promote the optimal and sustainable use of hydrocarbon resources and contribute to national energy security. [39]

Figure 29. ANH Logo. Source: Wikipedia

Among the main functions of the National Hydrocarbons Agency ANH, we find [40]:

- Identify and evaluate the country's hydrocarbon potential.
- Design, evaluate and promote investment in exploration and exploitation activities of hydrocarbon resources, in accordance with international best practices.
- Design, promote, negotiate, enter into and manage the contracts and agreements for exploration and exploitation of hydrocarbons owned by the Nation, with the exception of the association contracts entered into by Ecopetrol until December 31, 2003, as well as to follow up on the compliance of all the obligations set forth therein.
- Allocate the areas for exploration and/or exploitation subject to the modalities and types of contracting that the National Hydrocarbons Agency -ANH adopts for such purpose.
- To set crude oil export prices for tax and exchange purposes.

3.4.2.2 Colombian Geological Survey (SGC)

The Colombian Geological Survey is a science and technology organization that seeks to contribute to the economic and social development of the nation by conducting basic and applied scientific research on the potential of subsoil resources, evaluating and monitoring geological hazards, and managing geoscientific knowledge, research, and nuclear and radioactive control while always keeping in mind the priorities of the policies of the National Government of Colombia. [39]

Figure 30. Colombian Geological Service Logo. Source: Wikipedia

In order to achieve the adequate fulfillment of its purpose, the Colombian Geological Survey should fulfill different functions, among which the following stand out [41] :

- Provide the national government with advice on the creation of policies on the geosciences and the risks and hazards associated with the nation's geology.

- To manage subsoil data and information for the national area and to enhance basic and applied scientific research on the potential of subsoil resources.

- Compile and evaluate subsoil geoscientific data in order to learn more about the processes, composition, and evaluation that shape the subsoil's current morphology, structure, and dynamics in Colombia.

- To progress national territory reconnaissance, prospecting, and exploration programs in accordance with the guidelines established by the Ministry of Mines or the National Government.

- Identify, catalog, and characterize the regions that have the greatest potential for subsoil natural resources, including minerals, hydrocarbons, groundwater, and geothermal resources, among others.

- Define, assess, and create protection zones that, because of the nation's geological or paleontological heritage, may qualify as protected areas.

3.4.2.3 Mining and Energy Planning Unit (UPME)

The Mining and Energy Planning Unit is a specialized administrative organization of the national order, of a technical nature, in charge of the integrated, indicative, continuous, and coordinated planning with the mining and energy sector entities; of the development and proper use of energy and mining resources; of the support for the formulation of public policy; and of the production, dissemination, and coordination of sectoral information with the agents and interested parties.

Figure 31. Mining and Energy Planning Unit Logo

Within the functions and duties of this institution, we can find [42] :

- Employing demand predictions that account for the most likely evolution of the explanatory variables in a national and international context, to determine the mining and energy needs of the population as well as the country's economic agents.

- Plan appropriately, taking into account technological, economic, social, and environmental factors, in order to meet mining and energy needs using conventional and non-conventional resources.

- Analyze the development of renewable and non-conventional energy sources, as well as their energy consumption, for economic, social, and environmental viability.

- Give an evaluation of the economic and social viability of mining and energy resource exports and imports as well as a perspective on their suitability.

- In accordance with the National Development Plan, create and update the national plans for the expansion of the electricity sectors, national energy, coverage of interconnected and non-interconnected areas, and other sub-sector plans.

3.4.2.4 National Environmental Licensing Authority (ANLA)

The National Environmental Licensing Authority (ANLA), a government agency in Colombia, is in charge of ensuring that projects, works, or activities that require environmental licensing, permits, or other procedures adhere to environmental laws and regulations while promoting the nation's sustainable environmental development. Its main objective is to ensure that projects are evaluated, monitored, and controlled in a transparent manner while adhering to strict legal and technical standards, in order to support and contribute to the balance between environmental protection and the development of the nation.

***Figure 32. ANLA Logo. Taken from** [43]*

Its primary responsibilities in the nation include [43]:

- Approve administrative activities involving environmental licenses for mining operations, the building of road infrastructure, and concessions and licenses for the exploitation of forests.
- Deciding whether to grant or refuse licenses, permits, and environmental procedures that fall under the jurisdiction of the Ministry of Environment and Sustainable Development in line with the rules and laws.
- To monitor environmental procedures, licenses, and permits.
- Encourage the creation of environmental laws.
- Control the Integral Window for Online Environmental Procedures (VITAL) and the System of Environmental Licenses, Permits, and Procedures (SILA).

3.4.3 Entities related to the Ministry of Mines and Energy

In Colombia, there are currently 15 entities that are directly connected to the Ministry of Mines and Energy. Big Companies like Urrá S.A., ISA S.A., and Isagen S.A. are among them. The first two of these are distinguished by operating primarily in the electric energy sector, while the last one is distinguished by its portfolio of renewable energies that make use of resources like water, wind, and sunlight. However, in the oil business, and given that there are more oil corporations that are not affiliated with the ministry, Ecopetrol S.A. is currently the most influential company. As a result, this company will be the sole subject of this study.

3.4.3.1 Ecopetrol S.A

According to the Ministry of Mines and Energy, together with the National Hydrocarbons Agency (ANH), the most important oil operating company, including exploration and exploitation, in the country at the beginning of the year 2022 was Ecopetrol. In addition to managing around 66% of the nation's oil operations, this company also owns six of Colombia's top ten most productive oil fields. It is also considered the largest company in the country with a net income of 33.4 billion Colombian pesos and belongs to the group of the 40 largest oil companies in the world and is among the four largest in Latin America.

However, despite being the main oil company in Colombia, it is important to highlight the participation of Geopark Colombia, which owns 8% of the country's operations; Frontera Energy, with 7%; Gran Tierra Energy Colombia, with 3%; and Sierracol Energy Arauca, with 3%. In general terms, it is said that 87% of oil production in Colombia is managed by five companies.

Figure 33. Ecopetrol's Oil Plant. Source: Ivan Valencia / Bloomberg

By Decree 30 of 1951, on August 25, Colombian Petroleum Co., or Ecopetrol, was established as a state corporation with the purpose of managing the hydrocarbon resources received from Standard Oil of New Jersey as a result of the reversion of the De Mares Concession. From that point on, Ecopetrol was in charge of 140 million barrels of oil reserves, 25,000 barrels per day of production, and 2,700 employees.

The company's growth would be so strong that by the 90s, they would control all operations at the Barrancabermeja and Cartagena refineries; have acquired the Colombian Petroleum Co. (Colpet), its sister company South American Gulf Oil Co. (SAGOC) and Shell's oil fields in Casabe (Antioquia); signed an association agreement with Texaco for the exploitation in La Guajira; in association with Occidental Petroleum Company (OXY) would generate the best news for the history of the company and one of the best for Colombia by allowing it to return to being an exporting country, the discovery of the Caño Limón field; and in association with the British Petroleum Company, the discovery of the Cusiana and Cupiagua fields in the plains foothills, which would allow Colombia to prolong its oil self-sufficiency.

With the enactment of Decree Law 1760 on June 26 of the twenty-first century, the National Hydrocarbons Agency (ANH) was established to oversee the nation's hydrocarbons policy, the new Exploration and Production (E&P) contract was created, and the Colombian Petroleum Company was restructured, changing its organizational structure and turning it into a publicly traded company by shares that is fully owned by the state and connected to the Ministry of Mines and Energy, with the intention of expanding its global reach and improving its competitiveness within the context of the global hydrocarbons business [44]. Additionally, it would have offered 20% of its shares in the stock market within the first decade of the twenty-first century and entered the New York Stock Exchange.

From that point on, Ecopetrol S.A. would start a new phase in which, with greater independence, it would quicken its exploration activities, its ability to produce results with a business and commercial vision, and its interest in enhancing its competitiveness in the global oil market, until it became a crucial component of the annual budget of the country and the biggest oil company in Colombia. Furthermore, as a mixed company (88.49% of the shares are state-owned [45]), the majority of the corporation becomes part of the portfolio of Colombia's Ministry of Finance, and so the oil company's operations will have an important effect on the Colombian economy.

Currently, it operates in most of the country, concentrating mainly in the center, south, east and north of Colombia, as well as abroad. Thanks to its 8,500km network of polyducts and pipelines that connect production centers to refineries and ports in the Atlantic and Pacific oceans, it ensures the country and its investors the transportation and availability of multiple hydrocarbons for refining, export, or consumption. Also, despite having the most geological knowledge of Colombia's several fields, it

currently possesses the majority of the country's transportation and refining infrastructure. Additionally, participates in the biofuels business, has offices in Mexico, Brazil and the United States, and employs 33,964 workers, 84% of whom are local workers in Ecopetrol's regions of operation.

3.5 Regulatory Framework for the industry

As with all Colombian industries, the hydrocarbon sector's organizational framework includes a set of laws, decrees, and resolutions that generally serve the purpose of regulating both the functions and the activities that are intended to be carried out without running the risk of legal repercussions and while fully complying with the requirements of the state.

In this case, Colombia's extractive industry is managed by a broad regulatory and normative framework, whose goal is to give precise and defined standards in technical, environmental, economic, and social aspects for the development of the sector. In essence, it offers the foundation upon which these institutions create the scope and nature of societal engagement.

The current regulatory framework, in addition to the foundations and bases established in the Political Constitution of Colombia, includes general and essential normative postulates that are outlined in various laws, decrees, resolutions, circulars, and other documents. Generally speaking, within this regulatory framework, we may find legislation pertaining to allocation of areas, production control, liquidation and accounting of royalties and compensation, distribution and transfer of income, environment, social investment, etc. [46]

As a starting point, it is necessary to present the regulations that have been presented since the Colombian political constitution of 1991, as well as some of the most significant emerging regulations since that time, in order to later emphasize some of the specific regulations related to area allocation, exploitation, and the environmental field.

According to article 332 of Colombia's Political Constitution of 1991, the appropriation of subsoil and all non-renewable natural resources by the Colombian state is officially established on this basis. Article 360 further states that the exploitation of these non-renewable natural resources will result in an economic

consideration in favor of the state as a royalty, with the law defining the conditions for exploitation.

Later on, with Law 141 of 1994, the National Royalties Fund and the National Royalties Commission would be established, the state's right to receive royalties as a result of the exploitation of these resources would be regulated, criteria for the distribution and calculation of royalties would be established, as well as rules for the liquidation and distribution of these non-renewable resources. Finally, in 2011, with Legislative Act 5, Article 360 would be modified and the distribution, objectives, purposes, administration, execution, control, use and destination of the income from such exploitation would be established by means of the constitution of the general royalties' system.

In addition, the following table summarizes the main regulations in force for some of the aspects mentioned above:

Table 6. Example of some of the existing regulations related to the oil sector.

Aspect	Norm	Object
Assignment of Areas	*Agreement 04 of 2012*	The **management of areas for the exploration and exploitation of hydrocarbons** controlled by the country is determined according to certain criteria.
	Agreement 03 of 2014	Agreement 4 of 2012, is expanded to **include criteria and requirements for the development of unconventional reservoirs**.
	Agreement 02 of 2015	It is added to Agreement 4 of 2012, which is supplemented by Agreement 03 of 2014, in order to incorporate **rules and preliminary and conjunctive measures aimed at mitigating the negative effects of a drop in international oil prices, production levels, or reserves**.
Environmental License	*Law 99 of 1993 Art. 8 simplified by Decree 2150 of 1995, Art. 132.*	It is established that in order to carry out the full development of industrial activities, **the environmental license will demand compliance with a number of environmental standards, permits, and authorizations**. Also, it was determined that the duration of the environmental license is limited and comparable to the term of the permits requested.

	Law 99 of 1993 Art. 53, 57 and 58	In order to get an environmental license, an EIA (Environmental Impact Assessment) and/or a DAA (Environmental Assessment of Alternatives) will be required in some circumstances to **establish the environmental, social, and economic impact of a project and the methods to mitigate it.**
Environmental Assessment	*Resolution 1275 of June 30, 2006*	The terms of reference for the preparation of the Environmental Impact Study for **fluid conduction through pipeline projects in the petroleum industry are accepted.**
	Resolution 1269 of June 30, 2006	The terms of reference for the preparation of the Environmental Impact Study for **building and operation projects of refineries and petrochemical developments that are part of a refining complex are adopted.**
	Resolution 1543 of August 6, 2010	The terms of reference for the production of the Environmental Impact Study for **hydrocarbon extraction projects are accepted.**
	Resolution 2205 of December 27, 2016	The terms of reference for the production of the Environmental Impact Assessment - EIA, which is required for the **environmental license procedure of marine seismic exploration projects at depths less than 200 meters**, are accepted, as are other findings.
Seismic	*Decree 2820 of 2010, Art.8, numeral 1, literal a), Ministry of Environment, Housing and Territorial Development.*	**Establishes environmental licensing standards for seismic investigation that includes the construction of access roads**, and must also be licensed when marine seismic exploration is conducted at depths of less than 200 meters.
	Manual for Land Seismic Acquisition and Processing and its application in Colombia.	The National Hydrocarbons Agency develops a seismic oil exploration guidebook.
	Basic Environmental Guidance for Exploration Programs Land Seismic	The Ministry of the Environment developed a guide for monitoring land seismic exploration that is available to any competent authority.

Conduct typified as environmental crimes	**Resolution 760 of 2010, Decree 3678 of 2010 and Resolution 415 Ministry of Environment, Housing and Territorial Development.*	**Preventive measures and punishments are established for environmental violations**, which may be enforced by any of the environmental agencies, as the case may be, and conditions are made for the perpetrator to follow-up on the preventive measures and sanctions.
Offshore hydrocarbon exploitation projects	*Resolution 40687 of July 18, 2017.*	Technical criteria are defined for offshore hydrocarbon extraction projects in Colombia, taking into account elements like industry technical standards, process safety, disaster response capabilities, and process technical standards, among others.

It is important to note that because the Colombian oil industry is constantly growing and expanding, there is a constant updating of regulations (legislative act, agreement, circular, decree, law, or resolution) related to the sector (administrative, allocation of areas, hydrocarbon contracts, economic rights, supervision, royalties, reserves, and sectors). As a result, due to the huge size of this sector's regulatory system, it is difficult to cover all existing rules. However, all existing regulations and decrees can be accessed via the website of the National Hydrocarbons Agency (ANH).

CHAPTER 4

4 COLOMBIAN OIL MARKET

As has been indicated, the importance of Colombia's oil industry has increased, and with it has come a growing concern for its future, both in terms of its contribution to meeting society's energy needs and the overall wellness of the Colombian economy.

Although Colombia is not an oil economy, but rather a region with a significant participation in the oil sector, it is important to note that it has a strategic influence in regards to Gross Domestic Product (GDP), as well as a variety of income from exports, taxes, royalties, and even positively affects the labor market through labor demand.

Although Colombia's path in the oil sector has not been straightforward, Decree Law 1760 of 2003, in response to the crisis that Colombia was experiencing due to the decline in its oil reserves and the perception that there was a threat to oil self-sufficiency, allowed for the creation of the National Hydrocarbons Agency (ANH), which changed Colombia's oil policy and set the way for a new stage characterized by the intensity of exploration and exploitation of the resource, supported by a significant modification of the contracting scheme.

It is important to note that in addition to the contracting scheme that surrounds the oil sector and other various factors, a country's competitiveness is influenced by its ability and success in finding hydrocarbons during the exploration processes, as well as by the success of the projects it has undertaken and the proven reserves. For this reason, in order to analyze Colombia's competitiveness in the oil sector, different aspects such as reserves, production, exports and imports, refining capacity, among others, will be discussed and analyzed below. It is also important to mention that since the oil supply chain in Colombia follows the same pattern as globally, it will not be explained so as not to become redundant.

4.1 Reserves.

The National Hydrocarbons Agency (ANH), the authority in charge of the integrated administration of the country's hydrocarbon resources, publishes the country's **Hydrocarbon Reserves and Contingent Resources Report (See attachment)**

between the months of May and June each year, based on information reported by the operating companies. For the 2022 report, data from 62 companies, 11 external auditing firms, and 474 fields as of December 31, 2022 were consolidated. [47]

First of all, it's crucial to emphasize that an oil reserve must satisfy the ANH's requirements of having been discovered, recoverable, marketable, and remaining in order to be taken into account. It also develops a model to display the low, best, and high estimation of oil reserves to allow for a more thorough statistical investigation.

This ANH's model states that:

- 1P: Denotes the low estimate of Reserves, i.e., Proved Reserves (P1).
- 2P: Represents the best estimate of Reserves, which is the sum of Proved (P1) and Probable (P2) Reserves.
- 3P: Indicates the high estimate of Reserves, which is the total of Proved (P1), Probable (P2), and Possible (P3) Reserves.

$$1P = P1$$
$$2P = P1 + P2$$
$$3P = P1 + P2 + P3 = 2P + P3$$

Note that in this case, 1P is equal to P1, but P2 is not the same as 2P, nor is P3 the same as 3P.

4.1.1 Overall reserves

Taking Colombia's general oil reserves as a reference point and having already explained the reserves evaluation model, it was found that when comparing the Resources and Reserves report for the years 2021 and 2022, probable reserves increased by 1.28%, while possible reserves declined by 1.25%. However, in general, the best estimate of reserves (2P) climbed by 1.59%, the high estimate of reserves (3P) increased by 1.07%, and the low indication of reserves or proved reserves (1P) increased by 35 million barrels, or 1.72%.

Table 7. Oil Reserves Comparison 2021-2022

		Reserves as of December 31, 2021			Reserves as of December 31, 2022		
		1P	**2P**	**3P**	**1P**	**2P**	**3P**
Million barrels	Proved	2039	2039	2039	2074	2074	2074
	Probable	-	782	782	-	792	792
	Possible	-	-	641	-	-	633
	Total	**2039**	**2821**	**3462**	**2074**	**2866**	**3499**

On the other hand, according to this analysis done by the ANH, and as can be seen in Table 8, over 85% (1,773 million barrels) of Colombia's total proved reserves are controlled by five corporations, with the state-owned company Ecopetrol S.A. owning 67% (1,399 million barrels) of these reserves. It currently controls six of the country's most producing oil fields, while Geopark S.A. owns two and Frontera Energy S.A. owns only one. However, a more detailed analysis of these topics will be conducted later.

Table 8. Companies that manage proven oil reserves

Companies	Petroleum Million Barrels	%
Ecopetrol S.A.	1.399	67%
Geopark Colombia S.A.S.	131	6%
Frontera Energy	98	5%
Gran Tierra Energy Colombia	74	4%
Parex Resources	70	3%
Others	301	15%
Total	2,074	100%

4.1.2 Proved Oil Reserves by Department

As was already mentioned, some departments of Colombia have benefited greatly from and continue to be enriched by Colombia's oil history. However, as methods, procedures, and technologies advanced, it became possible to reach numerous regions

of the nation and thereby widen the oil network. Figure 34 is therefore offered with the aim of adequately informing which regions have higher participation in reserves.

In general, it can be seen that only 2 (Meta and Casanare) of the 33 departments—including the capital district of Bogotá—hold 70% of the country's proven oil reserves for the year 2022, with the department of Meta making up the majority with about 54%.

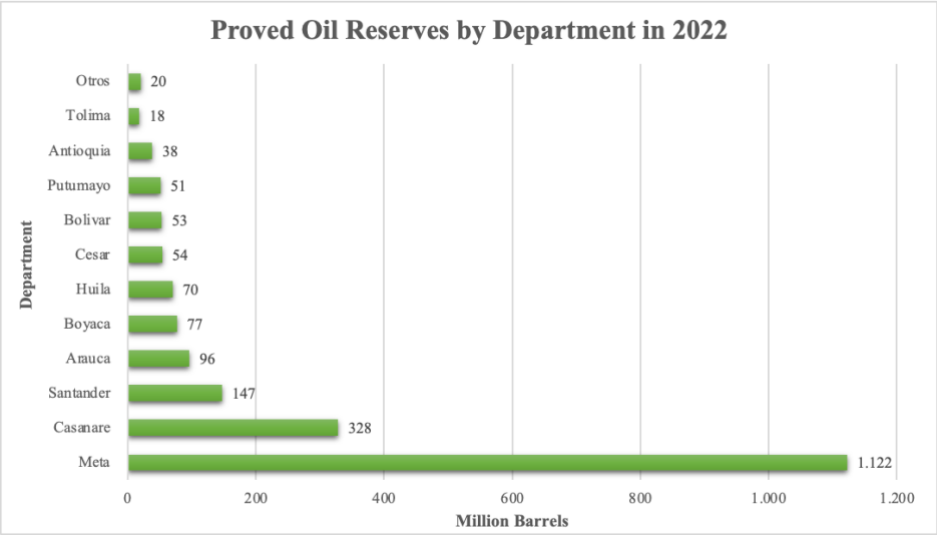

Figure 34. Departments with the greatest amount of Proved Oil Reserves

***Figure 35. Departments with the largest proven oil reserves on the map** [47]*

According to the history of oil in Colombia, the history of Meta as the first oil producing department in the country is recent. The armed conflict in Colombia, which was indicated above and is still in effect, was one of the worst adversaries of the oil industry, and this department was one of the key witnesses. Prior to 2003, the production of this department in central Colombia was limited to a few small wells in the high plains and foothills, where the Revolutionary Armed Forces of Colombia (FARC) and other paramilitary organizations were heavily present.

There was a division in the region, with the paramilitaries joining the men of the Castaño brothers (leaders of the United Self-Defense Forces of Colombia), on the one hand, and the guerrillas attacking the little infrastructure that was present in the area and kidnapping officials of the oil companies in charge of those areas, on the other. As a result, a war for the control of drug trafficking erupted in the region, where hundreds of murder victims were recorded and could only come to an end with a stronger presence of the Colombian national army near the oil wells and the demobilization of a sizable portion of the military structure. [48]

At that time, the foothills were the main oil exploration area in the department. However, in 2003, Ecopetrol expanded production in the Cubarral block and in the High Plains, businessman Germán Efromovich acquired the oil exploitation rights of the Rubiales field in the municipality of Puerto Gaitán through the firm Meta Petroleum, which later merged with Pacific Rubiales. Later on, the department of Meta would be even more "benefited" when oil companies, taking advantage of the security guarantees and the reduction of environmental requirements offered by the government of then President Álvaro Uribe, began to operate in the region, so much so that by 2008, it would become the first crude oil producer in the country, ahead of Arauca and Casanare.

Figure 36, which presents data taken from ANH [49], can be used to illustrate the aforementioned. Basically, it can be seen that Meta —the department with the largest oil deposits in Colombia—saw an increase in crude oil exploration and exploitation from 2008 to 2013, reaching the highest level of proven reserves in the previous ten years. The situation changed from that year to the present, though, when the world economy experienced one of the biggest drops in oil prices between mid-2014 and early 2016, which combined with the nation's declining exploration activity would result in the precipitation of about 32% of proven reserves.

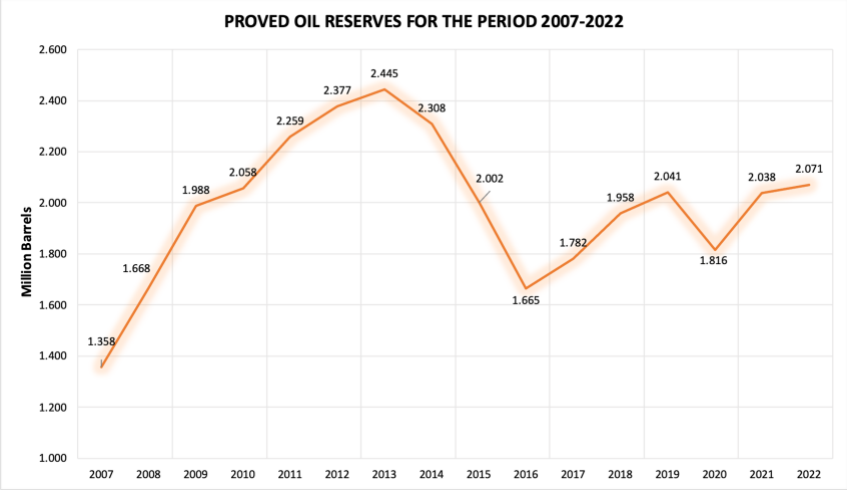

Figure 36. Nation Proved oil reserves in the period 2007-2022.

In summary, it can be said that according to the annual report of resources and reserves, Colombia is extracting hydrocarbons at a slightly higher rate than previously and this is affecting its reserves, to the point of saying that according to ANH analysis, the country has oil reserves for approximately 7.5 years.

4.2 Production.

As should be expected, production is directly proportional to reserves, where the higher the number of reserves, the higher the production and vice versa. In this case, with around 736,000 barrels of oil produced per day, Colombia currently ranks 22nd among the nations with the highest oil production index worldwide, according to the Annual Statistical Bulletin published by OPEC in 2022 related to the 2021 data. However, in order for the nation to be recognized internationally, it is crucial to examine various statistics from prior years and some of the fields that contribute the most.

Initially, based on information obtained from Production Statistics provided by the National Hydrocarbons Agency (ANH) [50] (See attachment), when we look at the average daily oil output that was produced each month (on a rolling basis) between 2019 and 2022, we can observe that the largest production peaks are gradually reduced over time. Fig. 37 also shows a trend line with a negative slope, indicating a drop in production, which is supported by a drop in proven oil reserves and other variables.

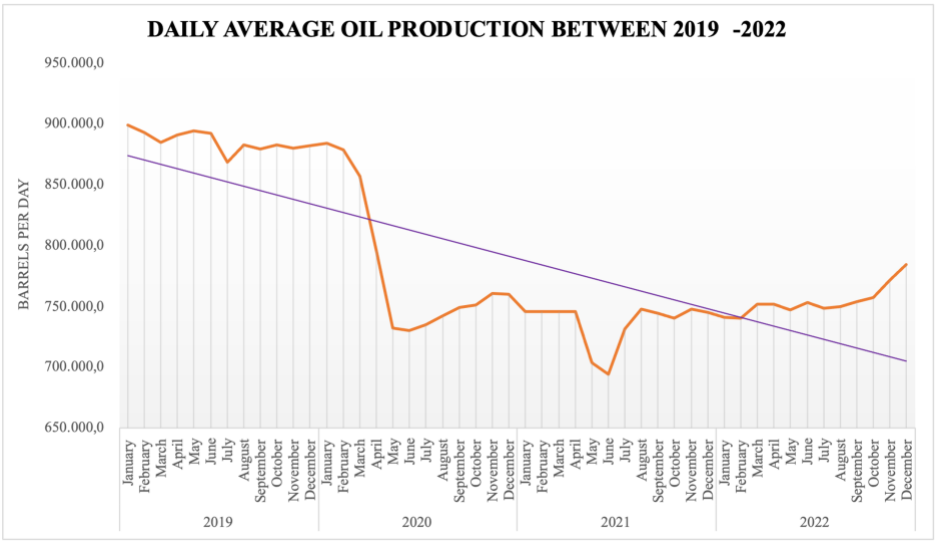

Figure 37. Oil Production Behavior between 2019 and 2022

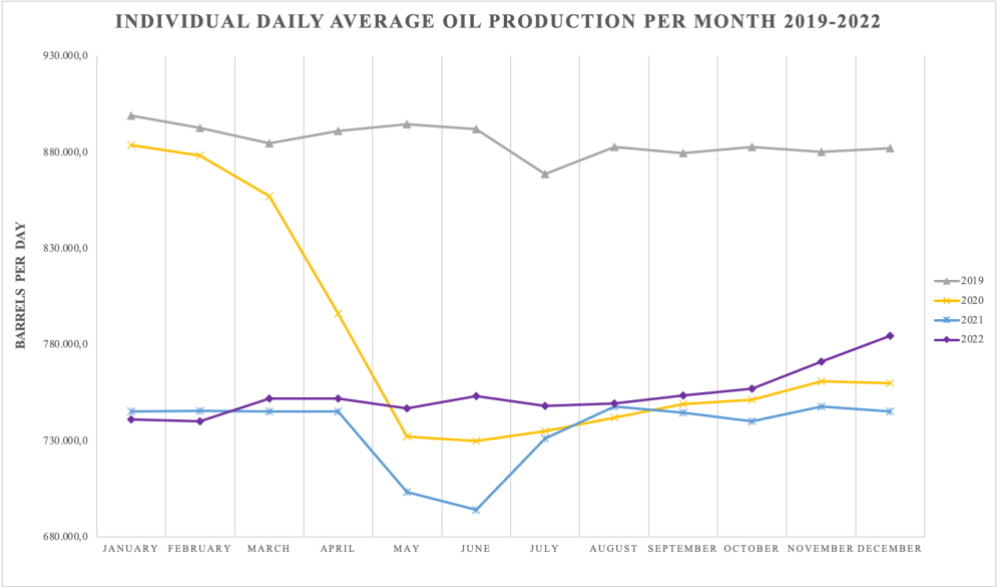

Figure 38. Individual year oil production behavior between 2019 and 2022.

By performing a broad analysis of the data in the graphs and calculating a yearly average, we can estimate that in 2019 roughly 886,000 barrels per day were produced. Only one year later, the average daily oil production would have decreased by about 12% due to the sharp decline in the price of crude oil on the world market, as shown in Figs. 22 and 23, which reached less than $20 per barrel of Brent and negative values

for WTI crude oil due to the severity of mobility restrictions around the world, which caused a decrease in energy demand in Colombia and the other countries.

So much so, that as a result of the mandated isolation, some oil fields in the country were forced to cease operations, and a huge number of enterprises in the sector lowered the investments scheduled for hydrocarbon exploration and exploitation. As a consequence of this reduction in investment destined to the sector to halt the natural decline of the country's fields, Electrical and mechanical failures were generated in the different production areas that ended up generating problems in the logistics of the sector's supply chain, causing that by 2021, oil production would reach 694,000 barrels per day, the lowest level in the last 14 years. [51]

Currently, it remains at a daily average of 754,196 barrels of oil, which indicates an increase of 2% over the previous year. It is worth mentioning that 2022 has been a historic year for Colombia and raises concern for the future, as Gustavo Petro was elected president in August of the same year, announcing the country a fundamental transformation, including a fair energy transition without jeopardizing the country's energy sovereignty. Within these modifications, there is frequent discussion regarding the possibility of canceling future oil exploration and exploitation contracts, which directly threatens enterprises and investors and causes widespread alarm among the general population.

Another aspect that is important to analyze, based on the data taken from Production Statistics [50], which is fundamental at the time of observing oil production in a global manner, are the productive fields and the most significant departments of the country. For this reason, the following is presented:

Table 9. TOP 15 OIL PRODUCTION FIELDS IN COLOMBIA 2022

TOP	Department	Operating company	Field	TOTAL
1	Meta	Ecopetrol S.A.	Rubiales	37,057,014
2	Meta	Ecopetrol S.A.	Castilla	21,296,903
3	Meta	Ecopetrol S.A.	Chichimene	15,561,681
4	Meta	Ecopetrol S.A.	Castilla Norte	15,212,748
5	Casanare	Geopark Colombia S.A.S.	Jacana	10,393,855
6	Meta	Frontera Energy Colombia Corp,	Quifa	9,184,805
7	Casanare	Geopark Colombia S.A.S.	Tigana	8,790,206
8	Meta	Ecopetrol S.A.	Chichimene Sw	7,182,768

9	Santander	Ecopetrol S.A.	La Cira	7,028,104
10	Arauca	Sierracol Energy Arauca Llc	Caño Limón	6,436,247
11	Meta	Ongc Videsh Limited	Indico	6,371,153
12	Cesar	Gran Tierra Energy Colombia, Llc	Acordionero	5,936,650
13	Casanare	Ecopetrol S.A.	Pauto Sur	5,699,783
14	Bolivar	Ecopetrol S.A.	Yariguí-Cantagallo	4,882,634
15	Meta	Ecopetrol S.A.	Akacias	4,587,755

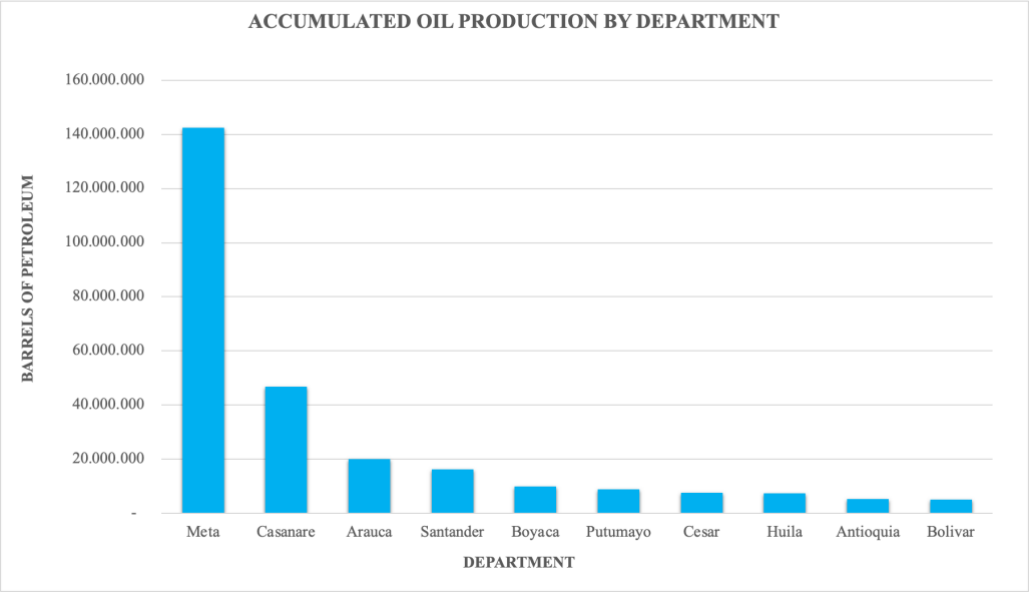

Figure 39. Departments with the greatest oil production in 2022

Also, it can be seen in this ranking that 60% of the fields are operated by the state corporation Ecopetrol S.A., which contributes 43% (118,509,389 barrels of oil) of the country's total production in 2022 (275,281,534 barrels of oil).

Finally, using Table 9 and Figure 39 as a guide, we can confirm and state that 11 of Colombia's top-producing oil fields are located in the Orinoquia region (Department of Meta and Casanare). While Casanare has the most productive fields (155), contributing about 17% of the nation's total oil production, it is the Meta department that takes the lead, accounting for about 52% of the nation's total oil production and

possessing 72 productive fields, including “Campo Rubiales", classified by the ANH as the greatest production field in Colombia, and by the media as "the jewel in the crown" for Meta's oil industry to position itself as a leader in the country.

4.3 Crude Types

There are numerous ways to classify oil, as was described in chapter 1, however in Colombia at the moment, it is referred to by its API gravity and sulfur content. According to our knowledge of API gravity, light crude is defined as having a value greater than 26, intermediate crude is defined as having a value between 20 and 26, and heavy crude is defined as having a value lower than 20 degrees. In terms of sulfur content, we are aware that sweet oil is defined as having a content less than 0.5% and sour oil as having a concentration greater than 1.0%.

Having said that, we can start by presenting the seven types of crudes that the Colombian market currently offers, as established by Ecopetrol [52]:

Table 10. Types of crude oil currently available in Colombia

Name	**API Gravity**		**Sulfur Content (%)**		**Description**
Castilla Blend	17.79º	Heavy	1.87%	Sour	Produced when heavy crude from fields in the Plain region and crude from the oil production field "Castilla" are combined. Virgin naphtha is added as a diluent to ensure proper transit in the pipeline system to the port of Coveñas.
Magdalena Blend	19.95º	Heavy	1.401%	Sour	Generated by blending certain sour crude streams from the Middle Magdalena Basin with Castilla crude from the Eastern Plains Basin
Vasconia Blend	23º	Intermediate	1.197%	Sour	A blend of crudes generated in the fields of the plains and the Upper Magdalena areas, whose currents meet at the Vasconia Station. Through the port of Coveñas, this crude is exported.

South Blend	25.01º	Intermediate	1.22%	Sour	Produced in fields in Colombia's southwest region
Mares Blend	20º	Intermediate-Heavy	1.99%	Sour	Derived from crude in Castilla. It is supplied via pipeline to the Colombian Caribbean port of Coveñas for export.
Apiay Blend	18.01º	Heavy	2.251%.	Sour	Produced on the eastern plains and pipelined to the Colombian Caribbean port of Coveñas.
Caño Limon	30.02º	Light	0.45%	Sweet	Produced in the Basin of the Eastern Plains. Carried to the Colombian Caribbean coast by the Caño Limón-Coveñas pipeline

4.4 Refining Capacity.

As has been stated repeatedly throughout this study, when we talk about refining, we are referring to one of the most significant and influential components of the global economy, not only because of the jobs that are created in these facilities but also because it serves as the base for the production of a wide range of goods that have become essential to the development of the economy and industry.

In Colombia, oil refining took place at the beginning of the 20th century. At the time, a still brought from Talara, Peru, was used to perform this chemical process manually in order to produce one or two items that were sold around the area. Currently, it has refining systems whose technology provides the possibility of reaching a capacity of more than 450,000 b/d barrels of crude oil per day and the production of more than 2,000 derivative products.

There are currently four refinery systems in the country, all of them owned by Ecopetrol. They are spread out among the departments of Santander, Bolivar, Putumayo, and Meta. However, since two of Colombia's five current refineries provide more than 98% of the nation's total refining capacity, according to Ecopetrol (EIA), just these two cases will be examined.

Table 11. Colombian Refineries.

Refinery	Capacity (Barrels per day)	Department	Company
Barrancabermeja	250,000	Santander	Ecopetrol
Cartagena	200,000	Bolivar	Ecopetrol
Orito	2,500	Putumayo	Ecopetrol
Apiay	2,500	Meta	Ecopetrol

4.4.1 Barrancabermeja

The main and most significant oil facility in Colombia, the Barrancabermeja Refinery, is located in the Santander department on the banks of the Magdalena River, one of the earliest places where the history of oil exploitation began. Construction on this massive infrastructure began with an installed capacity of 1,500 barrels per day, and it has since expanded to a capacity of 250,000 barrels per day [54].

It spans an area of 254 hectares, with more than fifty plants and processing units, as well as treatment, services, and environmental control, distributed throughout. This plant was even chosen as the best in Latin America by the World Refining Association during the Latin American Refining Technology Conference (LARTC), which took place in September 2022 in Buenos Aires, Argentina.

In essence, this plant is primarily involved in the production of diesel and gasoline, as well as polyethylene (low-density plastics), kerosene, sulfur (fertilizers), and acid (industrial and fertilizers), in addition to supplying the domestic market and exporting excess fuel oil and petrochemicals to the international market.

Figure 40. Barrancabermeja Refinery. Taken from: 360RADIO

4.4.2 Cartagena

The Cartagena Refinery (Reficar), bought by Ecopetrol in 1974, is in second place and has established itself as a big industrial and refining complex that has become a significantly important factor for the country's industry and economy, as well as for energy security and fuel production.

With a starting capacity of 80,000 barrels per day, it was able to increase that to 90,000 barrels per day in 2016, and then to 200,000 barrels per day in September 2022 with the help of more than 34,000 workers, the majority of whom were Colombians and with the aim to meet more effectively the rise in fuel demand and decrease its importation. With 34 units and a 140-hectare footprint, it is a complex that mainly converts 97.5% of its crude oil into diesel, naphtha, liquefied petroleum gas, and jet fuel, leaving the remaining 2.5% in coke and sulfur for the steel and agrochemical sectors. [55]

It is important to note that Reficar is currently recognized as the most modern refinery in Latin America, and the one that produces the cleanest fuels in Colombian history, including gasoline with sulfur levels between 80 and 100 parts per million (ppm) when the standard calls for 300 and diesel for export with up to 10 ppm, which satisfies the strictest international standards.

Figure 41. Cartagena Refinery. Taken from: Repsol

4.5 Imports and Exports.

According to the Observatory of Economic Complexity (OEC) [56], Colombia is currently the 65th importer and 19th exporter of crude oil in the world. In the same year, crude oil was the 27th most imported product in Colombia (351M), where its main sources were the United States ($225M) and Trinidad and Tobago. In general, it is observed that in the last decade, imports of petroleum and petroleum products made up, on average, about 8.6% of the country's total imports.

On the other hand, when talking about exports, it is mentioned that oil was the country's main exported product with more than eleven billion dollars ($11.3 MM), with the main destinations being the United States (29.9%), China (23.6%), India (17.3%) and Panama (17.2%), as shown in Figure 42.

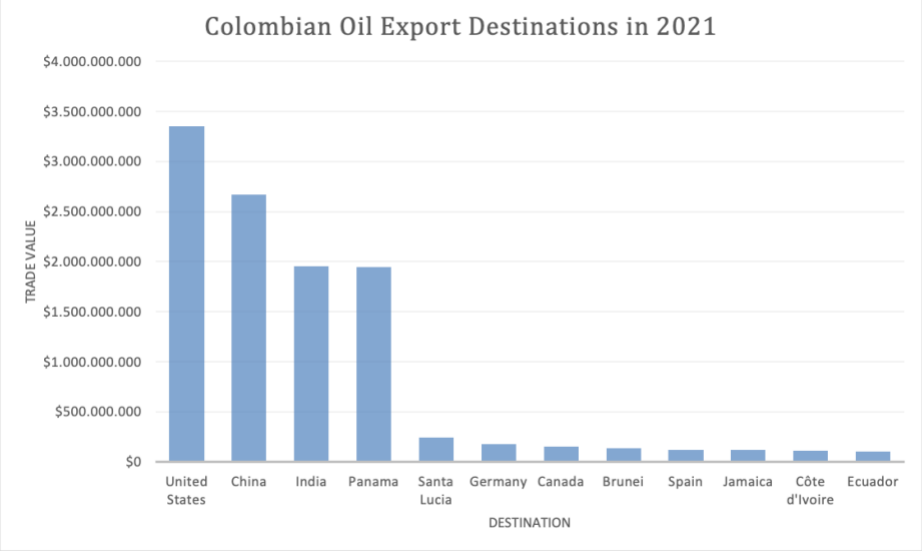

Figure 42. Main export destinations for Colombian oil

Based on the database provided by the National Administrative Department of Statistics (DANE) (See attachment) with respect to imports and exports, it was possible to perform an analysis complemented by Figures 43 and 44, which also shows a similar pattern overtime in the behavior of both trade activities, marked by an exponential rise between 1999 and 2014 and a sharp decline between 2014-2016 and 2019-2020.

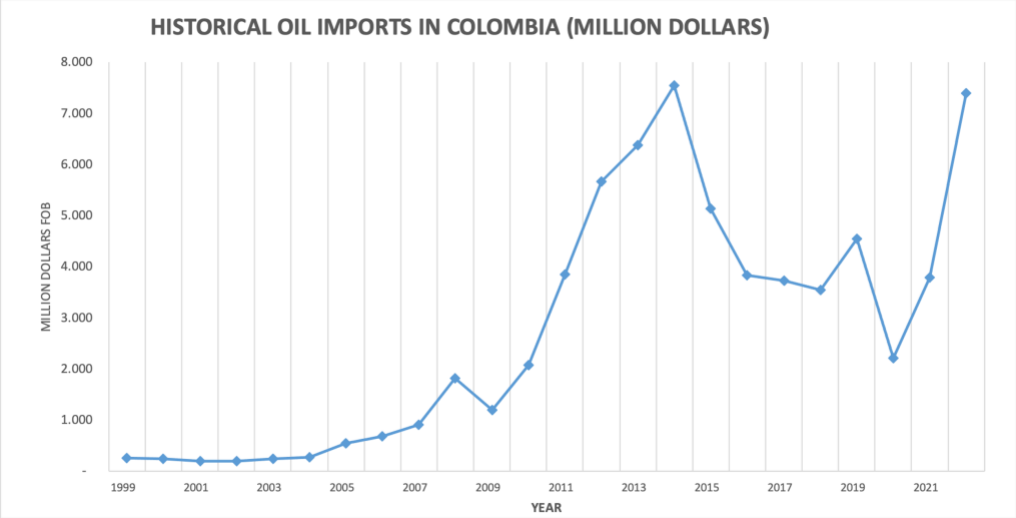

Figure 43. Colombian oil imports between 1999 and 2022. Data taken from DANE *[57]*

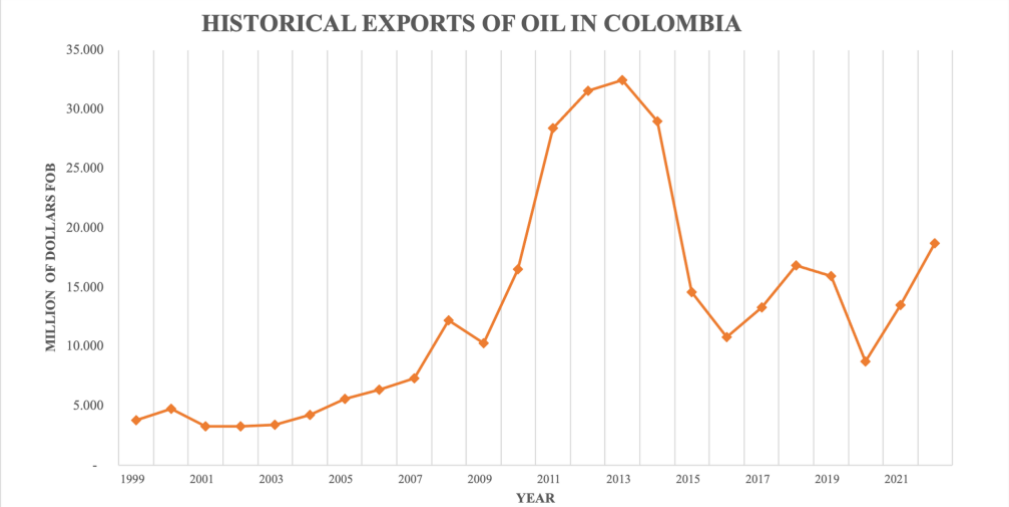

Figure 44. Colombian oil exports between 1999 and 2022. Data taken from DANE *[58]*

It is crucial to note that a variety of factors, including the price of a barrel of oil and the discovery and exploitation of both old and new oil reserves, have a considerable impact on how the nation's exports and imports behave. Additionally, as time passes, new technologies and equipment are being added to the oil system, thereby making it more accessible than ever before to exploit these kinds of reserves, refine, and distribute oil.

By slightly analyzing the aforementioned figures, we can see that both imports and exports peaked in the years 2013–2014, when the nation's historically proven oil reserves were at their highest level. However, as mentioned above, oil exports went down by one of the greatest margins between 2014 and 2016, as a result of one of the biggest drops in oil prices, which have been described as among the three worst since World War II and the longest since the 1986 supply collapse. In 2019 and 2020, when Colombia had already recovered growth by about 51% from the aforementioned scenario, two scenarios that had a direct impact on global oil demand—the trade war between the United States and China in 2019 and the COVID-19 pandemic in 2020—would cause exports to decline once more, this time more sharply.

However, according to data from the National Administrative Department of Statistics (DANE), Colombia managed to raise its exports by 54% in 2021, after the economic reactivation, and by 39% in 2022, compared to 2021.

As of the current year, we can remark that overall Colombian exports between January and June 2023 declined 13.6% from the same semester of the previous year. The group of fuels and goods from extractive industries, where there was a fall of 29.4% in this year's first semester compared to the same period in 2022, is even mentioned as the industry whose exports are experiencing the largest impact.

Nevertheless, the fact that Colombia has been undergoing what the current president, Gustavo Petro, refers to as "Decarbonization of the economy"—generally speaking, the reduction of dependence on fuels as a government policy—since August 2022 is a factor that has taken on importance in the country and largely explains the behavior of exports and imports. But we'll go into more detail about this subject further.

4.6 Price

As is well known, the price of oil in Colombia, like in other nations, is distinguished by its considerable variability and its susceptibility to changes in global markets. Additionally, since Colombia relies heavily on oil exports and production for its income, changes in global oil prices directly affect the country's economy.

As a starting point, it is crucial to know that the Colombian state-owned company Ecopetrol decided to switch the WTI oil reference to Brent in order to make new contracts and earn greater profits from the sales of domestic crude oil since 2011. This decision was made in light of the event in which both the overcoming of the Brent oil

quotation against the WTI and the lower production of heavy crude oil that was being generated in South America favored the negotiation conditions of Colombian crude oil. We must remember that Ecopetrol controls all of the nation's refineries, 4 of the 5 most prolific fields, and 67% of the proved oil reserves.

However, despite this, according to a number of reports, Colombian crude oil has been underpriced since its average quality has reportedly been lower than that of Brent oil for numerous years. Taking Vasconia Brent oil as a point of comparison, we can state that it is usually offered at a discount of 5 dollars per barrel with respect to Brent and that this difference will widen or narrow depending on the level of demand for crude oil [59]. A great instance is how the difference narrowed in 2019 as a result of U.S. sanctions on Venezuela that made it possible for American businesses to begin buying Colombian oil. As demand climbed, price increased, and the gap decreased as a result. On the other hand, another example would be when, in 2020, the gap increased to almost USD 8.9 per barrel due to the worldwide oil surplus and fluctuations in demand brought on by the COVID-19 pandemic.

It is also important to know that until 1998, the Colombian national government regulated the price of gasoline in the country without its behavior being tightly tied to the international price of oil, since it continuously issued subsidies to support consumers in the face of price changes abroad. However, as of that year, and as a result of economic liberalization, oil prices in the country began to correlate directly with changes in international oil prices, therefore it was decided that the Ministry of Mines and Energy would be the competent authority for setting prices of petroleum-derived liquid fuels.

The Colombian Ministry of Mines and Energy, therefore, would establish through Resolution 4-1281 of 2016 the pricing structure for liquid fuels distributed throughout the country, with the exception of municipalities and departments that are free trade zones. Within this structural framework, Components such as the maximum selling price to the wholesale distributor (PMM), the maximum selling price in the wholesale supply plant (PMA), and the selling price per gallon to the public (PVP) stand out.

In addition, the Ministry of Finance and Public Credit, in collaboration with the Ministries of Mines and Energy, was charged with the function of stabilizing fuel prices for Colombian customers through the Fuel Price Stabilization Fund (FEPC). Essentially, its main goal is to lessen the effects of changes in fuel prices on the Colombian market. As a result, it is in charge of balancing the gap between

international and domestic fuel prices and paying producers and importers the difference with funds from the national general budget.

Despite the fact that this fund prevents fuel prices from unexpectedly rising and sector inflation from going out of control, as shown in Figure.45 and data from the Ministry of Mines and Energy (See attachment), the price of gasoline has been gradually rising since 2020 in order to reduce the fund's current deficit.

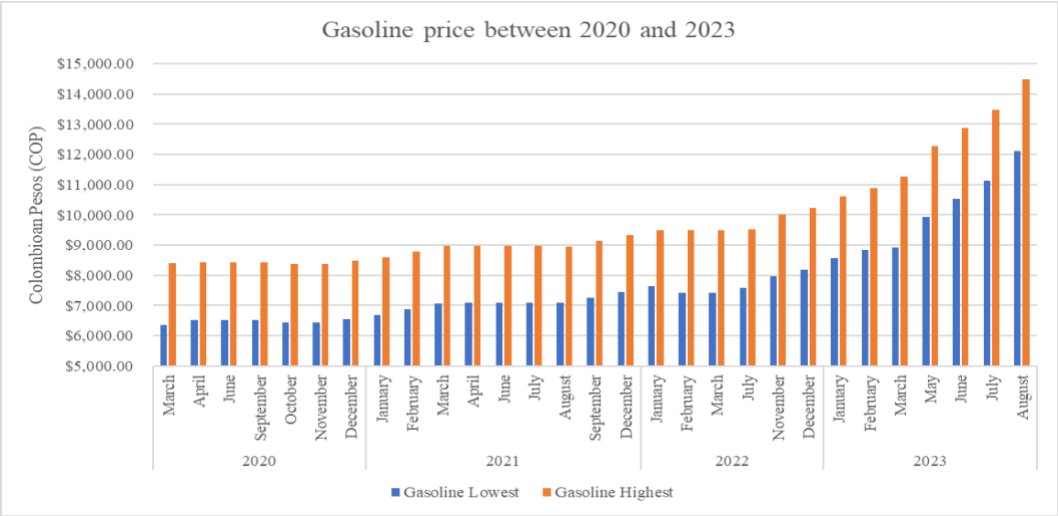

Figure 45. Gasoline Price Behavior between 2020 and 2023

According to the Ministry of Labor, when comparing the price of gasoline to the current legal minimum wage (including transportation allowance) associated with each year in question, the price of a gallon of gasoline for the month of September 2020, when the legal minimum wage was $980, 657 cop, was between 0.7% and 0.9% of each person's salary, while for the month of August 2023, when the salary was $1,300,606 cop, the price of a gallon of gasoline would already be between 0.9% and 1.1%.

It is important to note that if we use the value of the dollar as of the initial trading day of each month in the corresponding year, the impact is not as pronounced because, as the price of gasoline has risen, the value of the Colombian peso has declined, meaning that we now need more Colombian pesos to buy one dollar. As a result, the price of gasoline expressed in dollars has risen only slightly. As an example, the information below is provided: In Colombian pesos, one dollar (1 USD) was worth $3,539 in March 2020, $3,953 in December 2021, and $4,975 in November 2022.

On the basis of the premise that an average personal vehicle consumes 12 gallons of fuel and that the tank needs to be filled twice a month, we can calculate that in 2020, a person would need to set aside between 16 and 21% of his or her salary, and in 2023, the range would increase to 22 and 27%. When we compare this data to that of the United States, we can see how high the impact of gasoline prices is in Colombia, since, according to the Energy Information Administration (EIA) [60], spending on gasoline as a percentage of personal disposable income, in the US, (after taxes) has remained between 2.4% and 4.2% over the last 20 years.

Let us not forget that when the country is faced with an increase in gasoline, it automatically starts to produce adverse effects that immediately affect the country. In general, transportation becomes more expensive, which consequently drives inflation, increases inequality, increases the price of goods, including food and consumables, people begin to demand a wage increase, social demonstrations are generated, among others.

Furthermore, we should be aware that even though these organizations are in charge of setting and controlling the nation's oil prices, factors that are internal and external also have an impact. These elements include:

- Supply and demand on a domestic and international scale (more details in the following section).
- Political disputes between nations or regions that produce. (The conflict between Russia and Ukraine is an excellent example.)
- Events related to climate, the economy, and public health (ex. Covid-19).
- Fiscal policies (imposition of taxes and royalties to the industry).
- Transportation infrastructure, where prices may be higher or lower depending on the ease of access to the location.
- The dollar's movement in relation to the Colombian peso. (More details in the following section).
- Among others.

It is vital to highlight that it would be ideal to expand this research in the future and incorporate numerous variables of the country's oil pricing behavior in this work. Although it will not be discussed extensively due to its huge framework and adherence to the goals of this research, it is critical to present an overview without diving too deeply, therefore some of the above topics will be covered in the next section.

CHAPTER 5

5 FINAL CONSIDERATIONS

In order to close the analysis of oil in Colombia, it is considered important to dedicate this chapter to address the importance of this sector in the country's economy, as well as to explain how different factors such as the relationship between the price of oil and the dollar, and geopolitical factors affect the national economy.

5.1 Importance of oil in Colombia

As we have shown throughout this essay, the oil industry is significant not just on a worldwide scale but also in countries that produce and export oil. In the case of Colombia, it accounts for a significant portion of the total income associated with the country's exports, is an undisputed source of fiscal income for the government, creates a lot of direct and indirect jobs for the country's citizens, promotes technological and industrial growth, and is an undisputed source of energy for a number of industries, among which transportation assumes a greater significance.

When we consider the value of oil to the nation generally in terms of its financial contribution, we have:

- **Exports:** As was already mentioned, oil is currently the country's principal export product and a significant source of foreign exchange earnings.
- **Gross Domestic Product:** Given that the gross domestic product (GDP) is a metric used to measure both the state of an economy and the output of a nation's productive activity, we can say that the oil industry contributed 1.3% to Colombia's GDP in 2022, as reported by DANE, and that this percentage is predicted to rise to 2.6% in 2023 according to Fedesarrollo[7].
    - Let's not forget that a positive GDP can be understood as an instance of economic growth, which encourages investing, job creation, development, etc.

[7] Non-governmental organization dedicated to the investigation of political, economic, and social issues with the goal of positively contributing to Colombia's political, economic, and social growth.

- **Tax Collection:** According to the National Directorate of Taxes and Customs of Colombia (Dian[8]) [61], the amount of Colombian pesos collected in taxes in 2022 was $228.60 billion, with the oil industry accounting for 7.9%.
    - Let us also recall that tax collection is the primary means through which the state acquires money for maintenance, planning, and achievement of its goals.
- **Royalties:** Taking into account that royalties are the payment made by oil and mining companies to the Colombian State for exploiting deposits of a non-renewable natural resource, it can be said that according to The National Planning Department (DNP) the country received royalties totaling $17.08 trillion Colombian pesos [62], which were then used by the state to solve needs such as basic education, health, drinking water and sewage, as well as to finance large projects that promote growth and progress in the region.
- **Foreign Investment:** is a valuable source of resources that, in addition to financing national economic growth, promotes international trade, increases employment opportunities, enhances national competitiveness, fosters industry development and supports technological advancement.

  For this reason, oil being the economic engine of the country, it represents to a great extent one of the reasons why investors decide to look at Colombia. Even, to be more specific, The Central Bank of Colombia's Report on Foreign Exchange Balance states that in terms of foreign direct investment, in 2022, investments reached up to $11,304 million dollars, with 72% of that amount coming from the mining and oil industries.

Now, if we approach it from a perspective that is less centered on monetary resources, we have:

- **Generation of employment:** In general, according to the executive president of the Colombian Chamber of Petroleum Goods and Services (Campetrol), this industry is thought to produce about 120,000 direct jobs (in exploration and production) and five more indirect jobs for every direct job that is created.
    - If we take into account the employment produced by the resources offered by this hydrocarbon sector for products and services at the regional and national level, the number of jobs will undoubtedly change.

[8] The goal of this administrative entity is to safeguard the national public economic order as well as the fiscal security of the Colombian State.

- **Consumption:** In accordance with data collected by the Colombian Oil & Gas Association (ACP) between January 2022 and July 2022, Colombia consumed about 428 million gallons of fuel per month, of which slightly more than 46% was oxygenated gasoline, 45% was a mixture of diesel and biodiesel, and the remaining percentage was gasoline for airplanes.
    - Even according to the Mining and Energy Planning Unit (UPME), the country falls short on a scale of what is produced versus what is consumed, because the total production capacity of the two refineries serving the country currently corresponds to 74.7% of what is consumed.
- **Industries Functioning:** As has been mentioned repeatedly, petroleum derivatives serve as the foundation for many of the products that Colombians and people all over the world use on a daily basis. They even directly affect how many industries run effectively. A few of the numerous examples that already exist include the manufacture of medical supplies, the production of pesticides for agriculture, the production of lubricants for machinery, and the production of various textile inputs as well as others. In general terms, it can be said that many companies depend on oil, regardless of the sector in which they operate.

As we can see, oil has a wide range of factors whose contribution is indispensable for the country; however, this complex industry, which in one way or another has taken hold and has become the driving force of this nation, is to a great extent linked to and affected by different external events, which, depending on their magnitude, can positively or negatively affect the Colombian economy.

5.2 Relationship between oil and the U.S. dollar in the Colombian economy.

As we all know, the U.S. dollar is currently the most often utilized currency in operations involving international trade. This dependence on currency volatility makes this scenario a risk for both importers and exporters of Colombian goods. Also, within the Colombian economy's close relationship between the price of oil and the dollar, we may find various interrelated elements whose impact plays a critical role.

Despite the fact that the behavior of the dollar and oil prices is not a function of market forces but rather a consequence of economic policies adopted by the world's major economies, the dollar's value and commodity prices, including the cost of a barrel of

oil, have historically shown an inverse correlation. This inverse correlation shows that when the US dollar strengthens against other major currencies, commodity prices tend to fall. In turn, when the currency weakens, commodities prices rise.

Having said that, and taking into account the aforementioned relationship, we must know that in order to comprehend why these two variables present a dependence relationship that affects the Colombian economy, it is critical that we turn our attention to the problem of oil supply and demand determined by the market. To put it simply, we have that:

- The price of the product will rise if demand for oil rises while supply either stays the same or declines. As a result, exporters from Colombia will receive more dollars for the same amount of oil (Shortage/excess of demand).
- The price of the commodity will reduce if the demand for oil declines while the supply stays the same or grows. This implies that for a certain amount of oil, Colombian exporters will receive less Dollars (Surplus/excess of supply).

In general, when the price of oil rises on global markets, the value of the dollar falls in the Colombian economy. This is due to an increase in the amount of dollars entering the nation as a result of exports. As a result, there is an increase in the amount of capital available to invest in this industry, as well as an increase in the national budget to invest in programs and projects. The opposite scenario occurs when the market price of crude oil declines, lowering the amount of dollars available to the economy.

Overall, it can be said that this close relationship, which is distinguished by its complexity and multifaceted nature, has created an intrinsic link in the Colombian economy to global oil and currency movements, where its high dependence on export revenues gives a way to a direct impact on inflation, the national budget and other aspects of the economy.

5.3 What would happen if Colombia stops oil exploration (as proposed by the President Gustavo Petro)?

Another scenario that is essential to cover is the present situation in the country. The current president of Colombia, Gustavo Petro, who was running for president at the time, told the nation he intended to decarbonize the industry and get Colombia off its reliance on oil as its economic engine. These declarations generated a variety of responses from businesses as well as individuals, which caused the nation to consider the premise: what would happen if we stopped depending on oil?

It's crucial to cite a section of the current president's government proposal before moving on to this subject [63]:

"*We will move Colombia from a primary energy matrix, predominantly fossil fuels, economically dependent on coal and oil, to a diversified one, based on our renewable energy potential, which are the best energy sources to face climate change and strengthen the country's capacities for a productive economy. Our government will lay the foundations for this transition through a gradual de-escalation of the extractivist model and guaranteeing the reliability and stability of the energy system, sources of employment and economic resources from the sector. An inclusive and fair energy transition model for the people.*"

"*Ecopetrol will have a leading role in the transition, it will remain as Colombians' patrimony to guarantee the fuels that the country requires for the next 15 years, make contributions in inputs and derivatives for petrochemicals, comprehensively support research, science and development of technologies for the transition to clean energy and will contribute with taxes, royalties and dividends to the State.*"

In general, depending on the point of view from which it is assessed, a position can be taken in relation to what the then-presidential candidate presented. According to the president, who is more concerned with the global warming crisis, "we have to build another concept of wealth because wealth cannot be measured in CO2 equivalent and that only leads us to disaster" [64]. Essentially, the concept involves shifting capital production forms through an energy transition to clean energies based on the sun, wind, and water.

What the president is recommending is, to a significant extent, highly valid, starting mainly because the country already has some experience in the field of renewable energies. According to the Latin American Energy Organization (Olade), Colombia currently has the sixth cleanest energy matrix in the world and is the third most advanced region in energy transition in all of South and Central America, taking advantage of its landscapes to produce about 68% of its electricity from 33 hydroelectric plants.

In a similar vein, considering it from an environmental perspective, according to data from the United States Environmental Protection Agency (EPA), the primary source of greenhouse gas emissions worldwide is the burning of coal, natural gas, and oil for heat and electricity. Also, four experts in energy and renewable resources from University College London (UCL) have calculated that in order to prevent the average

global temperature from rising by 1.5 ºC (as stipulated in the global climate target set in the Paris agreement), the proportion of oil and gas that should cease to be used (without even extracting it from the ground), at least until 2050, would be almost 60%, in addition to reducing production worldwide by 3% each year until the aforementioned year.

On the contrary, from the population and industries point of view, this proposal would not be well received since oil has evolved over time into the nation's economic engine, bringing in even more revenue than coffee and serving as a source of income for the regions through royalties from its exploitation or tax contributions.

As previously noted, Colombia's main source of foreign currency comes from oil. Let's not forget that oil is the most exported good in the nation, bringing in around $11.3 million dollars from international trade activities, $17 billion in royalties, and in 2022, accounted for about 33% of total Colombian sales abroad.

It should be noted that if this decarbonization of the economy were to start, there would currently, according to former Minister of Mines Amylkar Acosta, be no other source of income that could make up for those earnings that would no longer be received.

Additionally, as discussed in chapters 4.1 and 4.2 of the country's oil reserves and production, some regions of Colombia are solely dedicated to oil extraction and production; three departments in the Orinoquia region have 77% of the proven oil reserves, as well as 80% of the most significant productive fields for Colombia; as a result, the region's economy would suffer straight away if the sector were to cease operations down.

Let's now examine what would occur to imports and exports if the President's plan were to be approved. If oil exploration activities are suspended in the country, there would be an imminent risk of losing Colombia's energy sufficiency and capacity. This would imply, as stated by Julio Cesar Vera, President of the Xua Energy Foundation, that Colombia would be forced to rely on external nations for its own supply, at least for the next 40 years, in which the hydrocarbon sector will continue to play a crucial and fundamental role in the world. As a result of this dependence, imports would rise and exports would correspondingly decline, increasing the deficit value of the trade balance.

Furthermore, in addition to the fact that the Colombian peso is currently undergoing a significant devaluation against the U.S. dollar, this would have an immediate effect on imports by driving up the cost of goods and services, on foreign investment by

making investors cautious of making large capital losses by staying in a nation where the local currency is depreciating, and on the country's current account because it would result in a rise in the amount of foreign debt needed to meet obligations.

What would happen to exports? The Colombian economy would contract by 2.6% (based on the predictions of the oil sector's contribution to the GDP in 2023) as a result of a gradual decline in the activity that brings in the greatest amount of money for the nation, which would consequently reduce the nation's income, which is used as funds for national development and to address social problems.

Therefore, without diminishing the importance of either point of view, and taking into account that the world does, in fact, require a transition to renewable energies in order to reduce the negative impact of the oil sector, it is crucial that Colombia and other nations interested in making an energy transition, look for alternatives to diversify their own production and at the same time allow them to be competitive globally, while implementing a responsible and sustainable transition without endangering the country's energy security.

CHAPTER 6

6 CONCLUSIONS

Petroleum, a product with a 6,000-year history has grown steadily to become one of the most significant commodities in the world, to the point of creating global dependence not only as a source of energy but also as the foundation for a wide range of goods that are essential to people's daily lives. From fossil fuels, which are necessary for the production of electricity, transportation, and industry, to petrochemicals, which are used to make plastics, fertilizers, synthetic textiles, medicines, home appliances, cosmetics, and even processed foods.

So much so that changes in the price of oil have a direct effect on the world economy, affecting inflation or promoting economic growth. Similarly, geopolitical stability, meteorological events, and public health events in oil-producing countries become crucial in prompting increases or declines in the pricing of this product due to the global interconnection, in terms of supply and demand, that has been formed around the world.

Like many of the industry's current products, its supply chain is sophisticated and essential to both the health of the world's economy and the environment. From processes like oil field extraction to the distribution of oil products to final customers, there are considerable obstacles connected to geopolitics, security, and the environment. The importance of the supply chain is such that, although oil has become the main driver of the economies of many countries, paradoxically, the largest producers and those with the greatest refining capacity are not necessarily those with the largest reserves.

For this reason, the constant adaptation to new technologies, and the good relationship with world powerful countries, has been responsible for removing and putting countries in the sights of this oil industry, as is the final the case of Colombia. Over time, Colombia has grown in importance in the oil industry. Despite the fact that, for a variety of security reasons, criminal groups have impacted the country's supply chain, endangering the country's health, environment, and economy, Colombia has been able to overcome its challenges and has managed to position itself as the world's #65 importer and #19 exporter of oil, making oil its economic engine and allowing it to play a crucial role in the nation.

Despite the fact that the quantity of reserves and their production have been declining since 2013 due to a variety of factors, including the dependence and volatility of international oil prices, the nation has made sizable investments in exploration, looking for new oil reserves in previously unexplored areas, as well as in the refining and production of this product, which in the long term are essential both for attracting foreign investment and to continue promoting the growth of production in the country and consequently its economy.

Nonetheless, although the commercialization of this finite resource is the country's largest source of income, contributing to economic and social development, its negative impact on the natural environment, biodiversity, and local communities that rely on the resources affected by exploitation or oil spill, has highlighted various challenges in order to move towards a more sustainable future. Among these is President Gustavo Petro's proposal, which continues to be a priority not only for Colombia but for the entire world, to diversify energy sources and reduce reliance on oil through a transition to cleaner and renewable energy sources.

However, it is crucial that plans for the development of the energy transition are implemented gradually and responsibly, allowing the country to maintain its competitiveness in international markets without endangering energy security or the economy. Thus, when talking about the future prospects of the oil industry in Colombia, several factors such as investment in exploration and production will be relevant, but it will be the challenge of balancing, hand in hand with investment in technology, these factors with the protection of the environment, who will define how the industry will adapt to the global environment and move towards a sustainable future…

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