

# Fracking as a guarantee of Energy Security in countries with low conventional oil reserves

## Fracking como garantía de Seguridad Energética en países con bajas reservas de petróleo convencional

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### Abstract

**Introduction**— Fracking is one of the most recent techniques presented by the hydrocarbon industry to guarantee the extraction of oil from non-conventional fields and thus maintain the energy security of many countries such as the United States, China, Canada, and even is one of the potential practices in Colombia. Although it is a promising technique because of its advanced level of engineering, its impacts, and environmental effects are today a subject of debate partly due to limited information and limited detailed research on the consequences.

**Objective**— This article presents the generalities of the technique, a historical timeline, advantages and disadvantages of the implementation, successful cases, and the implications on the environment.

**Methodology**— This is achieved through a review and classification of information from studies and research developed in the world on the named technique.

**Results**— The advantages are clear: increase in proven reserves, energy independence, increased employment, economic development, among others.

**Conclusions**— There are disadvantages such as excessive use of water, use of toxic additives, generation of earthquakes, and negative environmental effects. All of the above is related to previous investigations carried out with fracking.

**Keywords**— Oil; economy; environmental impact; water; improved recovery; fracking

### Resumen

**Introducción**— El fracking es una de las técnicas más recientes que ha presentado la industria de los hidrocarburos para garantizar la extracción de petróleo de yacimientos no convencionales y con ello mantener la seguridad energética de muchos países como Estados Unidos, China, Canadá e incluso es una de las técnicas potenciales en Colombia. Aunque es una técnica prometedora por su nivel avanzado de ingeniería; sus impactos y afectaciones ambientales son hoy en día un tema de debate en parte a la información limitada y poca investigación detallada en las consecuencias.

**Objetivo**— El presente artículo expone las generalidades de la técnica, una línea de tiempo histórica, ventajas y desventajas de la implementación, casos exitosos y las implicaciones en el ambiente.

**Metodología**— Lo anterior se logra mediante una revisión y clasificación de información de estudios e investigaciones desarrolladas en el mundo sobre la técnica nombrada.

**Resultados**— Las ventajas son claras, aumento en reservas probadas, independencia energética, aumento de empleo, desarrollo económico, entre otros.

**Conclusiones**— Se presentan desventajas como el uso excesivo de agua, empleo de aditivos tóxicos, producción de sismos y efectos ambientales negativos. Todo lo anterior relacionado con investigaciones previas realizadas en relación al fracking.

**Palabras clave**— Petróleo; economía; impacto ambiental; agua; recuperación mejorada; fracking

## I. INTRODUCTION

Oil represents almost 40% of the energy consumed globally. It is the fuel that makes it possible for the world to be as we know it [1]. Obtaining the fossil resource from the subsoil and its subsequent treatment has allowed humanity to have a remarkable development. Products such as gasoline and kerosene have revolutionized society's survival instinct and, if not available, could lead humanity to stagnation in terms of energy development.

In 2001, a 40.3-years of hydrocarbon reserves worldwide is reported [2]. For 2014, a 54-years of hydrocarbon reserves worldwide is reported, if oil production remain constant [3]. However, with increasing reserves comes a growth in population and greater development in the industry, increasing the demand for oil and gas.

Known as hydraulic fracturing, fracking is currently the most widely used technique in the oil industry, particularly in the United States, for the recovery of hydrocarbons from unconventional fields [4]. This technique was developed as a result of the ever more pronounced decline in conventional oil reserves, on which humanity has long relied, not only in the energy sector but also in other industries unrelated to it. Since the crisis of 2008, the application of this practice has stimulated economic growth in the United States [5], making it today the largest producer of hydrocarbons worldwide, and partially guaranteeing its energy security, besides proposing the vision of a potential exporter in 2030 [6], which will bring about positive socio-economic effects, related to the increase of jobs and the economic development of the country.

Hydraulic fracturing is not a new technique for the oil industry, developed approximately 100 years ago [7]; it has played a greater role in recent years, due to the difficulty of finding reservoirs with petrophysical properties suitable for the exploitation of hydrocarbons. However, society often relates this technique to problems such as water quality and availability, air quality, soil, greenhouse gas emissions, ecosystem integrity, and human health impacts [8]. These cause the technique to have a confrontation between the positive and negative side effects of oil reserve extraction. Once described, a question arises on which the present paper revolves: are the effects of fracking on soils, bodies of water, and human health justifiable to maintain energy security?

To answer this question, we will first discuss the technical details of fracking, based on its background, and then analyze the context of its development, from the causes and consequences of its use and finally compare its advantages and disadvantages, from where we can draw alternatives for its use as a conclusion.

## II. METHODOLOGY

The methodology used for this article is conducted through the collection of documents with pertinent information found in databases such as Science Direct, OnePetro, Google Scholar, Legis and EBSCO HOST, along with the use of different search engines. The study begins with an analysis of the historical period of publications related to hydraulic fracturing followed by an analysis of statistical distribution by language, type of document and country of publication.

### A. Historical Period

For the analysis of the historical period, the SCOPUS database is taken as a reference, which allows the collection of information from scientific articles and books, as well as the graphic representation of the results according to the use of Boolean operators using the key words and other filters such as the central theme, the type of document, the language and the year of publication. Next, Fig. 1 shows the graph of the historical period obtained through SCOPUS.

According to this figure, there is information about the technique since 1989, however, in the following years, no articles are published about this technique but from 2007. For this document, the information published between 2009 and 2020 is analyzed.

In Fig. 1, an increase in the research development around fracking is shown. In the scientific databases, there are documents related to this technique, addressing issues such as its origin, the political, economic, social, and environmental impact, and the development of new technologies that reduce environmental impact.

Documents by year

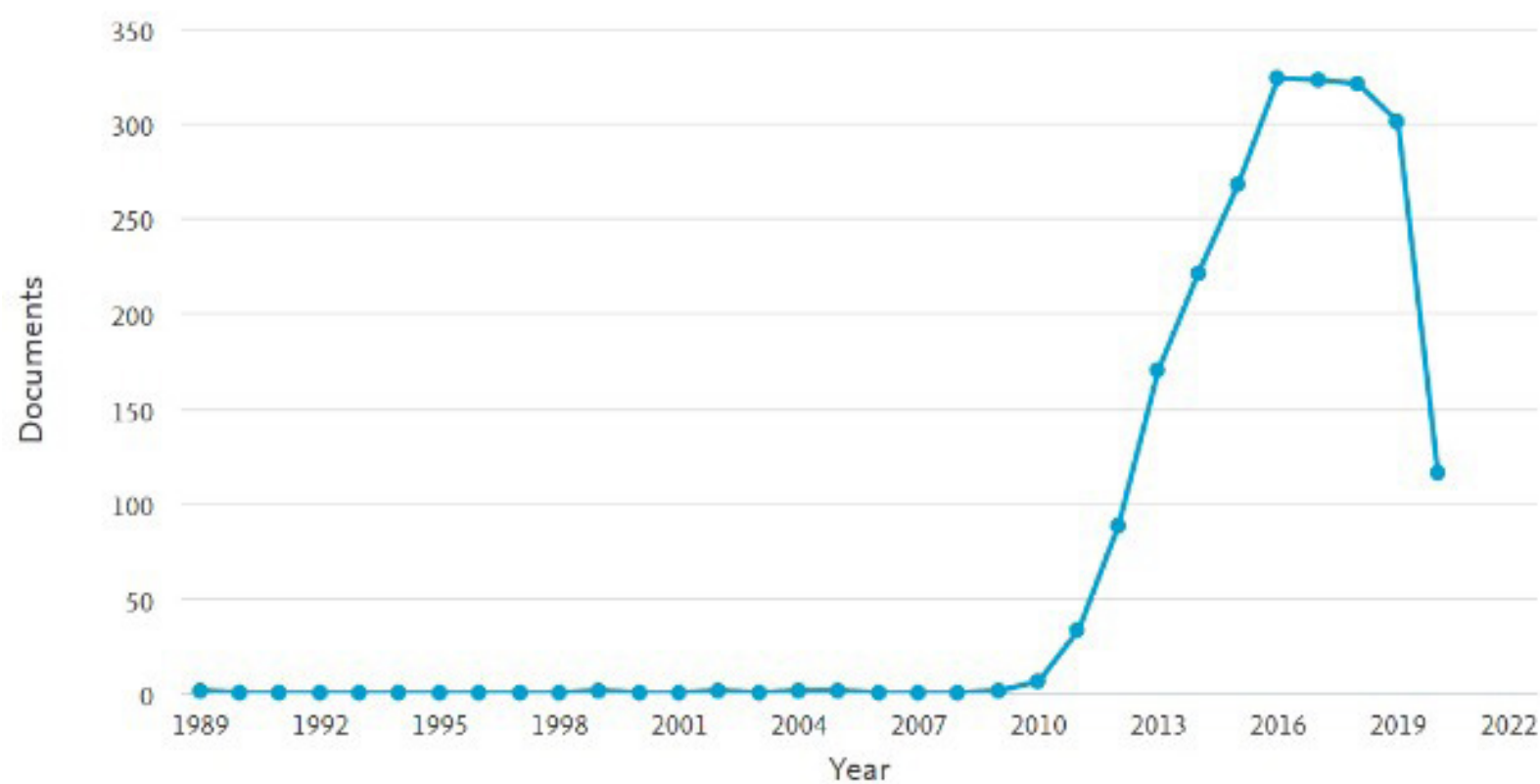


Fig. 1. Historical period of research on fracking.  
Source: Scopus, consulted on June 25, 2020.

### B. Distribution by Language

To search for information, the keywords described at the beginning of this writing are taken into account, in addition to a time interval from 2010 to the present. 69 documents are selected from different databases: Science Direct, Google Scholar, OnePetro, Legis and EBSCO Host, which are related to the technique. The percentage of distribution by language can be seen in Fig. 2.

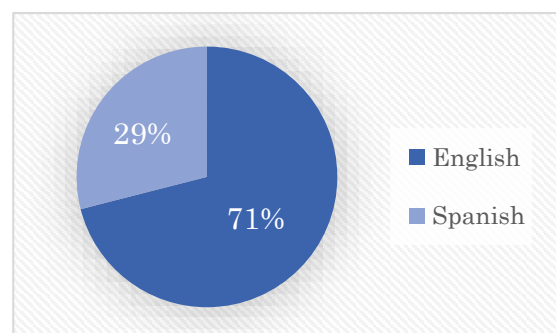


Fig. 2. Distribution by language.  
Source: Own elaboration.

In Fig. 2, it can be seen that the predominant language in fracking is English, with a 71% share coming from 49 documents, while Spanish has a 29% share in 20 documents. English is the most common language because the fracking technique comes from the United States, where it originated. However, information is available in Spanish because there are Spanish-speaking countries with reserves of unconventional deposits with feasibility studies, such as Argentina, with the Vaca Muerta field, one of the largest unconventional deposits in the world [9].

To choose the documents by language, a comparative analysis is made between scientific documents that provide truthful information depending on the context and place of origin. For example, to talk about fracking in Colombia, a compilation of documents must be made that deal with case studies from said country, which are generally in Spanish. But if it is about scientific information on the technique, this information must come mainly from countries where fracking has been developed for several years, which usually generate information in English, since this is considered a universal language.

### C. Distribution by Type of Document

Fig. 3 shows the distribution of the information found for the development of the topic according to the type of document in the databases consulted.

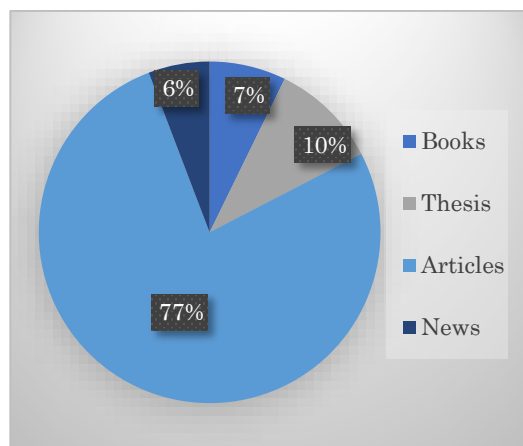


Fig. 3. Distribution by type of document.  
Source: Own elaboration.

According to Fig. 3, most of the documents recovered come from articles, because this type of document is published more frequently than a book. For this research, 53 documents were recovered from articles, with a 77% participation. The theses propose new technologies that aim to increase economic profitability or decrease environmental impact. In this document, there is information about seven degree projects, with a participation of 10%. To a lesser extent, there are news and books. Within the information gathered, there is a 6% participation from news, and 7% from books, which contain the concepts and generalities referring to fracking.

### D. Distribution by country

Fig. 4 below shows the distribution according to the number of documents published by country from 2007 onwards.

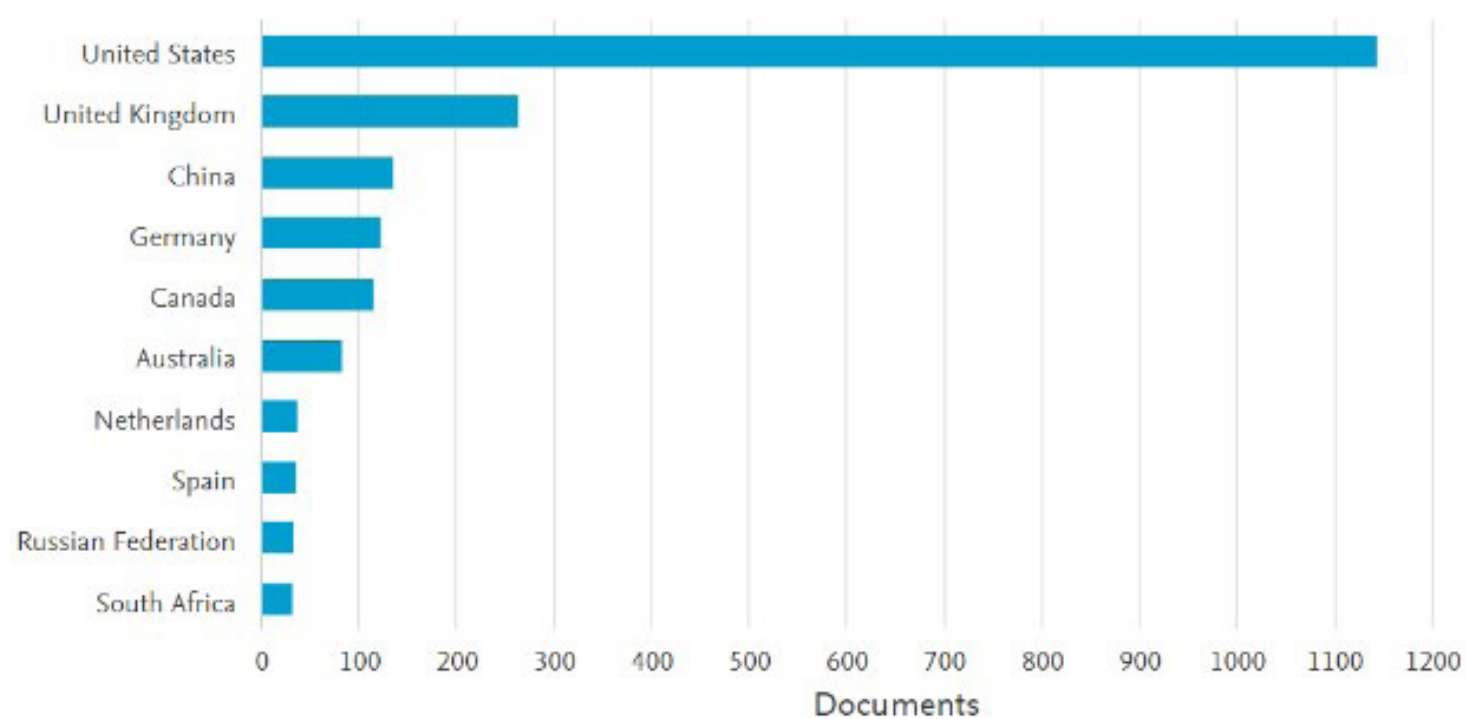


Fig. 4. Distribution by number of documents published by country.  
Source: Scopus, consulted on June 25, 2020.

According to Fig. 4, it can be seen that the United States heads the list with the highest number of published articles related to fracking. This is because this country invented and developed this technique to increase its reserves and become one of the largest hydrocarbon producers in the world.

Another country with the largest number of published documents is China because it is one of the largest importers of crude oil due to its low perspective. However, according to several studies, large reserves of oil and gas from oil shale have been found.

Canada, like China, is another country that has found a high amount of hydrocarbon reserves from unconventional fields. For this reason, they also study the viability and publish scientific articles related to the subject. Those two countries mentioned are mostly importers of this energy resource; but since they have deposits suitable for exploitation by means of hydraulic fracturing, they are studying how to reduce imports and generate greater energy independence through innovative techniques that will be presented throughout this article.

In Australia, Netherlands, Spain, Russian Federation and South Africa, less than one hundred documents have been published so far in 2020, however, the presence of hydrocarbons trapped by poor petrophysical properties means that technical-financial feasibility studies have to be carried out for the exploitation of non-conventional fields by hydraulic fracturing.

### III. DEVELOPMENT

This review article aims to take advantage of the research contribution of the documents consulted, to show aspects such as the generalities of fracking, its history, advantages and disadvantages, some success stories in energy, and finally, its environmental effects.

#### A. Generalities of Fracking

To address the issue of fracking, some concepts must be taken into account. Fracking, commonly known as hydraulic fracturing, is used in non-conventional deposits. These are deposits in which the generating rock is the same storage rock, that is, it is a shale with a high organic matter content. Since it is composed of shale, it does not contain a good connection between pores, which hinders the flow of hydrocarbons through the rock [10]. The main difference regarding a conventional deposit is that the latter has a storage rock composed of sedimentary permeable rocks that allow the flow of gas and oil [11].

Unconventional deposits have other subclassifications depending on the origin. Shale gas, also known as shale gas or lutite gas, is the gas trapped in the pores of clayey rocks that form the bedrock in the petroleum system. They are generally found at a depth between 3900 and 13100 feet [12]. Tight gas, known as compact sand gas, is found in formations with permeabilities below 1 mD and porosities between 3% and 10%. It is associated with almost cemented carbonate formations that hinder the flow of gas. This type of deposit is found at depths between 20000 and 21000 feet [13], however, being at such a high depth and degree of compaction, it has a low production yield. Coal Bed Methane is methane gas trapped in coal beds. This type of gas is found at depths between 500 and 10000 feet [14], it is also mentioned that they generate a lower production when exceeding 7000 feet deep due to the decrease in permeability of the formation.

Fig. 5 shows the exploitation of a conventional deposit, while Fig. 6 shows the exploitation of unconventional reservoirs.

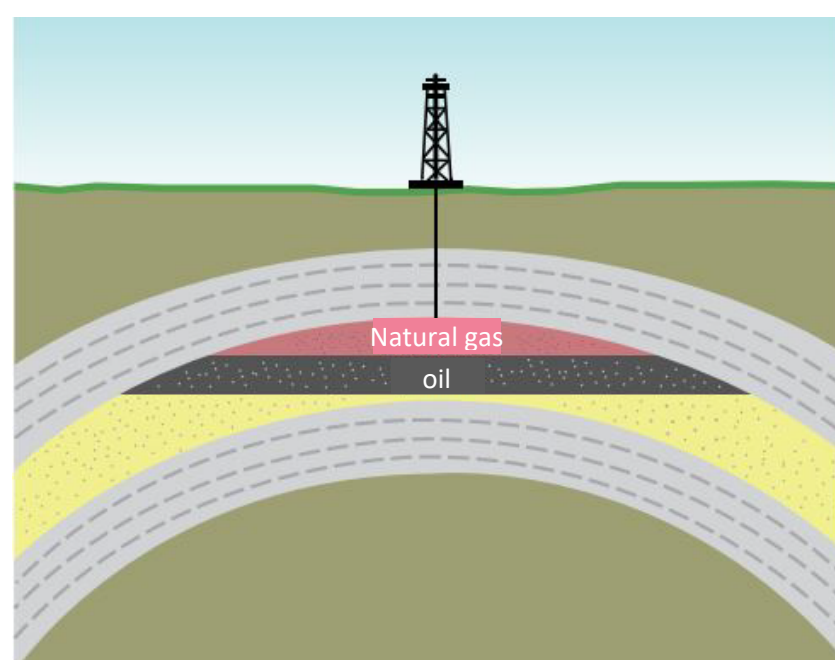


Fig. 5. Conventional Hydrocarbon Reservoir.  
Source: [12].

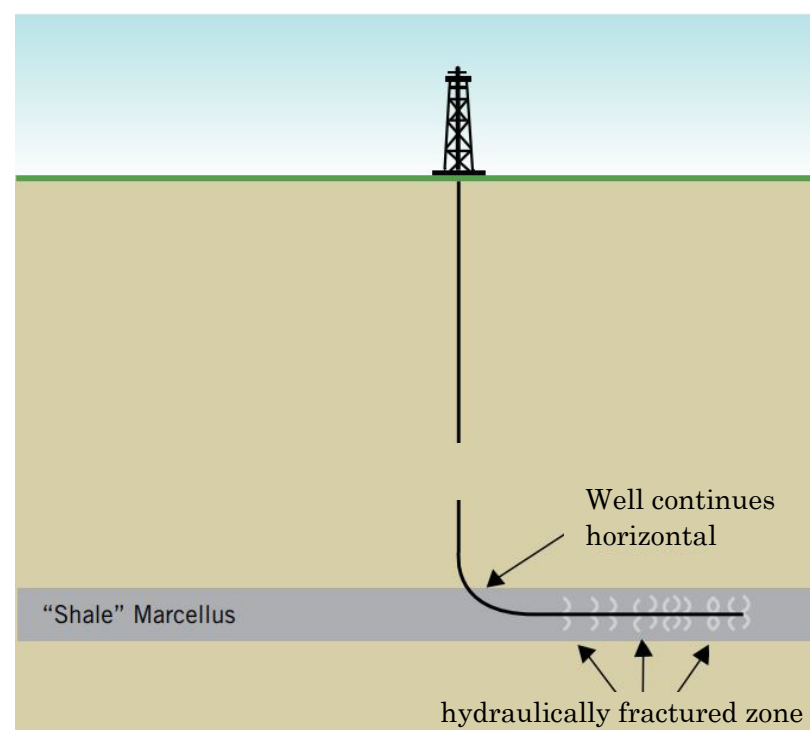


Fig. 6. Unconventional hydrocarbon reservoir.  
Source: [12].

Fig. 5 shows the conventional hydrocarbon extraction technique, in which the fluid is in a system composed of a source rock, a storage rock and a seal rock [12]. On the other hand, hydraulic fracturing or fracking, in Fig. 6, is the extraction technique for non-conventional hydrocarbons, which is developed through six phases. Initially, in the exploration phase, the amount of gas trapped in a formation and its economic profitability is determined; different techniques are used, but the most common is the three-dimensional seismic method through the use of dynamite cartridges on the surface, which are spaced from 5 to 20 meters [15], with the image obtained from this process, the direction of drilling is defined to reach the prospect zones. The next phase, called construction, is where the drilling platform is located and 100 to 150 trucks are used to transport equipment and another 100 to 1000 trucks to load fluids and chemical additives [16]. The third phase is drilling. Horizontal drilling is done in a layer of rock, the shales that form the unconventional deposits are generally found at depths between 1500 and 2000 meters [17]. For the fourth phase, which is hydraulic stimulation, a process of injection of a mixture of water, sand, and other chemicals is made, which generates a fracture and allows the flow of fluids through the rock [18]. The mixture that will be pressurized at the bottom of the well is composed of approximately 99% water and sand, which acts as a propping agent [19], while 0.5% is a mixture of hybrid chemical ingredients that perform additional functions during the fracture process [20]. The fractures that are generated must be amplified to generate more channel connections to have a bigger flow area, therefore, it is required to pump the mixture at pressures between 345 and 690 atmospheres, depending on the depth of the formation. In the fifth phase or production and distribution phase, the gas produced is separated by a three-phase separator, then treated and finally distributed through pipelines. The sixth and final phase is the well completion, in which the well is cemented according to abandonment protocols; after production is exhausted.

In addition to the previous phases, new technologies have been developed that allow the extraction of oil or gas from non-conventional fields with increased profitability or decreased environmental impact. One of the technologies is high-volume fracturing, in which each well fractures 15 to 20 consecutive times [21], and up to six independently working wells are produced from a single platform. Another technique being developed for the production of heavy oil is catalytic hydrogenation [22], which consists of an injection of nanofluid that reduces the activation energy, and when the hydrogenation is generated, which is exothermic, the viscosity is reduced to between 95% and 96% of its original value [23]. In China, an innovative technique was presented that ensures less environmental impact as well as a reduction in the cost of used water; the technique consists of injecting liquid nitrogen at  $-196^{\circ}\text{C}$  that generates a thermal shock at the bottom of the well, which generates fractures and a better connection between them [24], however, several recirculations are required to generate the expected fractures. Other techniques developed over time are Slickwater fracking, which uses larger quantities of water with

surfactants and lubricants to create longer horizontal fractures; the Movable Sleeves is a tube that generates the fracture and allows only the return of gas; the HiWAY process, patented by Schlumberger, creates larger cracks using less water and sand than fracking; and RapidFrac, which consists of fracturing the formations horizontally and then injecting fluids to ensure that neighboring rocks are also fractured [25]. It is claimed that this process is cheaper and faster than fracking. This type of practices is characteristic of lutite-type rocks [26], due to their high degree of compaction.

### B. *History of Fracking*

The trend in recent years is for emerging and developed countries to increase their consumption of natural gas [27]. With an upward consumption, proven oil reserves must also be increased, because it is a non-renewable resource. That's why companies are opting to extract oil from unconventional fields.

The first time the word "fracking" appears is on October 12, 1953, which originated in the hydrocarbon industry itself. On that date, an article was published in the Oil & Gas Journal entitled "Fracking, A New Exploratory Tool" [28]. However, this word was used five years after the technique was named "hydraulic fracturing," which was first mentioned in the same magazine on October 14, 1948.

The fracking technique was developed in the early 20th century in the United States; however, it was only applied until the mid-1940s. In that year, the extraction of natural gas was carried out in Grant County, Kansas, by the operating company Stanolind Oil [29]. However, that same year it was decided not to continue producing using the technique due to the low economic profitability. Later, in the 1970s, the United States launched a horizontal exploration research program, which concluded the technical aspects of fracking. In 2005 Barnett Shale began commercial production in Texas [30], with which hydrocarbons began to be extracted from non-conventional fields in the United States [31]. In 2011 the companies that applied the fracking technique in Wyoming were Halliburton, Devon Energy, and Chesapeake [4]. In 2012, an 8% increase in direct and indirect jobs was reported thanks to fracking [32]; in 2017, the United States applies the technique massively and is positioned as the largest producer of gas and oil in the world [6].

On the other hand, there have been various responses from governments: countries such as France and Bulgaria have a total ban on the operation, Austria and Lithuania have strengthened the regulations for the application of the technique [33], while Argentina is the country with the largest number of wells in production under fracking, with approximately 6 500 wells in operation [34]. The autonomy of governments is a critical variable in the development of techniques such as fracking in the oil industry because it can become their ally or, on the contrary, their principal opponent and determine the viability of a project that can bring energy benefits, translated into economic contributions for the populations or, on the contrary, a brake on operational development and even the abandonment of a production area, with considerable effects for the communities and the governments.

Hydraulic fracturing was created in response to the need to extract the high reserves of non-conventional hydrocarbons in, for example, the United States, with an approximate total of 23.4 billion cubic meters [35], and Argentina, with one of the largest formations in the world of approximately 30 000 square kilometers in oil shale tankers [36].

The reserves of these countries are based on shale gas present in the shale rocks, which are very low in porosity and permeability, making this extraction process costly and less productive than conventional explorations [37]. One of the reasons why the expansion of the hydraulic fracturing technique can be generated is the decrease of conventional oil and gas reserves worldwide [38] and the search for innovative exploitation techniques that allow the combination of operations already known [39], a condition that fracturing fulfills excellently. Humanity is heavily dependent on the consumption of fossil fuels, and although alternative energies are currently being sought, the use of oil and gas is considerable, that is, the demand for these sources is maintained; therefore, there is a need to continue exploiting this natural resource and with it the need to confront the new conditions in which the hydrocarbon is found and the requirements to convert it into an offer for consumers.

### C. Advantages and Disadvantages of Fracking

The advantages of fracking are vast. In the environmental context, this technique produces lower greenhouse gas emissions than the alternatives conventionally used in industry [40], concerning exploitable shale reserves, that is, non-conventional reserves, it has increased in recent decades a positive situation for the energy security of countries [41], especially for nations with low reserves, because this allows them to extend their energy sources [42]. This extension is important to countries' development since this makes them competitive internationally, allowing the economy to grow [43].

On the other hand, among the disadvantages associated with fracking, the main controversy is the high use of water to carry out the technique [44] and the possible generated seisms during and after its application [45].

In summary, Table 1 shows the main advantages and disadvantages of fracking.

TABLE 1. ADVANTAGES AND DISADVANTAGES OF FRACKING.

| Advantages   | Disadvantages   |
|--|---|
| Increases employment rates [46].   | Harmful to the environment [6].   |
| Reduces carbon emissions [40].   | Excessive water use [44].   |
| Positive impact on the country's economy [46].                             | Doubts about the presence of toxic and carcinogenic additives in the fluid, which affects the quality of life [12]. |
| Energy independence [43].  | Decreases the price of the barrel of oil due to over-supply [44].   |
| Water use is still lower than in other industries, such as livestock [43]. | Earthquakes may occur during and after fracking activities [45].  |

Source: Own elaboration [46], [6], [40], [44], [12], [43], [45].

By observing the advantages and disadvantages outlined in Table 1, the origin of the controversy about whether or not it is necessary to carry out the technique in countries that have large reserves of hydrocarbons from non-conventional fields is discussed. There are many situations supported: the improvement in the economy, a rise in the employment index, the useful life of the oil well, which can be up to 40 years [18]; is usually larger than a well that produces naturally; the care for the environment or the quality of life of ecosystems, the people and the stability of the subsoil and of the reservoir as such. Although there are cases in which fracking does not increase employability or decrease quality of life. There are several aspects that must be analyzed.

It should be considered that some of the advantages may have a short-term duration, for example, energy independence may be short-lived, due to the possibility of a production decline. Like some of the reported disadvantages, they are usually associated with a less serious effect. For example, excessive amounts of water are used, however, this water comes directly from the reservoir and not from surface sources, which makes the use of this type of water less worrying, since it is not consumable.

### D. Success Stories in the Energy Field

At present, Canada and the United States are the main countries exploiting unconventional deposits. These are characterized by not having a sedimentary rock as storage, but the hydrocarbon is stored directly in the pores of the seal rock, made up of clay, which must be fractured by techniques such as hydraulic fracturing, since it has poor petrophysical properties in as far as porosity and permeability are concerned. In 2015, approximately 668 reservoirs were reported, distributed in 142 sedimentary basins [25].

The U.S. House of Representatives aims to quantify the jobs created by the development of unconventional oil and gas fields, including in non-producing states such as Illinois, where fracking is reported to have created 38652 jobs in a 2012 campaign, almost as many as in Ohio, where fracking is underway. Wisconsin, Minnesota, and Michigan are among the top 10 non-producing states in the country in terms of fracking job creation. On the other hand, Ohio and North Dakota are among the top 10 producing states that create fracking-related jobs with 38830 and 71824 employees generated respectively, according to the study.



Texas tops the list with more than half a million jobs already created [46]. a total of 1.7 million jobs have been created, and it is projected to generate 3.5 million jobs by 2035 in direct and indirect jobs, associated with the exploitation of unconventional reservoirs. For the study, the IMPLAN model was developed, a tool that allows the quantification and prediction of direct, indirect, and induced jobs in each state. Direct jobs in producing states include construction, petroleum extraction, and metal manufacturing, and truck transportation. In non-producing states, jobs created include the manufacture of chemicals and electronics used for fracking, as well as financial and administrative services and real estate related to the properties. Induced jobs refer to wage spending by workers on goods and services that include health care, entertainment, food, and general merchandise. It should be clarified that the study does not relate the number of producing wells through techniques such as hydraulic fracturing, but only takes into account the number of jobs that were generated to improve the economic development of the country's states.

In China, research and feasibility studies are supported to carry out the technique through good practices and with responsibility, because, according to a report, in 2011, 70% of the total energy in that country was supplied by the use of coal and 4% came from natural gas. The idea of developing the fracking technique was thought since it presents a per capita consumption of 2.2 thousand cubic feet of gas per year; while in the United States the per capita consumption is approximately 77.4 thousand cubic feet of gas [47]; which led the Chinese government to create policies that promote the exploitation of gas reserves, given the potential of proven reserves coming from non-conventional fields, thus also increasing per capita gas consumption. The previous conditions such as the low consumption of gas per capita in China and the high prospecting of hydrocarbons from unconventional reservoirs, are added to the lack of environmental regulation, with which the use of the technique can be maximized by means of operating companies without waiting for a closure of activities.

#### *E. Environmental Effects*

The exploitation of subsoil resources always brings with its alterations and impacts that affect the environment [48]. It is relevant to study them because these changes tend to cut down the quality of life of ecosystems and the health of communities.

The effects produced on the soil are reflected in its contamination by the action of spills when executing procedures that fall within the technical scope. Many times, when a well is closed, the area is abandoned for restoration [18], but the spilled fluid can have such a high salinity that inhibits the growth of vegetation and affects potable aquifers [49]. Another impact on the soil is the landscape alteration, which affects the ecosystems of the species in the influence area [50]. However, the most controversial effect in the world is the generation and increase of seisms associated with fracking, which in some cases can be considered earthquakes [51], and undermine the stability of buildings. Thus, there is uncertainty since some scientists affirm the magnitude and intensity of vibrations generated by explosions at the bottom of wells are not considered as microseismic on the Richter scale [25]. Experts affirm that no direct relationship is found between fracking and the presence of earthquakes. However, the decrease in pore pressure can generate empty spaces that later become sinks, so it is necessary to inject the water produced on the surface to manage it at disposal.

About the pollution generated in the air, for example, the tendency to leak methane, which is a greenhouse gas, was initially given in 5% of the wells under this technique; after 30 years of work, 50% of the wells produce methane in high proportions [52]. The air that escapes into the atmosphere contributes to the weakening of the ozone layer; a phenomenon known as the greenhouse effect. However, these emissions must be monitored under legislative parameters [53]. Methane leaks are usually associated with several operations carried out during the completion of wells through which extraction will be made via the fracking technique. One of these operations is [54] drilling: during assembly and disassembly, there may be gas leakage from the pipeline. It is considered a flammable risk because it can generate explosions and fires; during the completion of the well, there is a gas return through pipes and separators. Being flammable fluids at high pressures, they can affect the integrity of the systems, generating mechanical problems. During production and processing, the pipeline, from the

Christmas tree to the surface processing equipment, is another opportunity for the presence of flammable gas, so purges should be made to help with system pressure relief. Although greenhouse gas leaks can occur in a well that produces the fluids of a conventional reservoir, this is less frequent, since there is a greater degree of control of the pressures coming from the reservoir, while in fracking, there is a high degree of uncertainty because the fractures occur randomly and it is not possible to predict variables such as the whereabouts of the reservoir gases or the fracturing fluid.

In terms of the impact of fracking on water resources, several authors have reported that the use of water from streams, lakes, rivers, and underground sources has consequences such as the reduction of water flow and the degradation of the quality of drinking water in the region. Besides, this generates conflicts linked to the competition for the resource with agriculture, livestock, and the supply of drinking water to communities [55]. The preparation of the mixture to be injected requires high volumes of water that reach the surface again, corresponding to between 1 500 and 4 500 cubic meters per week [56]. This water contains organic additional components, toxics, heavy metals, and natural material with radioactive residues, which can be harmful in an uncontrolled fracture and reach the shallow ground-water layers [57]. Likewise, if it reaches the surface, its treatment process would be complex, since techniques such as reverse osmosis or bioreactors do not meet the requirements to be treated [56]. Another disadvantage of the technique is that the 260 chemical compounds used as breakers, surfactants, foaming agents, acids, biocides, scale controllers, clay stabilizers, and pH controllers [58] are used in the injected mixture but are not very well known according to the parameters of the companies that supply them, leaving an open gap for their study, where it is determined that most of them are toxic, allergic, mutagenic and carcinogenic [59]. In some cases, the presence of heavy metals such as cadmium and arsenic has been reported in crops such as cocoa; this is due to the irrigation of plantations with water supplied by the drinking water tanks affected by the fracking return fluid [60]. Even if treated, contaminated water can carry traces that diminish the quality of life of the people who benefit from the water resource from shallow aquifers, which can generate long-term illnesses such as cancer. A study reports that 55% of the substances in the fracture fluid have effects on the brain and nervous system, 78% affect the respiratory system, skin, eyes, liver, and intestinal system, 47% concern the endocrine system, impairing reproductive capacity, and 44% of the chemicals are unknown in their effects on human health [26]. This problem, although critical, offers simple possibilities of a solution; at least in the short term, because within the autonomy of governments to manage initiatives such as fracking, they can demand that the companies marketing chemical products publish detailed technical data sheets on the additives, and thus promote more detailed technical studies that show a clearer picture of these substances' effects on ecosystems and human health. For example, in research conducted in 2019, scientists developed different methods to evaluate chemical risks caused by products used in fracking. The methods are generally divided into detection and indexing. By reviewing the advantages and limitations of both approaches, the scientists developed an integrated system for the detection of chemical hazards associated with fracking fluid additives [61]. The results of this research show that more than half of the additives are grouped into high health and environmental hazard designations, suggesting mitigation. Scientists emphasize the underestimation of risks by using each approach separately.

It is necessary to consider that the impact studies carried out do not yet have the last word, due to the uncertainty and ignorance of some variables related to the technique. It is convenient to give continuity to the study of hydraulic fracturing as a technique and its collateral effects, also providing the opportunity to the oil industry to rethink phases of the technique and to look for the ecoefficiency in the obtaining of non-conventional fossil energy resources. The first steps are the reuse of 95% of the wastewater obtained from the operation to reduce the consumption of freshwater [62], using propane-based gels instead of water for the extraction of non-conventional ones [63], for example; the evaluation of impacts from the planning, implementation, control, and monitoring of the fracking activity [64], among other strategies that maintain energy security through environmental, social and technical responsibility. It is also worth doing studies associated with complementary processes to hydraulic fractur-

ing, such as: studies of the regulations and regulations for the discharge of production water, whether in disposal, injection, among others, depending on the country where it is planned to carry out the technique; In addition to the above, the origin of injection fluids must be studied, which are not usually taken directly from rivers, seas and other valuable water bodies, but from bottom-hole water, which must be continuously injected into the well to keep reservoir pressure stable.

Any exploitation of natural resources implies an impact on the agents involved. There is a strong effect in the case of fracking due to the magnitude of the operation and the expected response. However, the oil industry has sought the mechanisms to mitigate the implications, particularly the environmental ones, for example, the recirculation of water currents used in the processes to reduce the amount of freshwater, the monitoring of gas emission through gas chambers, water simulator gels, among others, which offer great possibilities to reduce the effects on vital natural resources.

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#### IV. COLOMBIAN PERSPECTIVE

In Colombia, the exploitation of the subsoil is one of the activities that generate the major contribution to the country's economic development, since it is the most widely used energy fuel for transportation; moreover, with the current price of a barrel of Brent crude, the possibility of extracting hydrocarbons from non-conventional fields is becoming increasingly attractive [65]. However, there is controversy in the country, as some companies support this form of production in oil fields while other organizations refute the viability of implementing it in Colombia due to the environmental consequences reported in studies of countries where the technique is being used and the direct impact on human health.

The growth of the Gross Domestic Product related to the exploitation of hydrocarbons oscillated between 3.5% and 5% between 2000 and 2008 [66], while in 2010 and 2014 there was a growth of between 7% and 7.3% [67], and in 2020, the GDP was approximately 10% [68]. In Colombia, there is increasing interest in implementing fracking by operating companies since the economic development linked to this activity is on an upward trend. For this reason, the companies Drummond, Ecopetrol, Parex, Exxon Mobil, and Conoco Phillips have prepared US\$650 million to invest in pilot fracking projects in the country. This announcement made by the mentioned companies led the government to implement a viability plan for this technique of recovering hydrocarbons from non-conventional fields because this would increase gas and oil reserves to 9.8 and 6.2 years of consumption, respectively, which would make Colombia self-sufficient in energy [69]. The government was quick to issue a decree in March 2020 with the technical norms for carrying out pilot projects to evaluate the possible environmental and social impacts of applying this technique. In this way, the oil began to be produced through Zone Zero of fracking in Colombia, which is located in the Magdalena Medio region [70]. This project outraged the inhabitants of Pueblo Patiño and different organizations that oppose the hydraulic fracking technique, which led to the pilots not having the expected productivity. Due to similar situations, several protests against fracking have been held by activists and organizations, delaying oil activity because of the possible environmental risk that the technique could entail. Generally, they are manifested through sit-ins and communiqués, like the one issued on September 24, 2019, and signed by 44 organizations, [71] in which fracking is categorically rejected to preserve the environment over economic and social gain.

Despite the plans by environmentalists to prohibit fracking in Colombia, the government is managing plans such as improving recovery in mature fields, expanding onshore and offshore exploration in the Caribbean, and the feasibility study for implementation fracking, for the latter there are different channels of dialogue between the government and citizens for the debate and subsequent possible acceptance of the technique on Colombian soil.

## V. CONCLUSIONS

What has been exposed previously shows the importance that the hydraulic fracturing technique has taken, not only in the oil industry but also for the development of the countries' economic systems, in terms of the maintenance or growth projected towards energy security; it has become a competitive economic, energetic and even social advantage in the current situation of sensitivity and variability of the international markets. However, the environmental implications of fracking are clear, especially on ecosystems, and impact the expansion of oil field operations.

Fracking is a technique that, although not recent, has acquired significant importance in the last ten years; this is due to the need to find new reserves that make possible the development of industries. Also, different technological advances have been made allowing the application of fracking economically and environmentally.

The technique described above is expensive, and therefore requires extensive investment, which will be subject to the dynamics of the industry, bearing in mind the volatility of the sector. The scenario of a suspension of projects for the development of non-conventional deposits may arise under a significant decrease in the commercial value of the oil barrel.

Without a doubt, the fracking technique is one of the most promising possibilities to maintain energy security in countries with non-conventional deposits and to become an economic advantage concerning other countries and a decrease in the dependence on the fossil resource of other countries. However, the limited information about its impact on surface and subterranean ecosystems will be relevant parameters that will make its implementation slower in nations like Colombia, where the precautionary principle is used as a reference for new industrial practices.

The theoretical review of hydraulic fracturing should generate scope for new research and recommendations. One drawback is the lack of knowledge and access to information, which generates uncertainty and false news, which once increases the NO acceptance of these practices.

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