Chapter 2
Landscape Analysis: Fracking Technology

Rafaa Khalifa, Chih-Jen Yu, Joao Ricardo Lavoie, Momtaj Khanam, and Tugrul U. Daim

2.1 Introduction

Hydraulic fracturing of oil- and gas-bearing rocks, also known as fracking, is an established technology. Hydraulic fracturing was first started experimentally in 1947 in the Hugoton oil field in Kansas [1]. Fracking is an old technique that is used to increase the production of oil from the worked-out oil wells. However, it is considered as a new tool for producing natural gas. Fracking has been developed gradually by some international companies and organizations with no government support until the success has been proven.

Lately, in 2011, the shale gas boom has started to introduce the fracking technology with more power in the oil and gas industry. In the USA, researchers showed their interest to investigate the role of federal agencies in supporting gas industry experimentation by using shale fracking technique. The Department of Energy played a significant role in improving this technology. Also, the National Laboratories made a big contribution in developing the hydraulic fracking process.

Indeed, the fracking technology is considered in the oil and gas industry as a newly developed drilling technique because it is depending on a complicated process such as a high pressure, specific chemical solutions, and a huge amount of water mixing with the sand. These components are used to free oil and natural gas from the shale rocks under the earth's surface. This technology has made a lot of profit for oil and gas companies. However, fracking has some challenges, such as people from different societies arguing that fracking creates a negative impact on human and environmental health. On the other hand, others are saying that this

R. Khalifa (✉) • C.-J. Yu • J.R. Lavoie • M. Khanam • T.U. Daim
Portland State University, Portland, OR, USA
e-mail: rkhalifa@pdx.edu; yuchihjen@gmail.com; jlavoie@pdx.edu; momtaj@pdx.edu; tugrul.u.daim@pdx.edu

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technology helps to meet the current and future energy needs. Also, it could save the countries' economies from collapsing.

Therefore, most of oil and gas companies work hard to make sure that the fracking is a sustainable development process for money-making opportunities. Most of these companies often give large sums of money to societies by running some social investment programs or sustainable development projects. These initiatives aim to develop the people and their facilities around areas of fracking operations.

2.1.1 Fracking Process

The Environmental Protection Agency (EPA) described the hydraulic fracking as a high technology process which is drilled vertically or at a measured angle. This process is starting from the well surface to a depth of 1–2 miles (approximately 1.6–3.2 km, some times more). During the drilling, the vertical well is coated by steel or usually by the specific material of cement to ensure the well doesn't run the risk of leaking [2].

Once the vertical well reaches the layer of rock that includes the natural gas or oil, the drilling converts horizontally along that rock layer. Then, the horizontal drilling curves about 90°, and the drilling can extend more than a mile (1.6 km) after the end point of the vertical drilling process.

After the fracking well is fully drilled and protected (shielded) by adding a coating of steel or specific cement around the well formation, fracking fluid is pumped down into the well at extremely high pressure.

The high pressure that is created by high power machines is powerful enough to fracture the surrounding rocks. The high pressure is used to create cracks through the rocks that help the oil and gas flow to the surface.

The slick water is the fluid that is pumped into the well which contributes to fracture the deep rocks. The fluid is mixed sand, salts, and chemical components. The rate of the chemical solution that is added to the fluid is usually about 0.5–2%, while the remaining percentage consists of plain water. Sands and clay particles are also added to the fluid. Both of these elements are pumped into the fracking well to open the fractures through the rocks. The fluid is formed under high pressure to ensure that gas and oil can continue to flow out from the fractured rocks. The chemical solution helps the fluid to keep liquefied and direct the oil and gas to the surface even after the pumping pressure is released.

The injecting of fluid by high-pressure pumps is the most critical process in the hydraulic fracking operation. This fluid requires millions of gallons of freshwater and high-pressure pumps that are able to trap and extract the natural gas and oil to inject them back to the surface [2].

2.1.2 Research Objectives

This research aims at general Assessment of Fracking Technology in Energy Industry without being constrained to any specific issue. Thus, it had three distinct objectives which are designed as questions:

Q1. Why is the energy industry jumping into fracking?
Q2. What are the economical, environmental, social, political, and technical effects/impacts of adopting fracking technology?
Q3. Is fracking a suitable technology for future energy?

2.1.3 The Big Energy Source and Its Future Challenge

The future of energy has changed especially in the oil and gas industry. In the past, the growth in production was measured based on the western market demand. Natural gas has a significant role in the future energy. New technologies are being developed to explore and extract the conventional and unconventional gas with many ways to get a maximum benefit from its abundance. Increase in the natural gas production has improved producer countries' GDP growth [1]. During the past decade, oil and gas prices have moved to a permanently high level. Power companies have been working hard to produce more efficient power plants and transportation facilities and supply alternative fuels to reduce the future impact of the full dependency and the huge demand of the oil and gas in some industries. On the other hand, always there are new innovative technologies and techniques which have been introduced by some international companies and manufacturers to improve the production process and to reduce the production cost and uncertainty of producing unconventional oil and gas in this world. So, there is a question of why natural gas is the most inspiring product in the future? To answer this question, we should discover the oil challenges in the energy market in two scenarios (low and high price):

2.1.3.1 Low Oil Price Scenario

The Organization of Petroleum Exporting Countries (OPEC) is the organization that manages the oil and gas production market shares among its members. Although the significant efforts of OPEC are continued to control the oil and gas production, in the low oil price scenario, the results are still less successful in restricting production. As a result of OPEC effort in this scenario, its share of total world liquid production is expected to increase reaching 49% by 2040. On the other hand, in spite of the lower price of oil and gas in the world market, the non-OPEC producers are expected to maintain their production at roughly 54 million barrels per day, through 2030. Moreover, due to high cost, they decline to use the enhanced oil recovery (EOR) technologies to develop the existing worn-out fields. In the case of the low oil and gas price, the average costs for resource development are considered high. For this reason, the non-OPEC countries are not able to develop their worn-out fields. As the non-OPEC production rises slightly in the projection through 2030, the expectation indicates to return their crude oil production to roughly 51 million barrels per day in 2040. In 2015, the crude oil price had fallen below $80 per barrel and then to $70 after a few months. In 2016, the price fell below $50 and is expected to follow by a slow increase to average $75 per barrel in 2040. Due to lower economic growth especially in non-OECD (Organization for Economic Cooperation and Development) countries, the oil price impacted negatively the world [2].

2.1.3.2 High Oil Price Scenario

In this scenario, the GDP growth in non-OECD indicates that its rapid growth is more than the projected in the reference case. The liquid fuel consumption per unit of GDP is declining than projected in the reference case. Due to the continuing restrictions on oil production, OPEC maintains its market share of total liquid fuel production. OPEC produces about a million barrels per day which about 37–40% of the world market share. This value is lower than the value in the reference case. The limited access to the existing resources and lower discovery rates lead to consider the increase in the oil prices in non-OPEC petroleum production expanding approximately as the rate in the reference case. Other liquids rise to eight million barrels per day and are considered as strong in response to the higher prices in 2040. In the high oil price case, the oil increases from $155 per barrel to $237 in 2020 to 2040, respectively. Based on the increase in the robust price, the total world demand maintains within the range of expected production capabilities [2].

2.2 The STEEPLE Method (History and Rationalization)

The PEST (political, economic, sociocultural, technological) analysis technique was innovated by professor Francis Aguilar at Harvard. In the early 1970s, Arnold Brown came up with the acronym "STEPE" when he added a second "E" for Ecological issues in addition to Aguilar's Social, Technical, Economic, and Political Perspectives [3]. The technique went through a sequence of changes. Various acronyms used by practitioners are as follows: PEST (political, economic, sociocultural, technological), PESTEL (political, economic, sociocultural, technological, environmental (or ecological), legal), PESTLIED (political, economic, sociocultural, technological, legal, international, environmental (or ecological), demographic), and STEEPLE (sociocultural, technological, environmental (or ecological), economic, political, legal, ethical) [4]. STEEPLE analysis identifies the changes in the macro environment external to the organization in order to respond to the changing environment in a timely and appropriate manner [3]. In the energy sector, STEEPLE analysis helps

Table 2.1 Importance of STEEPLE for energy technologies [6–9]

Issues	Description
Social	It is important to clarify social acceptance at the initial stage of energy technology development. Conflict may cause a blockade of the technology. It is important to understand the intensity of rejection of the technology to manage or take a decision at the early stage of development
Technological	Energy technology systems need to be clarified objectively. Rather than relying on developers or practitioners, technology needs to be critically analyzed by experts to identify and recognize all consequences and issues
Economical	Initial investment and leveled cost of the technology needs to be assessed in order to rationalize its adoption
Environmental	Energy technologies should reduce emissions. A full assessment is needed to reveal consequences that may affect the plant, animal, and human species
Political	Political interference can significantly affect energy technology adoption. Political pressure can make the government facilitating the development or arranging subsidy programs or other incentives contribute in increasing the number of beneficiaries. On the contrary, politicians may exacerbate the adoption by propaganda
Legal	Legal or policy instruments enhance the adoption and commercialization of energy technologies. The government is the key player in formulating policies that pervade all other criteria. Social, technological, economical, and environmental consequences can promote adoption or rejection of a certain energy technology. However, these consequences are mediated by government policies
Ethical	Any technology that harms the environment and puts human life in jeopardy is ethically unjust. In spite of its huge potential, the development of energy technologies gets hindered if it cannot live up to ethical codes

to analyze technology from a different perspective. It facilitates the development and diffusion of energy technologies [5]. Table 2.1 describes the importance of different perspectives for energy technologies.

2.2.1 Description of the Model

The STEEPLE model in Fig. 2.1 describes the different issues that are considered in assessing the fracking technology.

2.3 Fracking Technology Assessment

2.3.1 Social Perspective

Social perspective identifies aspects that affect society positively or negatively [10]. Four important aspects in social perspective are public perception, employment, health and safety, and Local Infrastructure Development.

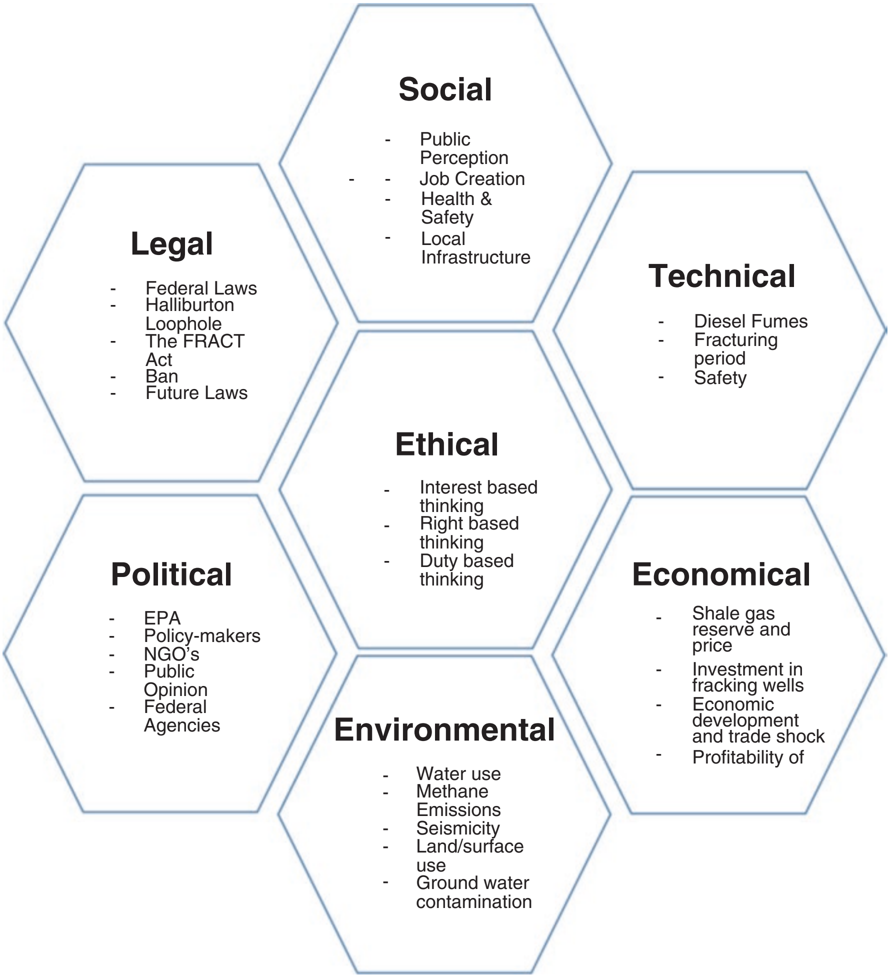

Fig. 2.1 STEEPLE for fracking technology assessment

2.3.1.1 Public Perception

Views that are shared by population, social norm, and media coverage shape the perception of the mass. Public perception is reflected in aesthetics, lifestyle, social benefits, and social acceptance. National polling data published in the year 2014 found American population to be mostly ignorant or ambivalent toward fracking. A small minority who knows about fracking are equally divided into a pro-fracking and antifracking stance. Those who are in opposition to fracking are found to be mostly women, open minded, and knowledgeable about fracking issues as these women possess a habit of reading the newspaper more than once a week and talks about the impact of fracking on the environment. People in favor of fracking are mostly older; minimum educational qualification is bachelor's degree, conservative political views, watch TV, and appreciative about the economic and energy supply effect due to fracking. The accepted perception that better education creates negative impression toward fracking is proved wrong through the survey [11].

2.3.1.2 Employment

Employment is pertaining to job. It clarifies job creation, availability of workers, and poverty alleviation. The creation of job opportunities by fracking is an issue of controversy. Different groups have conflicting claims. Pro-fracking groups claimed the creation of 48,000 jobs from the end of 2009 to early 2011. However, antifracking parties denied this claim in the plea that these were new hires and the actual number was proven to be 5700 during the same period. Bureau of Labor Statistics revealed that the employment created by oil and gas operations (onshore and offshore) is less than 1/20th of 1% of the overall US labor market since 2003–2011. Moreover, employment of less educated workforce and high wage lead to increased number of dropouts of college students in these counties and cripple the ability for future development [12]. Migration of more people in the fracking areas burdens existing services, traffic, and accommodations, and there is a struggle for limited resources that sometimes leads to animosity among people from different cultures and places.

2.3.1.3 Health and Safety

Health and safety are concerned with safety, health, and welfare of people, society, and workplace. Technology should not affect public safety and work safety and should not cause long-term health issues. People and workers are vulnerable in areas of fracking to different contaminants emitting out of fracking operation. This causes many forms of respiratory diseases. Occupational health hazard of workers in the fracking industry is an issue of concern. Workers may get affected by chemicals and also machineries used in fracking sites. Workers are exposed to dust, crystalline silica, and fracking fluids that cause fatal health hazards. Also, workers may get hit by moving equipment and high-pressure lines, be entrapped in between two moving parts of a machine, or suddenly be exposed to high-pressure release. Due to flammable gas and materials in fracking sites, there is a high probability of fire explosion. Worker sometimes needs to work in a confined space under high power lighting. All these events may lead to fatal injury, disability, or sometimes death [13]. The nonoccupational health hazard is caused by polluting gases and harmful chemicals and silica that are used in the fracking process and contaminate groundwater or atmosphere. Sudden economic expansion or recession which is known as "Boom and Bust" sometimes causes mental stress to people in the community. Fracking causes a sudden increase in economic activity. This increase in local economic activity is often followed by a rapid decrease upon depletion of the resources. Living cost soars as oil and gas industry can pay more. This creates hardship for the community.

Local Infrastructure Development Infrastructure development is supposed to improve transportation, help to develop related industry, and better productivity and quality of life.

Due to the construction of well pads, waste pits, access roads, pipelines, compressor stations, and other infrastructure, pristine landscapes are ravaged by industrial zones. Spoiled infrastructure and economic, environmental, and social degradation are the aftermaths of a sudden halt of fracking. The cost of destruction is shared by taxpayers. Human habitats are replaced, lands are divided, open spaces are sacrificed, and sometimes tourist attractions are crushed to make way for fracking [12].

Many probable actions have been proposed by government, practitioners, and researchers to minimize or eliminate the negative impacts of fracking. Occupational Health and Safety Administration (OSHA) and National Institute of Occupational Health and Safety (NIOSH) developed a detailed guideline for protecting workers of fracking industries. Protective equipment, planned work process, engineering control, worker training, and mostly minimizing exposure of workers to harmful chemicals are some of the suggestions made by the organizations [14]. In many states, the probable impact of fracking is assessed for a certain locality and ranked based on their severity. Depending on the intensity of impact, preventive measures and action plans are prepared ahead of time to reduce the negative effect of fracking on human health [15]. Several states as well in many countries, for example, in South Africa near diamond production zones, industries are compelled to pay an impact fee, and it is saved as fund during the boom period. This fund is utilized when fracking process discontinues or the bust period starts, to compensate the people impacted, restore the landscape, or drive the economic activity. Rural, forests, farmlands, and locations of tourist attractions are impacted with fracking constructions. This can be reversed by implementing zonal restrictions by the government and protecting places and landscapes of public importance [16].

2.3.2 Technical Perspective

The oil and gas industry has a positive impact on the economy by introducing the new fracking technology to extract hydrocarbons from areas and distances that previously thought unreachable. The new technology improves the horizontal drilling in addition to the enhanced oil recovery (EOR) [17, 18]. The fracking new technology could extract oil or gas double recoveries of that amount in the conventional drilling [19]. Recently, light and medium oil and gas production have started to get more attention by smaller players in oil and gas business. They are focusing on the more profitable light-to-medium oil production. Also, as a result of increasing market demand regarding the natural gas, international oil and gas companies develop sour gas plants to increase the natural gas liquid productivity [20].

2.3.2.1 Diesel Fumes

The hydraulic fracking uses the diesel fuel as the main source to power the drilling machines in the drilling and production process. However, the diesel-powered equipment can be a high potential risk or annoying source of harmful pollutants. Also, it can be a source of the carbon emissions that might affect the environment and cause global warming. Recently some international companies announced that the natural gas would be the primary source of fracking power machines. The natural gas will reduce the carbon emission and the fuel cost that is used during the fracking operation by about 40%. Solar panels are another energy source which has been adapted by Halliburton oil and gas service company in the fracking process. The company innovated the sand castle vertical storage silo technique to use entirely with the solar panel. Moreover, Halliburton was successful in reducing the consumption of power on site by 70%. They developed the powered pump trucks to be working at the location of the natural gas [21]. The diesel fuel contains BTEX compounds (benzene, toluene, ethylbenzene, and xylene). These compounds are considered as risk that might impact the human health through its potential leaks to the drinking groundwater [22]. Now companies are working hard to sophisticate engines and turbines that use natural gas as a fuel [23–25].

2.3.2.2 Fracturing Period

There are differences between the typical use of hydraulic fracturing between the US states. The fracking process may take weeks to get access to the oil or gas sources through the reservoir rocks. Horizontal drilling is a complicated process which requires lengthy fracturing periods. Also, the horizontally drilled production wells need about four to eight millions of gallons of water. This amount of water is injected under the surface with constant pressure which might need extended period of time to complete its process. However, the fracking in California has sophisticated by using innovative technology to reduce the fracturing time. They use less fluid to fracture within a narrow vertical band along a well; then they change the direction of drilling horizontally only a few hundreds of feet from the last point of vertical drilling [26]. To integrate a steam fracking process, the use of low-gravity hydrocarbons as a diluent for the targeted heavy oil can decrease the fracturing periods [25, 27].

2.3.2.3 Safety: Blowout Prevention

According to statistics of energy wire organization, the federal labor section, the oil and gas industry workplace fatalities result in about 10% of deaths caused by fires and explosions during the past 5 years. Safety has become increasingly important in the oil and gas industry. Due to fracking boom which pushes into closely populated areas, oil and gas companies are required to perform the safety process before, during, and after the drilling and production operations. Also, the workforce and people inside and around the operation areas should have enough knowledge of safety procedures.

Recently, the Wall Street Journal reported that “At least 15.3 million Americans lived within a mile of a well that had been drilled since 2000, that is more people than live in Michigan or New York City” [28]. Also, a research paper from the Public Health School at the University of Colorado noticed that “Accidents at well sites don’t simply threaten workers but can also expose those who live nearby to fires, explosions and hazardous chemicals” [28].

Fracking companies are required to comply with all safety procedures and processes that are recommended by the American Petroleum Institute (API). They should carry out all blowout prevention equipments of inspection process during the drilling and production. Companies are required to register and record all inspection and closure test as scheduled by the safety department. In case blowout prevention equipment is not functioning well, the operation should hold the blowout prevention equipment until it is fixed and retested [29].

2.3.3 Economic Perspective

2.3.3.1 Abundance of Shale Gas Reserve/Supply

The US Energy Information Administration (EIA) assessed 48 shale gas basins in 32 countries, with a result of 6622 Tcf (trillion cubic feet) shale gas and 6609 Tcf conventional gas worldwide. This means that the shale gas reserve contains a similar amount of conventional natural gas [30]. Later, EIA report indicated that 2013 estimation for the total world would be increased to 7299 Tcf, considering 41 countries, 95 basins, and 137 formations, as shown in Table 2.2 [31]. It appears that the global estimation of shale gas reserve has been promising over the recent years.

In the USA, the Marcellus Shale is reported to contain large amount of shale gas across western New York, Pennsylvania, and Ohio states. The reserve has been estimated to be sufficient for 45 years of the consumption [30]. By looking at the estimation reports over the past few years, the reserve of the shale gas seems to be increasing, due to more basins and formations being discovered and incorporated.

Table 2.2 Reports of shale gas reserve from EIA 2011 and 2013 [31]

ARI report coverage	2011 Report	2013 Report
Number of countries	32	41
Number of basins	48	95
Number of formations	69	137
Technically recoverable resources, including the USA		
Shale gas (trillion cubic feet)	6622	7299
Shale/tight oil (billion barrels)	32	345

2.3.3.2 The Increase of Natural Gas Production

As a result of the sufficient reserve fund, the gas production has been stimulated and growing. For instance, the natural gas production in the USA has been increased over a decade. The shale gas is considered as the largest contributor to this growth from 2012 to 2040 [32]. EIA (2015) reported that the total natural gas had been produced 35% more during the period 2005–2013, which is mostly attributed to developing shale gas in 48 states. In addition, for the year 2040, the shale gas production is estimated to be increased by 73% and reach to 19.6 Tcf under reference case [33]. These figures and numbers reflect the significant increase in natural gas production in the USA over the past 10 years and the tendency of the continuous growth for the next 25 years.

2.3.3.3 Lower Natural Gas Price

Shale gas has depressed natural gas prices in the USA significantly, compared to the major markets. The natural gas price is estimated to be 2.5 times higher by 2050 if shale gas has not been developed. This may facilitate global competition and geopolitical shifts that break long-standing monopolies. For example, this could lessen European dependence on Russian gas, reducing Russia's ability to leverage higher prices [30].

2.3.3.4 Increased Global Investment in Fracking Wells

It has been reported that International Energy Agency (IEA) predicted global investment of $6.9 trillion in the shale gas development including lots of expected new wells during the period 2012–2035. This causes the rise of unconventional oil and gas and a fast shift from traditional producers to plentiful domestic resources. It has been estimated that 80% of natural gas well drilled in the next decade is expected to employ hydraulic fracturing [30, 34]. With more fracking well established, the production of shale gas will continue to grow accordingly.

2.3.3.5 Economic Development Growth

Some evidence has been reported about the economic development as a result of the increase in shale gas production. For example, in Pennsylvania, the active wells grew from 350,000 to 650,000 and generated 29,000 new jobs in 2008. For the Marcellus Shale across West Virginia and Pennsylvania, it was reported to bring $4.8 billion in gross regional product, caused 57, 000 new jobs, and generated $1.7 billion in tax collections. For Texas at the Barnett Shale, $11.1 billion annual output

Table 2.3 Direct and indirect economic benefits from shale gas production in the USA

Shale play	Estimated impact	In the year	To the economy of
Marcellus	$4.2B in output 48,000 jobs	2009	Pennsylvania
Marcellus	$8.04B in revenues 88,588 jobs	2010	Pennsylvania
Barnett	$11B in revenues 111,131 jobs	2008	Dallas/Ft. worth area
Haynesville	$2.4B in revenues 32,742 jobs	2008	Louisiana
Fayetteville	$2.6B in revenues 9533 jobs	2007	Arkansas
Marcellus	$760M in revenues 810 jobs	2000 wells over a 10-year period	Broome county, NY
Marcellus	$2.06B in revenues 2200 jobs	Gas production per year	Broome county, NY

Adapted from Kinnaman (2011) [35]

and 100, 000 jobs have been reported [30]. These direct and indirect economic benefits from shale gas production are shown in Table 2.3:

It also has been observed that fracking has transformed the USA into an energy super power. In 2013, the USA has become the world's largest producer of oil and natural gas. The personal income is projected to be increased to $3500 more per home in 2025. Fourty percent more oil and natural gas jobs has been estimated during 2007–2012. Government revenue is estimated to be $1.6 trillion increase to federal, state, and local government from 2012 to 2015. $180 billion trade deficit is estimated to be reduced by 2022. $1.14 trillion is predicted to be spent on infrastructure between 2014 and 2025. $533 billion increase in US GDP in 2025 is forecasted [36].

2.3.3.6 The Effect of Trade Shock

One of the potential effects induced by fracking is to impose trade shock on the exporters and importers of oil and gas. There is an estimation of economic effects of a 50% reduction in the volume of US gas and oil imports over the period 2007–2012. As a result, some countries may encounter some negative effects. For example, Canada appears to experience a reduction of 0.5% of GDP. Other countries such as Yemen, Egypt, Qatar, Equatorial Guinea, Nigeria, Algeria, and Peru have also been estimated to experience a decline in GDP of up to 0.5% [37]. This indicates that fracking can provide major benefits to some countries like the USA, but also may create significant negative economic impacts on some countries relying on exporting oil and gas.

2.3.3.7 The Profitability of Drilling Shale Oil

Since fracking involves more sophisticated drilling and extraction process, it is considered costlier to operate. In views of the declining oil price, oil companies are forced to consider the cost of expensive compared to less expensive fracking extraction methods. A report from *The Wall Street Journal* revealed that at $90 a barrel and below, many hydraulic-fracturing projects start to become uneconomic and the break-even point may lie around $80 to $85 [38]. Another article shows that fracking may still survive below $60 per barrel. However, new exploration and production may decrease, and some wells with higher cost have been shut down [39]. This information did indicate that further oil price declining risk is very likely to make expensive shale drilling unprofitable. Therefore, for a drilling company, more investigation and analysis on profitability challenge are deemed necessary, in light of the higher cost of fracking and the declining price of oil.

2.3.4 Environmental Perspective

Fracking requires an enormous amount of water as much as four to eight million gallons per well. The Environmental Protection Agency (EPA) in America indicated that about 35 thousand of fracking wells during drilling annually required a huge amount of water (equivalent to five million usages) [40]. Also, the big issue that the water sources are used for fracking operations varies and is not well documented or monitored. Some studies referred to the danger of the chemical solutions that are used in the fracking process; about 25% of fracking chemicals could cause cancer or other diseases.

Also, fracking can be one of the reasons of climate change because it produces methane which harms the environment. Methane is often released from the fracking wells during the drilling and production process. Some studies have shown that if the percentage of leakage is more than 3%, the burning of natural gas can be worse for the climate [41].

Fracking operation can also cause earthquake even though it is sometimes considered as small or under low-risk category. Many reasons can cause earthquake; in fracking, earthquake can be caused by drilling vibration or injecting water under a high pressure. Researchers referred to some actual cases that exposed to significant earthquakes because of the abuse of using underground injection during fracking. Those cases were registered in Oklahoma and Prague; many local homes were impacted and thousands of dollars worth of damage [41].

Wildlife also has been affected by fracking which comes with strong and fast industrial development, including the massive truck traffic. Fracking requires multiple routes for trucks to transport millions of freshwater from its sources to the operation areas. Animals are poisoned by chemicals added to water, and they are pushed to leave the wild areas to survive [41].

Human, animals, earth, water, and weather have been affected by the oil and gas industry operations [42]. Its processes have significant impacts on the environment because of the lack of control and complying with the environmental policy and regulations [43]. Due to the fast growth of the fracking operations in North America, people and some health and environment organizations continue protesting and asking to band the fracking activities [44, 45]. Recently, Alberta Energy Regulator (AER) issued a restrictive policy regarding the fracking operations including a list of requirements. Fracking companies are required to provide all information relating to the fracking operation such as the amount of waters used during the process and its sources and also the type of chemicals and solutions added into the water and used in each single operation.

Richards [43] pointed to the debate and the miscommunication between the environmental organizations and the producer companies regarding the propaganda and fact. The industry is always fighting back to prove that all information and data provided against the fracking are classified under the misrepresentation, misinformation, or misunderstanding category [46].

2.3.4.1 Water Use

Fracturing technology and its risk to water resources gained much attention from both environmental organizations and the media. They argue against the chemicals used in mixing with the fracking operation fluid and its risk for groundwater contamination. Water management is required to reduce the environmental and the media debate surrounding the fracking operation areas. Despite the continued development of fracking technology, using and reusing the vast quantities of produced water during the fracking process is one of the key issues that need to find alternative management strategies for managing this issue [47]. Drought contingency plans are started to be legally required by water companies for assessing the potential risk of using water resources before approving its use for fracking. Moreover, minimizing water consumption and reusing of fracturing fluid are challenges that need comprehensive management and disposal of wastewater plans [41, 47].

2.3.4.2 Methane Emissions

Methane is a type of gas that is usually located under the Earth's surface. Due to the fracking process, methane released from the land to the air creates poisoning emissions. Recently, some governments and environmental organizations have taken some steps to control the gas emissions produced by conventional and unconventional gas industry. Releases of methane have long been noticed and recorded in several parts of the world. After completing the fluid injection process, the fluid returns to the surface combined with significant quantities of methane gas [48].

Nowadays, there is an innovative technology that helps reduce the methane gas emissions by up to 90%. This technology is called the reduced emission completion (REC), and it is used during the flow-back period. However, this technology requires a proper implementation process such as installing special pipelines to the well in preparation for the fracturing completion [48]. Fracking companies have shown high interest in making more business than investments to reduce methane gas emissions. In this case policies and regulations are needed to push these companies for complying the reducing of methane emission rules [49].

In America, the federal oil and gas leases pointed to the study that proved the difference of methane emission rate among regions. The Utah state has strict regulations regarding reducing the methane emissions compared with the state of Colorado [50]. On the other hand, the study mentioned that in some areas with no fracking activity, a methane emission increase was recorded; the origin of the trends in the data is far from clear. So additional measurements and research are required by the US Energy Information Administration (EIA) [51].

2.3.4.3 Seismicity

The hydraulic fracking induced seismicity during or after the fracking operation. It typically forms an elongated cloud of event locations [52]. Recently, several innovative technologies were implemented to control seismicity occurrence and mitigate the seismic hazard. Increasing number of sensible earthquakes would be a sign of real seismicity that might increase the rate of damages and fatalities. Fracking is a complicated process, and the injecting of fluid under high pressure is considered the most difficult stage that may cause seismicity. The shear slip may occur during the fracking process due to high pressure that might lead to creating shear stresses. This explanation is still under studies, and some researchers argue in the way of creating the seismicity during the fracture operation [54]. However, some of them pointed to the induced shear slip might lead to the diversity of fracture surfaces and create new layers formation [55]. EIA experts illustrated in their report that in over 35,000 hydraulically fractured wells, only four wells had noticeable earthquakes in the USA [56]. To avoid this issue, fluid injections should be short-lived and injected at lower pressures [53].

2.3.4.4 Land/Surface Use

Usually, in the conventional oil and gas industry, the operations need a huge land area, but in the unconventional, operations by fracking technology require less land use. However, in both types, the surface that uses resources is still the main issue in some cases. Environmental and safety organizations continue complaining against the fracking operations in regard to negative environmental impacts. Some cases that had harmed the land or surface during the oil and gas operation were recorded by the industry or environmental and safety organizations. In Louisiana (2009), some animals were poisoned by chemicals and founded near a drilling area. In Pennsylvania (2008), the Monongahela River was contaminated by chemicals and a high level of salt content found in the river. In the same state (2009), a spill of fracking fluid into a surface and the depth water results to death of organisms that live in the river [57]. So, the impacts of surface disturbance can extend over large areas and both plant and animal species. Continuous improvement of best practices is required by industry organizations [58].

2.3.4.5 Groundwater Contamination

The fluid that is injected into the oil or gas reservoir contains from more than 750 distinct chemicals. Fracking uses high-pressure pumpers to pump fluid through the drilling well to the host rocks [59]. The chemical represents about 2% from the total fracturing fluid volume. Large quantities of wastewater are generated during the fracking process and represent about 98 percent of the volume. The Environmental Protection Agency in America has started since 2010 to identify the potential risk of hydraulic fracturing on drinking water [60]. The fracking companies are getting benefits from exemption under the regulation of Safe Drinking Water (SDW) that was issued by the Energy Policy Act (EPA) in 2005. However, the environmental agencies are still working to identify contamination from shale gas exploration. Scientists explained the reason of limited identification of the groundwater contamination from shale gas operation. They emphasized that the large-scale exploration of shale gas has begun recently compared to groundwater flow rates. So, the much longer time frame is needed to identify and evaluate possible groundwater contamination.

> *The fraction of drinking water wells that had chloride concentrations >250 mg/L (EPA threshold for drinking water) in groundwater from Garfield County doubled between 2002 (4%) and 2005 (8%), with chloride up to 3000 mg/L in drinking water wells.*

Overall, there might be real cases that exposed chemicals affected the groundwater in some areas, but many researchers and environmental agencies believe that conventional and unconventional oil and gas exploration has an impact on the environment and health [61–64]. For eliminating the impact of this issue, more studies are undertaken by EPA including a review of the literature, analysis of existing data, laboratory studies, and real case studies [59].

2.3.5 Political Perspective

The political perspective deals with players and factors that can potentially influence the creation and/or modification of policies and also with players and factors that can influence and modify the perception and attitude of those whom policies are made for. Although usually overlooked, this perspective can be very important and change the competitive scenario in many cases.

Regarding the case of fracking technology, the most important factors and players identified are as follows:

The Environmental Protection Agency (EPA) The agency's mission is to protect human health and the environment [65]. After 1997, EPA was mandated (by law) to regulate fracking fluids, as they caused many health and environmental concerns. Since then, it has started to conduct several studies about fracking fluids and also to regulate its usage (what would be the allowed and not allowed substances and chemicals) [66]. EPA, with their studies and regulations, might have the ability to hinder shale gas extraction and put more pressure on the oil industry through public opinion. On the other hand, EPA representatives have already stated that fracking can be done without harming the environment [67].

Policy-Makers and Legislators Either on the State or Federal level, there are clearly two distinct movements, a pro-fracking and an antifracking. Both have power depending on the state/region. Pro-fracking movements highlight and trust the economical and strategic benefits America would get from exploring more natural gas reservoirs, and they open an opportunity to the industry when they are open to discuss how to use fracking techniques while decreasing environmental impact (e.g., Colorado and Texas) [67]. Antifracking movements highlight the environmental and social hazards that may surge from fracking and state that potential economical benefits are not worthy of the risk. They pose a threat as they do not want to take chances and are leaning toward banning the technique (e.g., NY and Vermont) [66].

Nongovernmental Organizations (NGO's) Nongovernmental organizations play a major role in today's policy-making [73], and their importance is growing in every sector. For fracking technology, the ones that are most relevant are environmental organizations and activist groups. These organizations can be very powerful in influencing the public opinion, by organizing constant protests, manifestations, and making studies showing the potential hazards of fracking.

Public Opinion The public opinion is the perception of public over any given issue/subject. The public in general can exercise strong influence over policy-makers and legislators [74]. Public opinion against fracking can make it very difficult for activities to continue, once policy-makers would then be leaning toward more restrictive policies and regulations.

Federal Agencies Strong agencies include Department of Energy (DoE), Department of Defense (DoD), and Department of Homeland Security (DHS). Such powerful institutions could, once they decide to support any given initiative/movement, influence policy-makers (not through political lobby but through the experience and expertise of its employees and leaders) [75]. These agencies might easily realize the benefits of the expansion of fracking and future American independence from foreign fossil fuels. In that case, the fracking industry might gain powerful allies.

2.3.6 Legal Perspective

The legal perspective deals with factors that reflect the legality or illegality of the technology, namely, laws, standards, codes, and regulations. The importance of these factors is obvious, given the fact that once a technology (or anything related to it) is set outside the limits of any legal instrument, it automatically becomes not suitable. Regarding the fracking technology, these are the legal factors that should be considered:

The Fracturing Responsibility and Awareness of Chemicals Act (FRACT Act) In 2009, twin laws were passed in the House of Representatives and in the Senate [68, 69], giving EPA authority to regulate fracking and mandating fracking companies to disclose the chemicals used in the fracking fluids. The law was seen as a threat since the industry would have to deal with more regulations. Also, it would have to disclose some of their trade secrets, the fracking productivity highly depends on how the cracks in the shale rocks are kept open, and these cracks are "produced" and sustained by the chemicals and other substances used in the fracking fluid. Therefore, no company wants to publicize the composition of its fluids.

Federal Laws As of now, eight different federal laws apply to fracking (same as to conventional drilling) [72]. The discussion evolves around the question of whether or not new laws and regulations would be needed. It presents an opportunity for companies to argue that no extra or specific laws and regulations are needed. Nonetheless, antifracking movements argue that none of these existing laws properly deal with fracking, because fracking involves different techniques and therefore different hazards when compared to conventional drilling and oil/gas extraction.

The "Halliburton Loophole" The Halliburton Corporation is one of the biggest companies in the oil sector, providing services of several natures to the oil companies [76]. In 2005, a provision in an energy bill exempted fracking from the Safe Drinking Water Act, removing any authority of EPA over fracking activities [69, 70]. Although it helped the industry in the short term, it was terrible for the image of fracking and oil companies in general (especially because the then vice-president, Dick Cheney, was a former Halliburton CEO, which has risen numerous suspicions).

The Ban on Fracking In December 2014, New York joined Vermont by banning fracking activities in the State [71]. Those laws pose a serious threat to fracking. If public opinion supports it, several other states might join the ban.

Prospective Laws Potential laws that might be enacted could present either opportunities or pose threats, depending on the content. As an action plan, the industry should pay close attention to all political factors and players, as these can be a motivation for new laws.

2.3.7 Ethical Perspective

Technological innovations have changed our lives in an unprecedented way. However, new technological innovations are never without dispute as there are many shades of gray underlying its application. The same technology can shape our future on the one hand when used to make this world more humane, while on the other hand, it can make us disconnected or extinct as a human race due to dishonest demagoguery [78]. Fracking technology is no exception to this controversy and has sparked dichotomy between its benefits and potential drawbacks. The key stakeholders in this issue are industry, government, pro-fracking and antifracking advocacy groups, landowners, and community or neighbors.

Ethics is a standard that guides human behavior in different context. Many times, innovators are ignorant or possess a telepathy mindset about the impact of technology [77]. Some of the issues that cause conflict among social norms, moral values, and technological innovation are information use; human interaction, reproduction, privacy, values, and discrimination; sustainability; power disparity; and international relations. Ethical perspective is intended to anticipate diabolic consequences of technology and address ethical issues not only during technology development but also during the whole life cycle of the technology and prevent probable backlash [78].

In an attempt to analyze the ethical perspective of fracking, a model known as "CAT scan" is used. The tool was first proposed by Goodpaster, a former professor at Harvard Business School, in his book *Conscience and Corporate Culture* in the year 2006 [77]. The CAT scan is a matrix that combines five steps of case analysis and discussion with four ways of ethical analysis.

Describe There could be several interest groups or people. It is important to identify the people whose actions prompt ethical questions. Clarifying relevant facts and information helps to find out ethical implications.

Discern There could be several ethical issues. But it is imperative to find out the most important ethical issue(s) and trace the connection or impact to other issues.

Display Understanding the players and the ethical issues facilitates to list out probable actions by the actors. However, the actions need to be specific, brief, and doable.

Decide At this stage, the players must choose optimal solution considering the environment. It should be the best ethical response in the prevailing contexts.

Defend Finally, the decision should be backed up by moral principles [77].

The four major means of ethical analysis are interest based, duty based, right based, and virtue based.

2.3.7.1 Interest-Based Thinking

In this view, ethics is related to actions that impact a human being. Hence, a certain action or policy is only ethically acceptable if the outcome positively serves the interest of the human society or reduces the cost of achieving benefit.

2.3.7.2 Right-Based Thinking

An action is morally agreeable if it ensures social justice or “fairness.” Everyone should get an equal share of opportunity, wealth, liberty, or freedom.

2.3.7.3 Duty-Based Thinking

The motto of this philosophy is whether an individual is contributing their share as part of the whole community. Hence, ethical behavior is playing one’s part according to social and legal norms.

2.3.7.4 Virtue-Based Thinking

Ethical actions are measured against prudence, temperance, courage, justice, faith, and love. Deviation from these virtues is considered as unethical action or behavior [77].

The ethical analysis using CAT scan model is shown in Table 2.4.

Half of US oil and gas is now being produced by fracking [79]. Marcellus Shale formation is assumed to contain 489 trillion cubic feet of natural gas. At the present rate of consumption of natural gas in the New York State, the reserve is calculated to last for 400 years. However, some of the potential impacts of fracking are contamination of groundwater, tributary, and the difficulty of disposing a large amount of flow-back water. The gas employees and shareholders of the gas companies are benefitted economically. Landowners also gain from leasing. However, the landowners are at risk in case the surface water gets contaminated as it would reduce the property value [80].

A number of cities, states, and countries have banned fracking. Two California counties (Boulder County, Colorado) – New York and even in Texas where the technique was developed – have banned fracking. Also, there are other states who joined in this group such as Pittsburgh, Pennsylvania (2010); Philadelphia, Pennsylvania (2012); Broadview Heights, Mansfield, Oberlin, and Yellow Springs, Ohio, (2012); Hawaii County (2013); Mora County, New Mexico (2014); and Beverly Hills, California (2014). Internationally, fracking is prohibited in some European countries such as Germany, France, Scotland, Northern Ireland, and Bulgaria [81].

Table 2.4 Ethical analysis of fracking technology by CAT scan model [77–80]

C.A.T. Scan — **Four Avenues of Ethical Analysis for Fracking**

1. Describe the key factual elements of the situation	Hydraulic fracking has the potential to contribute in economic growth and improved life for the community. It helps the U.S. in its quest to get closer to energy independence. Displacing coal causes less CO2 emission [91]. Half of the U.S. oil and gas production relies on fracking. The enormous shale natural gas reserves are expected to create more than one million jobs by 2025. The U.S manufacturing sector thrived on 2.08 trillion cheap natural gas in the year 2013 [92]. However, contamination of ground water by fracking fluid increases the risk of polluted drinking water that causes health hazard. Escaping methane gas adds to greenhouse gas emission. Large amount of flow back water poses threat to plant, animal and human life [93]. The ethical dilemma is extracting natural gas without collateral damage. Ethical agent is government.			
2. Discern the most significant issues at stake	Identify Interest	Identify Rights	Identify Duty	Identify Virtues
	Government: Energy self sufficiency Business/ Landowner:: Profit People: Safe environment	Government: Ensure rights for all Business: Right to do business People: Right to protect self from harsh externalities	Government: Must ensure energy supply as well as safety for citizens Business: Manufacture, create jobs People::Stay informed of issues affecting community	Government: Justice Business: Prudence People: Love for all people
3. Display the main options available to the agent	• Government may allow business to continue production but provide support for eliminating effect on society and environment. • Government may completely ban manufacturing. • Government may compensate people who are affected.			
4. Decide among the options, offer a plan of action	Government allows business to continue production but provide support for eliminating impact on society and environment.			
5. Defend Final decision and moral framework	Natural gas from fracking has displaced coal as a primary producer of electricity. Moreover, fracking produces half of the U.S. oil and gas. Completely banning fracking would need other options of energy to fill the gap. Solar and wind only covers 2.4% of the energy needs. Also, in absence of gas, an alternate clean energy source that would fuel half a billion vehicles, produce one third of electricity to heat and cool homes and commercial buildings would be hard to find or generate in short term. Moreover, through research and technology, engineers have already made progress in finding solutions to most of the odds facing fracking [94][95].			

5D Approach of Case Analysis

2.4 Conclusion

The aim of this chapter is to analyze the hydraulic fracturing (fracking) technology through the STEEPLE methodology. STEEPLE assesses a technology from different perspectives, namely, social, technical, economical, environmental, political, legal, and ethical. The model concludes if fracking technology would be an oprion for addressing energy challenges by the USA in the near future.

Specifically, the three research questions posed are why is the energy industry jumping into fracking? What are the STEEPLE factors that come into play when adopting fracking? Is fracking a suitable technology for the future? The first question is addressed in the introduction part where the present industry situation is discussed, and the reasons why the key players are interested in fracking are identified. The second question is addressed in the assessment section where each perspective of the methodology is analyzed, and main factors and players are identified, explained, and discussed. The third question is addressed in this section.

A summary of the technology assessment with pertinent benefits and/or challenges for each perspective is captured in Table 2.5.

As discussed earlier, there is an ethical dilemma involved in choosing whether to use fracking or not. Also, the political and legal perspectives may offer benefits and/or challenges depending on how the many players behave. On the technical side, there are minor benefits and challenges (The technology is not new, and it is evolving. It is perfectly feasible from a technical standpoint). The economical perspective is, by far, the most positive. It presents several advantages that could be beneficial for the USA. However, both social and environmental factors are unfavorable and offer serious challenges for the technology to be fully deployed.

Table 2.5 Analysis summary table

Perspective	Benefit	Challenge
Social	NO	YES
Technical	YES	YES
Economical	YES	YES
Environmental	NO	YES
Political	NO YES	NO YES
Legal	NO YES	NO YES
Ethical	YES	YES

Taking the perspectives altogether, one can say that fracking is a very promising technology, but it has extremely serious adversities associated with it. It is clearly feasible from the technical perspective, and it has great economical potential. Ethically, it has been proved to be acceptable. Nevertheless, the social and environmental issues make it unsuitable as an energy option. The key point is, if negative impacts are taken care of – al least mitigated – fracking can become a suitable energy technology for the near future of the USA. In order for that to happen, the technology needs to evolve to deal with those issues, and at the same time, all the political players involved need to be willing to talk and negotiate.

2.5 Recommendations

As some major environmental drawbacks associated with fracking technology have been identified, other alternatives such as renewable energy sources as well as exploring safer means of extracting natural gas may need to be taken into account for meeting sustainable energy expectations. Besides, in order to enhance the commitment of environmental protection and social welfare, the laws and regulation pertaining to fracking technology need to be reviewed and improved by involving all stakeholders and considering all relevant perspectives and impacts.

In view of the diverse arguments of fracking technology, both research works and monitoring of fracking activities are deemed essential and required to be reinforced by the US Energy Information Administration (EIA) and Environmental Protection Agency (EPA). These efforts are expected to clarify the relevant benefits and challenges, reduce the negative impacts, and validate the suitability of being a future sustainable energy technology. In addition, all environmental groups and O&G companies should support and encourage the Center for Sustainable Shale Development (CCSD) to continue the implementation of improvement and innovative practices for fracking technology development, because the sustainability consideration cannot be thoroughly enhanced without close collaboration among all stakeholders.

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