ACHIEVEING SELF-SUFFICIENCY IN ENERGY PRODUCTION: ADAPTING TO THE TECHNOLOGY OF HYDRAULIC FRACTURING

by

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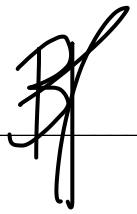

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ABSTRACT

ACHIEVEING SELF-SUFFICIENCY IN ENERGY PRODUCTION: ADAPTING TO THE TECHNOLOGY OF HYDRAULIC FRACTURING

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2024

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The present study has illustrated that self-sufficiency has played a significant role in human society. It highlights the aim and purpose of this thesis. Arab Oil Embargo and Russian Supply Cuts have resulted in creating self-sufficiency in the energy sector as early as 1970. The dependency on the supply of energy can be reduced with strategies of mergers and acquisitions. The current research has defined that hydrocarbons could be a potential source that can drive the conveyance and generate electricity. Global energy players and governmental institutions have identified alternate sources of energy such as wind energy and solar energy. To provide more solutions to the problem of relying on crude oil and other renewable resources for energy production is the purpose of this thesis. Some of the research questions that have been answered through this research are; What strategies are you using to extract a high quantity of shale gas? What is the true meaning of being energy self-sufficient for a nation?, and What competitive strategies to increase profit margins and achieve high efficiencies? It can be determined that the application of these useful energy sources assists in decreasing a high level of pollution. Those engaged in such research have examined the viability of wind energy in the North Sea in the UK. The sector of global

energy typically suggests both essential scopes and severe challenges. The shale revolutions define the ***"hydraulic fracturing"*** and ***horizontal drilling"*** that assist the USA in enhancing their production of ***"oil"*** and ***"natural gas"***. It has been estimated that the application of ***"Cradrilla Energy"*** is mainly utilized for hydraulic fracturing to facilitate the potential production of shale gas in the UK. This research aims to explore the impact of using hydraulic fracturing as an alternate source of energy and enlist the challenges that such an effort would entail. Based on the research, the outcomes have been mixed where the UK can produce shale gas through hydraulic fracturing if they take help from other nations as well as keeping their research active in this field.

Keywords: Energy, wind energy, solar energy, hydraulic fracturing, oil and gas

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CHAPTER I: INTRODUCTION

1.1 Introduction

The desire for self-sufficiency has continued to play an important role in human society (Aslışen & Hakkoymaz, 2022). No economy wants to be perpetually dependent on other countries for commodities and other services. From a geopolitical standpoint, the sentiment is arguably strongest in the energy sector. In the 1973 when the Arab Oil put an Embargo on the US and other nations for supporting Israel in Arab-Israel War. Now the Russian supply cuts, and threats to use the "oil as a weapon" increased the global desire for energy self-sufficiency.

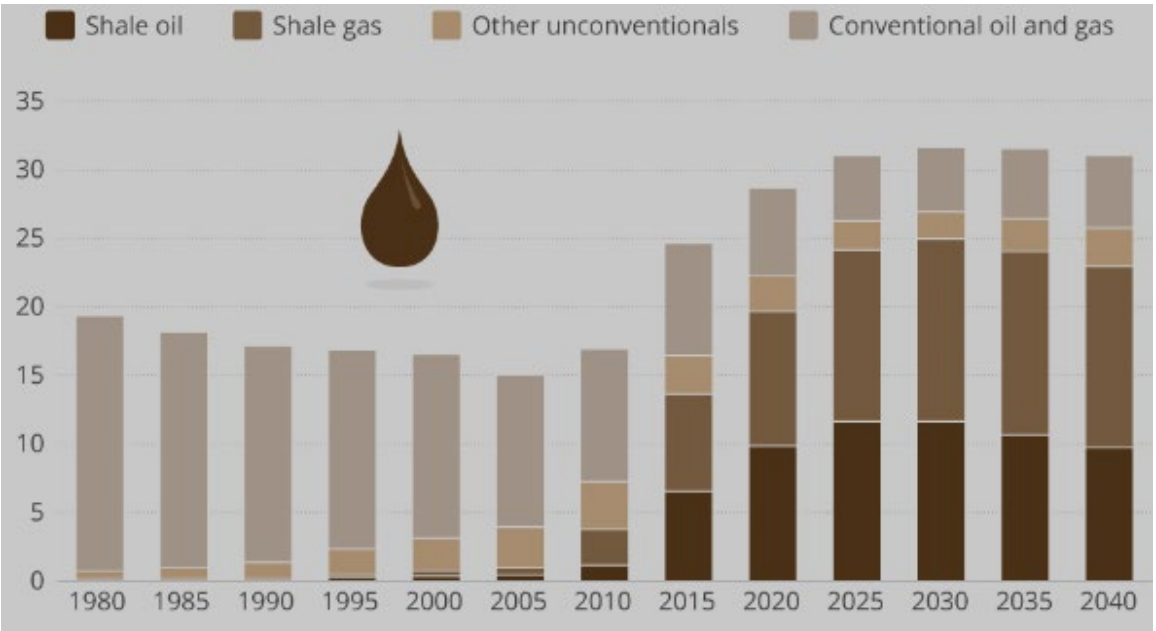
When we talk about a country's pool of energy commodities, we mean the various commodities that make up that pool, such as natural gas, coal, uranium, and other non-renewable energy sources. In general, a country can become self-sufficient in some of these commodities. For example, the electricity sector in the United States is nearly self-sufficient today, and nuclear power generates the majority of electricity supply in France (Rosati et al, 2022). Due to insufficient refining capacity, even oil-rich countries such as Venezuela, Brazil, Saudi Arabia, and Russia import some of their energy in the form of refined petroleum products. The reliance on energy supply can be reduced with some effort and investment. Hydrocarbons dominate the transportation and electricity systems, hence it is challenging for most countries to be self-sufficient as they continue to rely on the global energy trading system. Other ways of becoming self-sufficient for the economies is using renewable energy and its technology. UN has recognized these energy resources like wind and solar power as the energy sources for the future and advocates decentralization of knowledge, copyrights and funds to be allocated in this sector. It would help to make these energy sources a globally available as a public commodity. It will decrease the

reliance on fossil fuel generated energy sources and will improve the environmental and climate changes. A large sum of money needs to be invested in this sector. The supply chain of raw materials should be developed in an efficient and effective manner (Hassan et al, 2022). By using these resources on a global level will facilitate reduction in levels of pollution which will enable saving money for the whole world that could be further used in making these energy sources commoditized.

It may appear to be an unrealistic endeavor at first, countries must investigate ways to achieve this energy generation and supply which will result in consumption independence. When it comes to energy resources like coal and gas, many countries had to rely on imports from other countries to meet their domestic energy needs. The government had investigated wind energy projects in the UK's North Sea, for example, though they have not been entirely successful. In terms of quality, the UK's shale gas reserves have been shown to be superior to those in the US (Jana, & Ghosh, 2021). After a decade, the 13th Onshore Licensing Round, the fracking industry in the United Kingdom has received only GBP 400-500 million in anticipated investments, and commercial production remains uncertain.

The "shale revolution" has been a boon to the oil and gas industry. Shale revolution includes using hydraulic fracturing and horizontal drilling. It helped the USA to increase its oil and natural gas production. The immediate benefit was the decrease in the domestic energy prices of oil and gas industry (Jew et al, 2022). Cuadrilla Energy in the United Kingdom used hydraulic fracturing to assess the potential for shale gas production (Bradshaw et al, 2022). Despite being granted permission, the experiments were eventually halted due to seismic shocks and the negative effects of the technology. Hydraulic fracturing became a contentious issue in the United Kingdom prior to Brexit, owing primarily to EU environmental regulations. Due to its impact on certain environmental

damages, the growth trajectory has shown signs of slowing down. The US has shown very less contribution globally in worldwide oil production growth. In the next few years, it is evident that OPEC will again be in the driving seat of this industry. During his tenure, President Biden tried to cajole oil producers to increase the production, but he met with little success.



Source 1(Statista, 2017)
Figure 1.1 Revolution of Shale in America

The above stacked bar graph shows different variants of oils and gases produced from 1980 with projections to 2040. The vertical axis shows the oil and gas quantity produced measured in millions of barrels per day (Mbd) and the horizontal axis represents different years. During the period of 1980-2005, majority of production comes from conventional oil and gas. The other unconventional and shale oil and gas were almost non-existent at that period. From 2010-2020, it can be seen that there is a sudden increase in the production of shale oil and gas, particularly from 2015. This shows the impact of

advancements in technology like hydraulic fracturing. From 2025-2040 which is projected, the total production of shale oil and gas seems to be increasing making it a significant portion. On the other hand, the production of conventional oil and gas seems to be decreasing with a slight increase in other unconventional. Overall, the graph shows the shift from conventional oil and gas to increased dependence over shale and other unconventional sources over time.

Energy resource development and production methods, such as hydraulic fracturing, raise several environmental concerns, including seismic vibrations and soil and water pollution. Environmentalists believe that these problems are the result of operational errors and poor practices rather than inherent flaws in the technology. In terms of lowering greenhouse gas emissions, shale gas development has a greater impact on global warming than switching to cleaner fuels or establishing a low-carbon technology footprint. Working closely with environmentalists and members of the oil and gas industry can aid in resolving this issue.

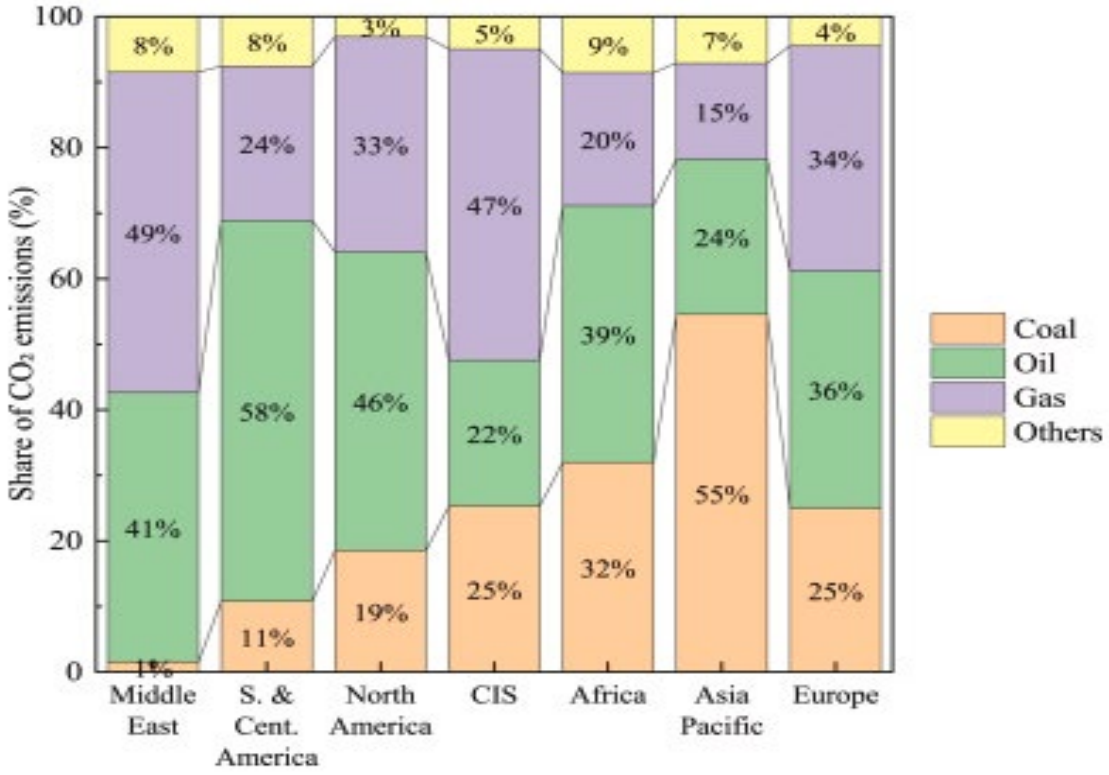
1.2 Research Problem

Northop (1966) elaborated on a research problem stating that the researcher starts conducting the inquiry the moment he finds it unsatisfactory traditional beliefs are inadequate and it is necessary to solve the unanswered questions. Brewer (2005) further states that all theories have some inkling of being problematic in principle and hence subjected to further investigation. A researcher observes problematic loopholes in the research and takes the initiative to correct the wrong interpretation (Martyn, 2008). Problem formulation is the first step in conducting the research which stems from the background of the study and requires a further study of the literature to backup various contentions (Olanrewaju, 2007).

Developing measures for becoming self-sufficient for the production of energy is quite crucial. However, the question that linger around is that what are these measures that can be applied by the nations to do that? The main focus of this research is to understand one such measure that is hydraulic fracturing. There can be many question arise in the reader's mind after going through this thesis, however, the issue can only be resolved with the help of collaboration between the countries. This research is limited to focus on limited events that have created a situation to delve on these such measures. These focused events are only those that have changed the oil market. Focusing on the smaller events was not possible due to the time restraints and that is the research gap. This problem can be solved by identifying the impact of some smaller events that has disintegrated the oil economy. Certain observed events, problematic theories, and current ideas are challenged by the researcher to indicate the inherent research problem (Brewer, 2005).

The importance of achieving self-sufficiency in energy production and its e consumption is the primary question for this thesis. To evaluate Hydraulic fracturing, a common practice in natural resource extraction, although it has the potential to cause seismic tremors, and soil and water contamination (Lange, 2022). Environmentalists argues that these concerns are the result of operational errors and poor practices rather than inherent flaws in the technology. Shale gas production could have a greater impact on global warming than switching to cleaner fuels or establishing a low-carbon technological footprint. Solving this issue may necessitate collaboration between environmentalists and members of the gas industry. In this thesis, the researcher aims to explore the impact of using hydraulic fracturing as an alternate source of energy and enlists the challenges that such an effort would entail. It aims to consider the opinion of the environmentalist's lobby as opposed to the benefits that can be derived from using this technology. The researcher

wishes to explore the benefits that this technology might bring in creating self-sufficiency in the energy sector.



Source 2 (Wang et al., 2023)
Figure 1.2 CO_2 emissions by world region in 2020

As per the graph above, fossil fuels (coal, oil, and gas) are the primary sources of CO2 emissions in all regions, highlighting the need for transitioning to cleaner energy sources to mitigate climate change. The carbon emissions due to fossil fuels in every region are between 92%-97%. Europe is the only region in which the carbon emissions are somewhat close to when looked at coal, oil, and gas. This suggest that there is a need to shift towards more cleaner sources. The graph provides valuable insights into the regional and energy-source-specific patterns of CO2 emissions, which are crucial for understanding

the global climate challenge and developing effective mitigation strategies. One such strategy is shale oil and gas production that is being challenged in Europe by the population.

A problem statement is a way to express the research problem and is the focal point of any research study. While the research problem is the gap or the loophole that is found in the subject the problem statement is the logical explanation of the problem and creates a missing link to the background of the study (Brewer, 2005). The statement prompts the researcher to further conduct the study and provide an explanation for the investigation with its specifics (Olanrewaju, 2007). The researcher in this study wishes to explore the possibility of hydraulic fracking as an alternative source of energy that would make countries self-sufficient in their energy consumption. This problem statement would give directional guidance to the entire study and help the researcher to collect appropriate data to substantiate his claims.

1.3 Purpose of Research

Scientific knowledge about a subject is only derived when it is subjected to a rigorous study by gathering evidence in the form of data to justify the hypothesis formulated for the study. It is a systematic process that requires looking at the problem with a fresh pair of lenses to formulate an alternate theory or perspective towards the problem. Multiple methodologies are adopted by the researcher to arrive at a conclusion regarding the research problem that he is engaged with.

In this case the researcher wishes to offer to the world a safe and alternate form of energy that would free nations from the grip of the oil-controlling countries and make them self-sufficient. A study has been conducted and referred to in the thesis about the current scenario of the energy sector in the context of fossil fuel and its consumption. The historical trends were examined to create a background for the study. A detailed study on hydraulic fracturing revealed that it could be an alternate source of energy and might help in making

nations' energy sufficient. The process is fraught with certain issues like environmental pollution and other negative impacts. The researcher showcases the issues as well as the positive aspects it can create in the energy economy. The researcher invites the readers of the thesis to examine the concept as they read the report and the outcome of the study.

1. To gather data of energy production and supply, as well as various methods that can be implemented for doing so, one such method being hydraulic fracturing.

2. To prepare an analysis by using hydraulic fracturing to accelerate the growth of a country's energy economy, particularly in the United States.

3. To conduct research on hydraulic fracturing, one such research is the hydraulic fracturing done by Cuadrilla Resources in northwest England and made a claim that there is shale gas flow.

4. Examining the potential routes to reduce the negative environmental impacts of hydraulic fracturing so that it can be increasingly and permanently adopted by the countries. The experiment conducted by Cuadrilla Resources heavily resisted by the people of Lancashire due to environmental impacts (Chestney, 2019). This is why researchers must make it more ecological.

5. Investigating the concept of hydraulic fracturing in conjunction with achieving autonomy in energy supply and consumption.

1.4 Significance of the Study

1. To conceptualize factors that may contribute towards achieving self-sufficiency in the energy production of a particular country to meet its energy demand, to enlist the importance concerning its economy?

It is the dream of every country to achieve self-sufficiency in energy consumption. It would be an ideal situation if the countries do not need to rely on others to meet their demand for vital commodities and services. The European Union's excessive reliance on

Russian energy supplies is a recent example of such dependency (Bardt et al, 2022) The European Union is currently in turmoil due to the Russian authorities shutting down the Nord Stream pipeline, which transports Russian gas to the European Union. Achieving self-sufficiency in this sector will boost national security, result in lower and more stable oil and gas prices, and help to alleviate the debt and budget crisis.

2. How do new technologies like hydraulic fracturing interact with energy production and consumption?

Using the US ‘shale gas revolution' as an example, the US hydraulic fracturing sector has undergone several significant changes as the sector's major players have altered their initiatives and business strategies in response to a push for cleaner production solutions while dealing with market tightness and rising costs (Shakya, S., Li, B., & Etienne, 2022). These modifications have largely revolved around the goal of experimenting with new technologies to improve the process as a whole by increasing efficiencies.

3. What has been the global environmental impact of hydraulic fracturing, particularly in the United States, where there has been a massive energy boom primarily due to the use of hydraulic fracturing?

While the exploration and production of shale gas in the United States has resulted in a massive economic revolution, there is no doubt that the technology also had a negative impact on the environment. Shale gas development in the country has resulted in groundwater contamination, seismic activity, and air pollution. What is important to examine in this fracking problem is whether these environmental impacts can be mitigated by implementing best operational practices that avoid environmental degradation while still employing fracking technology. The main issue with hydraulic fracturing is, it emits a large amount of greenhouses gases. These gases add to pollution and adversely affect the

environment. In this process a lot of water wastage, air and noise pollution are also generated. This has a bad impact on the surroundings. Animal and plants, and the population is in decline in the nearby areas (Wu et al, 2022). These operations also lead to continues land deterioration and disruption in migratory cycles. In future it can impact the fertility of the land and may result in the decline in primary industry.

4. Is it critical for countries to increase their investment in hydraulic fracturing in the future, despite its current negative environmental impacts?

With increased awareness of climate change concerns, the world is slowly and gradually progressing toward exploring more renewable resources; however, it is also important to investigate technologies that can facilitate tapping conventional sources of energy that cannot be extracted through traditional drilling methods. Fracking is one such technology that, through horizontal drilling, can access non-porous rocks for shale gas that would otherwise be inaccessible through simple vertical drilling. While technology has caused some environmental concerns, it is critical to use technology in a way that results in the best operational outcomes.

5. Can countries such as the United Kingdom replicate the 'shale gas boom' experienced by the United States and learn from its example?

The Cuadrilla incident in the United Kingdom in 2015, which used fracking for the first time in the country, was met with strong public opposition (O'Brien, 2022). This eventually led to the technology's trials being halted entirely, as the trials caused seismic activity, water contamination, and air pollution. However, one must keep in mind that this was the first time the technology was used in the UK and it needed time to develop into an appropriate procedure.

1.5 Research Purpose and Questions

1. Understanding the concept of energy production and supply, as well as the various methods for doing so, such as hydraulic fracturing.

This question will help the readers to understand the background context of the production and supply of energy in today's world. It will help understand the dynamics of oil control and deficit and surplus nations.

2. Examining the history of using hydraulic fracturing to accelerate the growth of a country's energy economy, particularly in the United States.

The concept of hydraulic fracturing in central to this thesis and an overview of this production process and its successful use in the USA will help the readers to understand the ease of the process and its benefits.

3. Environmental research on hydraulic fracturing, such as the Cuadrilla experiments in the United Kingdom.

The process of hydraulic fracturing had come under some flak from environmentalists with issues about environmental pollution. This section will provide a correct perspective on the nature of the environmental impact that this process can create in the near future.

4. Investigating ways to reduce the negative environmental impacts of hydraulic fracturing so that it can be increasingly and permanently adopted by countries.

If the process of hydraulic fracturing is used by other nations to become energy self-sufficient then reducing the negative impacts is essential for the oil producers. This section will provide various ways through which these negative impacts can be mitigated.

5. Investigating the concept of hydraulic fracturing in conjunction with achieving self-sufficiency in energy supply and consumption.

The researcher would also delve into the benefits of the process and how this process can make nations self-sufficient and reduce their dependency on other oil-producing nations and talk about the merits of implementing this process.

CHAPTER II: REVIEW OF LITERATURE

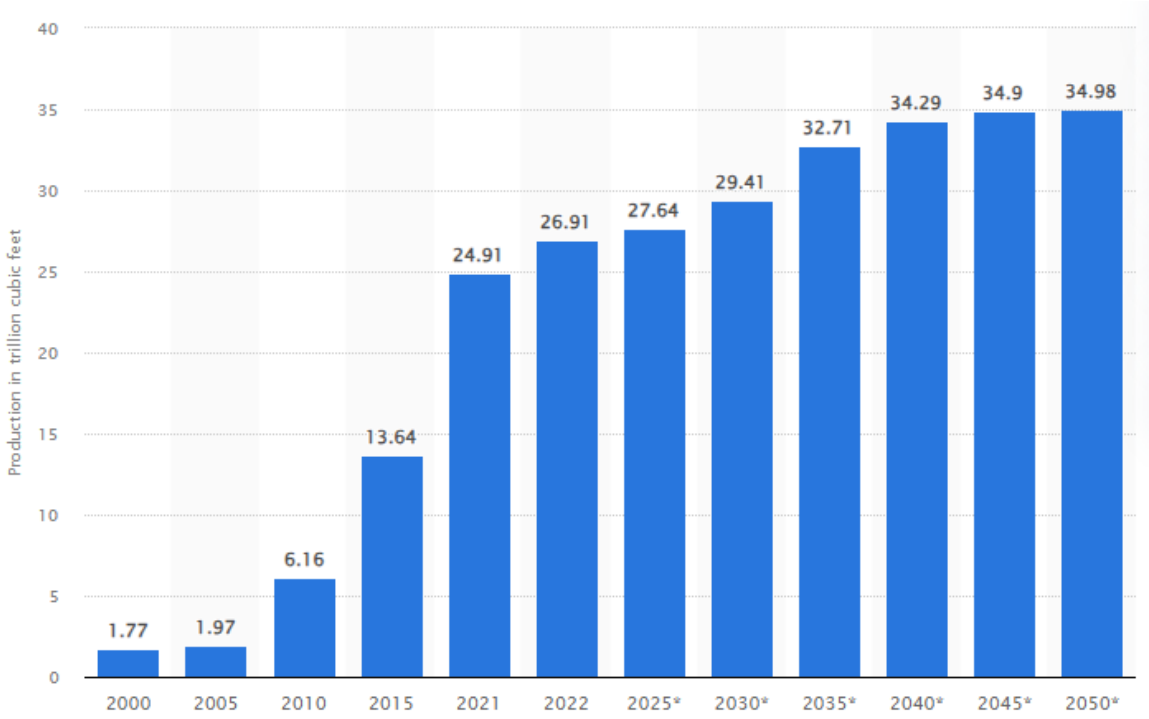
2.1 Data by Country on Shale Oil and Gas

2.1.1 USA

The last ten years have seen a notable increase in the production of shale gas and oil in the United States, mostly due to developments in hydraulic fracturing and horizontal drilling techniques. Due to this growth, the nation is now a significant producer of energy and is less dependent on imports from outside. Shale oil production has increased significantly and now accounts for a large share of the country's crude oil supply. This expansion has been facilitated in large part by important shale oil regions like the Permian and Bakken. US shale oil output of approximately 60% was accounted for by the Permian basin in 2023 (Tang et al., 2024). Likewise, the development of shale gas has surged, augmenting the domestic natural gas reserves and impacting energy costs. The shale revolution has improved the economy and increased energy security, but it has also sparked worries about possible groundwater contamination, increased water usage, and induced seismicity. A major obstacle for the sector and legislators continues to be striking a balance between the benefits to the economy and the environment.

The graph displays the historical and anticipated production of shale gas and oil in the US from 2000 to 2050, expressed in trillion cubic feet. Production increased somewhat from a low base of 1.77 trillion cubic feet in 2000 to 1.97 trillion cubic feet by 2005. Production reached 6.16 trillion cubic feet in 2010, marking the start of the genuine rise, which was driven by improvements in extraction technologies including horizontal drilling and hydraulic fracturing. The influence of the shale revolution on U.S. energy production was highlighted by this quick growth, which reached 13.64 trillion cubic feet by 2015 and more than doubled to 24.91 trillion cubic feet by 2021. Production continued to rise as

more shale deposits were tapped, reaching 26.91 trillion cubic feet by 2022. Production is expected to climb to 27.64 trillion cubic feet by 2025, 29.41 trillion cubic feet by 2030, and 32.71 trillion cubic feet by 2035. It is anticipated that production will increase to 34.29 trillion cubic feet by 2040 and reach 34.98 trillion cubic feet by 2050, indicating that growth may start to plateau. This chart demonstrates how important shale oil and gas are to the US energy market, and how resource exploitation and technical advancement have made them possible. The anticipated steadiness of production after 2040, however, may indicate future resource constraints, economic considerations, or a gradual transition to renewable energy sources. While hinting at the necessity of long-term energy planning, the chart emphasizes the significance of shale oil and gas for U.S. economic growth and energy security.



Source 3 (Statista, 2024)
Figure 2.1.1 Historical and Projected Shale Oil and Gas Production in the USA

2.1.2 UK

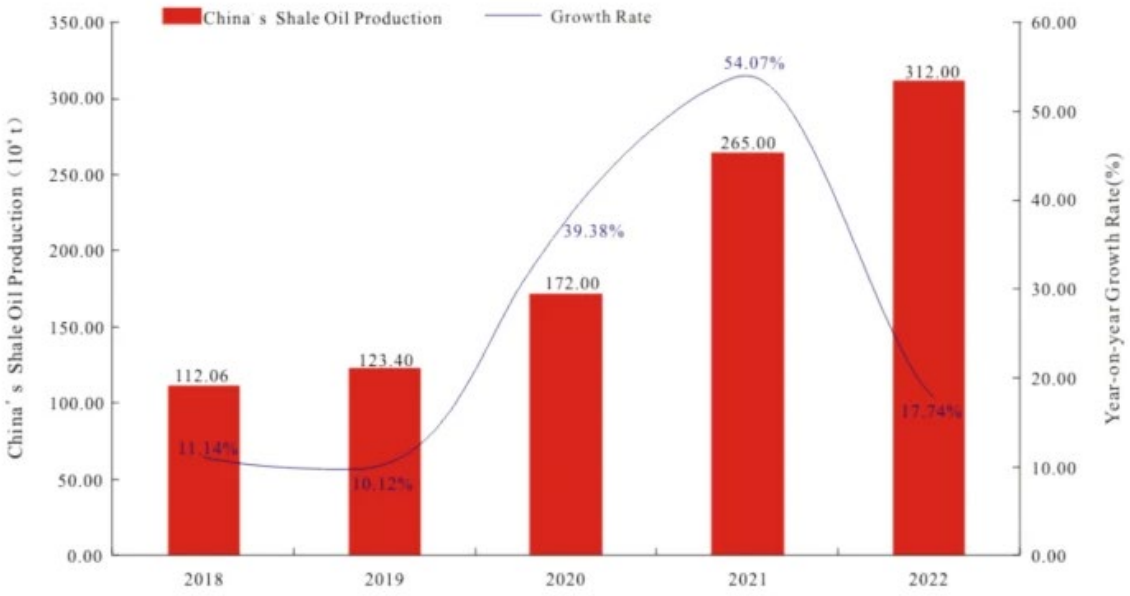
Despite the UK's abundant shale gas deposits, commercial production has been constrained by a number of issues, such as planning laws, environmental concerns, and economic feasibility. Comparing the UK's shale gas production as of 2024 to other nations with sizable shale deposits, it is still quite low. The nation has not yet attained large-scale commercial output, notwithstanding a few small-scale production projects and exploratory drilling operations. Shale gas still makes up a small portion of the UK's total energy mix; the majority of the country's energy comes from conventional sources including coal, natural gas, and renewable energy. Nonetheless, there is still discussion and research being done on the possibility of developing shale gas in the UK.

It is challenging to generate a trustworthy estimate of the UK's technically and financially feasible shale gas resources given the uncertainties. In 2013, the US Energy Information Administration calculated that the UK possessed 3.8 trillion cubic metres of proven shale gas in Northern and Southern England (United Kingdom, 2015). Of this, 0.7 trillion cubic metres were deemed technically unrecoverable, meaning they could not be easily accessed, would not be profitable, or their existence was presumed but not verified. There was no estimate offered by the US EIA regarding the potential amount that could be economically and technically recovered.

2.1.3 China

The country's abundant geological resources, government assistance, and technological breakthroughs, China has been producing more shale oil and gas in recent years. China now uses a large amount of its natural gas supply from shale gas production, which has grown significantly. Shale oil output has been more restricted, although it is steadily increasing. China produced about 25 billion cubic meters (bcm) of shale gas in 2022 (Fu & He, 2024). This constituted a noteworthy surge in contrast to prior years. Shale

gas produced about 25–30% of China's total natural gas, which is a significant amount. Compared to shale gas, China's production of shale oil in 2022 was comparatively small. Although precise numbers are not readily available, estimations point to several million tons. Complicating the development of shale oil in China include intricate geological formations and increased production expenses. But the sector also has to deal with issues including complicated geological formations, increased manufacturing costs, and environmental concerns (Zhang et al., 2022). China's shale oil and gas industry is predicted to expand in spite of these obstacles, bolstering the nation's economic growth and energy security.



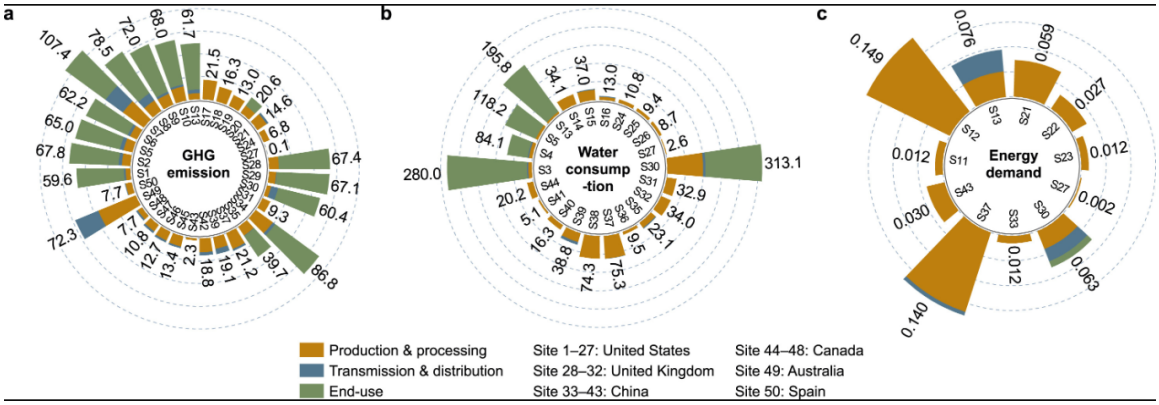
Source 4 (Fu & He, 2024)
Figure 2.1.3 China's Shale Oil Production

The graph shows the annual growth rate of China's shale oil output from 2018 to 2022. The blue line indicates the proportional growth rate, and the red bars indicate the production of shale oil, expressed in 10^4 tons. With a growth rate of 11.14%, China produced 112.06 × 10^4 tons of shale oil in 2018. In 2019, production reached 123.40 ×

10^4 tons, while the growth rate decreased to 10.12%. 2020 saw a notable increase in production, with a substantially higher growth rate of 39.38%, reaching 172.00 × 10^4 tons. In 2021, the output reached 265.00 × 10^4 tons, indicating the highest growth rate of 54.07% throughout this era. This upward trend persisted. Nonetheless, in 2022, the output reached 312.00 × 10^4 tons, but the growth rate decreased to 17.74%, suggesting a deceleration in the pace of production growth. Despite varying growth rates, the graph shows a significant increase in China's shale oil production over the years.

2.1.4 Critical evaluation

The information on shale gas and oil production in the USA, UK, and China that has been supplied provides insightful information about how these resources are used in each nation's energy system. To properly assess this data, however, a number of important factors need to be taken into account. First and foremost, it's critical that the data sources be trusted. The data for the US, which indicate a notable rise in shale output between 2000 and 2022, are supported by sources including Tang et al. (2024) and Statista (2024) and are in line with industry trends. Even though these sources might be reliable, it's important to confirm their legitimacy—especially considering Tang et al.'s peer-reviewed status and the original sources of Statista's data. The US Energy Information Administration's (EIA) 2013 estimate and a 2015 report's estimates serve as the foundation for the statistics in the UK. These estimations could not be current because fresh geological surveys and technological developments could drastically change the potential for the resources. The validity of the UK's estimate of its shale gas potential is called into question by the absence of more recent data. China's data, credited to Fu & He (2024), on the other hand, suggests new research, but it does not include enough background information to evaluate the validity of these conclusions. To guarantee accuracy, more information on the process and data validation is required.



Source 5 (Li et al., 2022)
Figure 2.1.4 Environmental Tradeoff Comparisons

Three circular bar charts that show various energy and environmental indicators across different sites connected to shale gas activity are included in the illustration. Greenhouse gas (GHG) emissions are shown in graph (a), which is colored according to the stages of production and processing (orange), transmission and distribution (blue), and end-use (green). This graph shows how GHG emissions vary greatly between sites; some have considerable emissions during production and processing, while others exhibit higher emissions during end-use. Water usage is shown in Graph (b), which is divided into the same three stages as before. It demonstrates that some locations use more water than others, especially throughout the production and processing stages. For example, S3 is one site that uses a lot of water. Finally, Graph (c) shows the energy demand, subdivided similarly, for each of the sites. This graph shows that there are variations in energy demand, with certain sites showing high energy consumption during processing and production and others maintaining low energy demands during end-use, indicating superior efficiency. The websites are numbered and arranged according to nation, with representation from China, the United States, the United Kingdom, Canada, Australia, and Spain. When taken as a whole, these infographics shed light on the energy needs and environmental impact of shale gas operations, highlighting the distribution of these effects over several lifecycle stages

and geographic regions. This knowledge is essential for streamlining operations, lessening environmental impact, and enhancing the sustainability of shale gas extraction and use.

Though at a slower rate, the historical patterns and forecasts for the USA's future point to a sustained increase in shale oil and gas output. Because they frequently assume stable technological, economic, and regulatory conditions—conditions that are subject to change—these estimates should be viewed with caution. These forecasts could be greatly impacted by variables like market dynamics, environmental laws, legislative changes, and technological advancements. On the other hand, the data from the UK emphasizes uncertainties and shows that large-scale commercial shale production has not yet been accomplished in the nation (Li et al., 2022). Due to technological, governmental, and economic obstacles, the figures provided indicate potential rather than actual development prospects. The production of shale gas and oil has grown significantly in China, according to data; nevertheless, the growth rate of shale oil declined from 2021 to 2022, indicating possible difficulties. It needs to be observed if this tendency points to a transient variation or a more persistent problem.

Economic and environmental factors are also quite important. Concerns concerning increased water use, induced seismicity, and groundwater contamination have been brought up by the rise in shale extraction in the USA. These issues have the potential to affect public opinion and regulatory frameworks. Moreover, shifting oil prices and increased competition from renewable energy sources might jeopardize the economic feasibility of shale development indefinitely (Schuetze & Hussein, 2023). Even in the event that commercially viable reserves are found, environmental concerns and strict planning requirements pose substantial obstacles to shale production in the UK. Even though China's shale production has grown significantly, scaling up operations will be difficult because to complicated geological formations, high production costs, and environmental concerns.

Unit consistency is a crucial methodological requirement for comparative analysis. Direct comparisons are problematic due to the usage of different units throughout the data for different countries, such as trillion cubic feet, cubic meters, and 10^4 tons. It would be easier to compare these numbers if they were converted to a common metric. Furthermore, to provide a better understanding of the range of possible outcomes and the level of certainty associated with these forecasts, the projections—especially those for the USA up to 2050—would benefit from the inclusion of uncertainty measures, such as confidence intervals or error margins.

Lastly, the information raises questions about the larger picture of a worldwide energy shift. The prospect of a peak in American shale output beyond 2040 points to a gradual transition to renewable energy sources. Comprehensive insights could be obtained by delving deeper into the potential effects of global energy transitions, policy shifts towards decarbonization, and developments in renewable technologies on the future of shale oil and gas (Botão et al., 2023). Furthermore, trade policies, geopolitical dynamics, and variations in the price of oil and gas globally might all have a major impact on the shale oil and gas sector. Comprehending the strategic significance of China's increasing domestic production in lowering energy imports, as well as the USA's prominent role in energy exports, would enhance the study. In summary, the data provided offers a helpful overview of the production trends of shale oil and gas in the USA, UK, and China. However, in order to fully understand the future of shale oil and gas, it is imperative to critically assess the reliability of the sources, take into account economic and environmental factors, and incorporate broader energy transition trends and uncertainties into the analysis.

2.2 Theoretical Framework

The researcher reviewed several literature sources to find the appropriate theoretical underpinnings that would help to formulate the foundation of the study. The literature findings have been listed under several headings as was needed for the research.

2.2.1 Attainment of self-sufficiency in energy production through shale gas and its effect on the economy

Every nation desires self-sufficiency as no one wants to rely on others for essential commodities and services. There are additional reasons to be self-sufficient, particularly in terms of energy production. Self – sufficiency helps to reduce the nation's economic debt, mitigate the budget crisis, improve national security, and result in a lower and more stable gasoline crisis. In today's globalized world, maintaining an uninterrupted energy supply at affordable prices provides true energy security to any nation. Due to the vulnerability of the global economy and the oil price spikes, it appears that achieving energy self-sufficiency for nations remains an unrealistic goal that has yet to be realized.

The rise in oil prices in the ailing global economy have already caused havoc. Asia's thirst for crude oil grows by the day and there is a risk of conflict over access to oil (de Carvalho et al., 2021). Where nations are attempting to achieve energy self-sufficiency and development through oil, the approach should be different to achieve better and more fruitful results. If the aim shifts to achieving energy production needs through other means rather than downplaying the strategic importance of oil, the conflict may be avoided.

Shale gas has evolved into a new-age energy producer with enormous potential to serve countries with reserves and other countries through import. In the United Kingdom, shale gas extraction began in 2008. Conventional oil and gas extraction began in the 1970s in the North Sea using the hydraulic fracturing technique. Hydraulic fracturing is also used to produce shale gas, but it came to prominence at a much later stage. The United Kingdom

recently received a license for shale gas exploration. There was a conflict of interest among the public. The debate arose because shale gas extraction via hydraulic fracturing has a significant negative impact on the environment. The extraction is environmentally friendly or not debated, and groups of environmentalists voiced their opinions against it. When it comes to the positive impact of extracting shale gas from UK basins, the positive impact of such production in meeting the nation's energy needs and contributing to the economy has more points on its side.

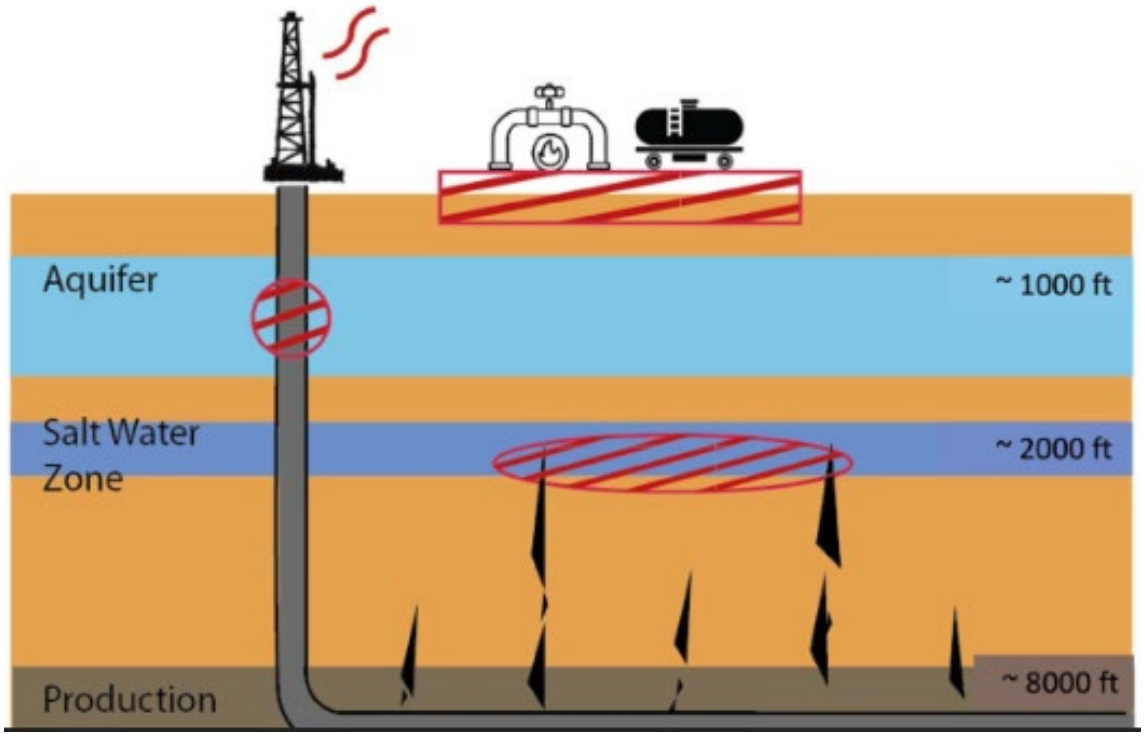
The United Kingdom has abundant shale gas reserves, which is good for the country's ability to become self-sufficient in the energy production sector. However, drilling for shale gas in the UK shale basins can be very costly. If a proper strategy is used for the gas production process, it can be much easier. A proper strategy can also reduce the cost of production, lowering the price of natural gas in the United Kingdom. The rising price of natural gas in the United States and Canada has had a significant impact on the economy. The presence of shale gas reserves in the United Kingdom gave the entire country hope that the country will soon become a global powerhouse in the energy industry. Experts are yet to determine how much can be recovered from shale gas reserves, but this gaseous source of energy has enormous potential to propel the UK economy forward (Brauers, 2022). Though recovering the entire reserve of shale gas is not currently possible, 10% of the gas present in the basins can be easily extracted. The recovered gas from this 10% extraction can meet the needs of the United Kingdom for the next 50 years. In this way, the United Kingdom can become one of the world's most powerful economies.

2.2.2 Hydraulic Fracturing Contributing towards Production of Energy through Shale Gas

Shale gas or natural gas is the most traded commodity between developing and developing countries worldwide. Shale gas is a significant fuel in the world's energy resources. The countries with the most shale gas reserves are capitalizing on the opportunity to generate massive amounts of national income through exports, thereby improving their financial stability. Russia, Iran, Qatar, Turkmenistan, and the United States are the five countries that produce the most shale gas on a global scale. Globally, shale-gas reservoirs have been developed in North America (Canada and the United States), Latin America (Argentina, Brazil, and Mexico), Africa (Algeria and South Africa), Australia, China, Russia, and the Middle East. Outside of the United States, China is estimated to have the most shale gas resources. Outside of the United States and the United Kingdom, China is thought to have the most shale gas resources. China has doubled its shale gas production in the Sichuan Basin in the last two years, bringing it to 20 billion cubic meters (bcm). Sinopec's Fuling Shale Gas field in the Sichuan Basin and PetroChina'sChangning-Weiyuan and Zhaotong Shale Gas fields account for the vast majority of China's domestic shale gas output (Gao et al, 2021). Unlike in the United States and the United Kingdom, marine shales were used to produce the majority of China's shale gas.

The diagram below illustrates the hydraulic fracturing (fracking) process used in shale oil and gas production. It begins with a drilling rig at the surface that bores a well deep into the earth, penetrating through various geological layers. The well first passes through an aquifer, located around 1,000 feet below the surface, which is a critical layer containing fresh water that must be protected from contamination during drilling and fracturing operations. The saltwater zone, which is located at a height of about 2,000 feet below the aquifer, has salty water that is unsafe to drink. It is made sure that fresh and saltwater do not combine in this stratum, which is separate from the aquifer. The production zone is reached by the deepest portion of the well, which is normally found 8,000 feet

below the surface. This is the location of the shale gas and oil. Horizontal drilling is frequently used in this zone in order to access a greater portion of the shale formation.



Source 6 (Hwang et al., 2023)
Figure 2.2.2 Hydraulic Fracturing

Hydraulic fracturing has been used for six decades and is a tried-and-true method of extracting shale gas and other energy resources. Despite being used for over 60 years, hydraulic fracturing has only recently been used to generate a significant portion of shale gas in the United Kingdom. Owing to this method, which is frequently combined with horizontal drilling, the United Kingdom has been able to increase its oil production faster than at any other time in its history. Based on the most recent state data available, the EIA estimates that hydraulically fractured wells now produce more than half of all energy resources output. Hydraulic fracturing involves applying high pressure to a liquid (often water) coming from within a rock formation to fracture it, resulting in a borehole. The

crack grows longer as the high-pressure liquid in the wellbore seeps into the formation. This injected liquid contains prop pants, or tiny solid particles, which fill the widening crack (often sand or a synthetic granular solid of comparable size). When the injection is stopped and the high pressure is reduced, the formation tries to return to its previous configuration, but the prop pant keeps the fracture open. This allows hydrocarbons such as crude oil and natural gas to move from the rock formation back to the wellbore and eventually to the surface.

As the region has few export markets for the resource and no pipelines or LNG export facilities, any shale gas produced in North America is primarily used within the country. As a result, gas prices in the United States have dropped dramatically, with current prices (in 2013) being roughly one-third of peak energy prices in 2008 (Fell & Kaffine, 2018). The United States is currently converting LNG import terminals into LNG export terminals. A recent agreement between the BG Group and the US energy company Cheniere Energy Inc. may allow for the shipment of 3.5 million tons of LNG per year from the US to Europe beginning in 2015, at a lower cost than gas from Asia or Europe. The price of shale gas in the United States, and, more importantly for the United Kingdom, whether the price of gas falls, will be closely monitored. Currently, the United States exports LNG to the global market. For the first time, direct competition will exist between European natural gas produced locally and shale gas produced in the United States.

Shale gas as a potential industry in the United Kingdom did not take off until 1995, when the British Geological Survey (BGS) first identified the possibility of extraction. Shale gas was not mentioned in the Department of Trade and Industry's Oil and Gas Directorate's prospective UK petroleum resource reviews published in 2003. (Paul, 2021). Later that year, the 6th Petroleum Geology Conference on the Global Perspectives of Northwestern Europe took place. The three-day program concluded with an overview of

this unconventional petroleum. This enabled the distribution of the revised findings of Imperial College research conducted some fifteen years previously, as well as a presentation on the UK's shale gas resources. The UK could potentially benefit from the developments in the US with regards to shale gas. The British Geological Survey began reviewing UK shale gas resources in 2008, and their findings were presented at the 7th Petroleum Conference in March 2009. The Department of Energy & Climate Change later ordered the BGS report Unconventional Hydrocarbon Resources of Britain's Onshore Basins - Shale Gas. As a result, after the 13th Onshore Round of UK licenses was announced in 2006, several companies began investigating shale gas prospects in the UK.

2.2.3 Impact of Hydraulic Fracturing of Shale Gas on the Environment

The United States is now the world's leading natural gas producer. The reason for this is the advancement of hydraulic fracturing technology, with shale fields accounting for a sizable portion of the output. One of the major impediments to the advancement of knowledge in this field is the lack of transparency surrounding the chemicals used in hydraulic fracturing. Federal rules requiring hydraulic companies to disclose the composition and concentration of fracturing fluid to healthcare experts as well as federal and state regulatory authorities who needs to encourage this practice. With full disclosure of fracturing chemicals, future studies will be able to fill knowledge gaps for a better understanding of the effects of hydraulic fracturing on human health and the environment.

In the United States, natural gas production has increased exclusively onshore, with most of it concentrated in shale fields. Shale gas accounts for roughly 25% of US natural gas production and is primarily produced in the country's western, midwestern, and northeastern regions (Hibbard & Gilfillan, 2024). The use of shale gas as a resource would not be considered feasible or commercially profitable without the invention of hydraulic fracturing. Even though hydraulic fracturing has the potential to help the United States

achieve energy independence and thus benefit the economy, there are still several environmental concerns that must be addressed.

The primary source of concern for the public and environmentalists about hydraulic fracturing is the government's lax regulatory approach. Congress amended the SDWA's definition of "underground injection" in the Energy Policy Act of 2005 to expressly exclude from UIC regulation "underground injection of fluids or propping agents (other than diesel fuels) under hydraulic fracturing operations related to oil, gas, or geothermal production activities" (SDWA Section 1421(d)(1)) (B). Between 2005 and 2009, the top 14 oil and gas service companies used 780 million gallons of chemical compounds in fracturing fluids (Zhang & Hascakir, 2021). The concentration and composition of the fluid used in hydraulic fracturing vary depending on the type of formation. Some of these compounds may not be dangerous, while others have not been thoroughly tested. It is being researched and could be potentially hazardous to both human health and the environment. The only law that currently requires oil and gas companies to disclose the names of the chemicals in their fracturing fluids is the Emergency Planning and Community Right-to-Know Act (EPCRA), which requires owners or operators of facilities where specific hazardous hydraulic fracturing chemicals are present above certain thresholds to comply with emergency planning requirements. This makes the hydraulic fracturing industry more competitive.

In contrast, due to environmental concerns, hydraulic fracturing for gas production has been banned in France and Bulgaria. If hydraulic fracturing causes the release of hazardous substances at or below the surface in a way that endangers public health or the environment, all potentially responsible parties in the United States could be held liable under CERCLA for cleanup costs, natural resource damages, and the cost of federal public health studies. However, federal controls on hydraulic fracturing in general have been lax.

Proper documentation/reporting systems for wastewater discharge and spills must be enforced at the federal, state, and industrial levels. Furthermore, under the SDWA, hydraulic fracturing operations should be subject to UIC requirements.

2.2.4 Importance of hydraulic fracturing investment despite its negative impact

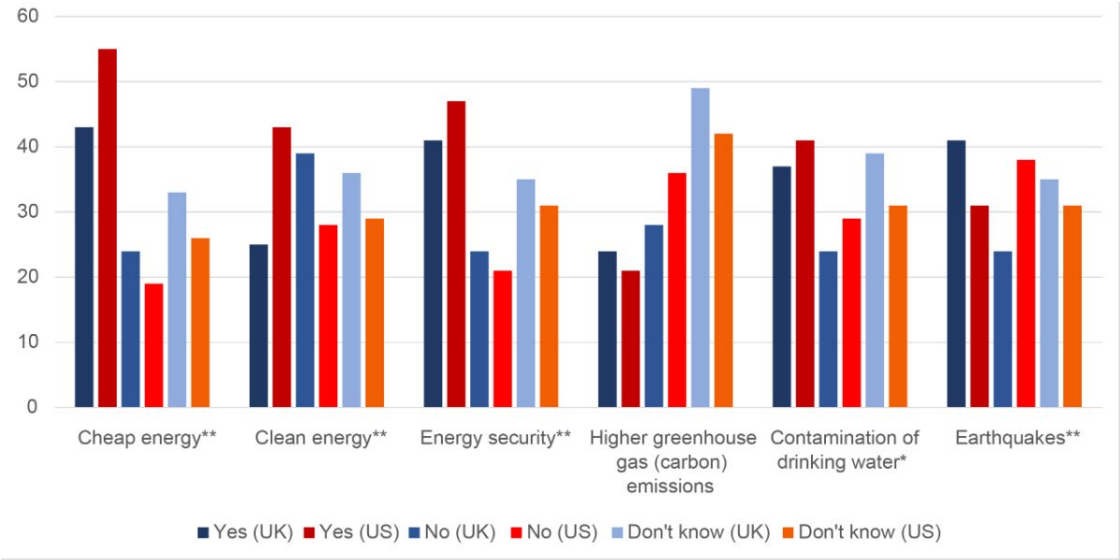
Fracking, or hydraulic fracturing, was possibly the most significant energy breakthrough in the previous 50 years. Hydraulic fracturing of shale gas has significantly increased energy resource availability in the United States, as has oil and natural gas production. This growth has dramatically reduced energy prices, improved energy security, and even reduced air pollution and carbon dioxide emissions by replacing coal in the production of electricity. Lower energy prices have resulted in prosperity among American families and businesses. With significant reductions in air pollution across the country and, at least in the short term, for the climate, lower emissions are unquestionably beneficial to human health.

It is up to the communities where drilling occurs or may occur whether society continues to benefit from the numerous benefits of hydraulic fracturing. These towns must perform a calculation to determine whether the local benefits outweigh the local expenses, which necessitates the accuracy of a large amount of data. Hydraulic fracturing is beneficial because it increases income, employment, economic activity, and house prices (Bartiket et al 2019). It does, however, result in increased truck traffic, increased crime, and potential health effects from air and/or water pollution. It has been demonstrated that the benefits of hydraulic fracturing outweigh the costs for the average household living in a neighborhood where it occurs; in fact, it is worth nearly twice as much amounting to $2,000 a year. A yearly cost of $2,000 was calculated based on people's current perceptions of the health effects at the time of our study. If people's perceptions of the health effects changed, the overall benefits of legalizing hydraulic fracturing of shale gas would most likely change.

The hydraulic fracturing of shale gas has altered the American energy sector. It has significantly reduced the country's energy costs, increased energy security, reduced air pollution, and reduced carbon emissions (although its long-run impact on carbon emissions is less clear). Hydraulic fracturing of shale gas, according to research has found to be harmful for local communities' health. One must be aware of the consequences of fracking as governments and communities in the United States and other countries continues to debate whether such a technology should be allowed to be used. This could be the only solution that ensures the world can reap the benefits of hydraulic fracturing while minimizing its drawbacks.

2.2.5 UK and US comparative analysis on the production of shale gas

The United Kingdom has significant shale gas reserves, but the complexity of its shale basins will make drilling for that gas more expensive compared to other countries. The problems can be mitigated if the proper production process and strategy are used to drill for shale gas. This will also result in lower natural gas prices in the UK. According to surveys conducted a few years ago, prices were three times higher than in other countries and twice as high as in the United States and Canada. As a result, the United Kingdom's burgeoning shale gas industry has the potential not only to boost the country's economy by lowering natural gas prices, but also to help the country emerge as a global player. The problem lies in the fact that it is impossible to know for certain how much shale gas is recoverable (Laherrère et al., 2022). This hazy estimate of the amount of gas that can be recovered from shale rocks is critical for the UK's future development as an independent energy producer. To have significant offshore gas reserves, the recoverable component of this unconventional gas must be established at the earliest.



Source 7 (Evensen et al., 2017)
Figure 2.2.5 Comparison of view on Shale gas

Looking at the bar graph above, the highest agreement is in the US, with over 50% believing in the possibility of cheap energy. In contrast, the UK shows lower agreement, with a significant number of "No" and "Don't know" responses. When asked about clean energy, Both UK and US respondents are divided, though there is slightly more optimism in the US compared to the UK. Similar patterns are seen in energy security, with both countries showing moderate agreement but also notable uncertainty. The US has a higher percentage of "Yes" responses over higher greenhouse gas emission as compared to the UK, indicating more concern about this issue. The contamination of drinking water is more prevalent in the UK than in the US. Both the UK and US show a mixed response, with a significant number of respondents unsure regarding earthquakes.

The scale of production activities that the country should develop in the shale gas sectors is always defined by the United Kingdom's potential shale gas resources as well as the policy-making authorities of the UK government. Formality and various legislation nuances in this area has remained a growing concern for the UK government. Shale gas is currently leading the unconventional gas sector, which has made significant contributions

to the gas industry's golden era. The United Kingdom has several favorable geological features that allow for significant shale gas extraction (Szolucha, 2019). High natural gas prices, advantageous geological characteristics in the UK, possession and ownership of private land, and mineral rights are among these advantageous features. The market structure, an abundance of available water, and the presence of natural gas pipeline infrastructure also contribute as an advantage. All of these factors, when combined, may enable the United Kingdom to successfully commercialize shale gas. In terms of shale gas production, the UK can outperform the US, but technological innovation remains as the most important factor.

The shale gas revolution boosted the American economy. As a result of this revolution, global gas prices fell dramatically, and the United States eventually became a net exporter of natural gas. In 2000, the United States produced 1.6% of the world's natural gas; by 2010, that figure had risen to 23.1%. The introduction of shale gas altered the dynamics of the US energy market. According to extensive research and numerous academic and governmental studies, the United States is profiting significantly from shale gas. The research also focuses on the most effective technology for achieving a country's energy independence consisting of the fracturing process used in the production of shale gas and its development throughout the world. Extensive qualitative research has been conducted in the United States. Even though it has not yet begun to extract shale gas in the same quantities as the United States, the United Kingdom will have larger reserves and better prospects in the coming years than the United States. Using all the favorable variables, the UK can quickly become energy self-sufficient by producing and extracting shale gas (Esmaeili et al., 2022). The development of shale gas will also benefit the citizens of the home country because every residence will have more security in their gas supply. According to Warwick Business School research, the UK can use shale gas mining and

production to meet 17% to 22% of total national consumption between 2020 and 2050. To support the shale gas industry, the UK must exhibit a minimal number of imports.

2.2.6 Issues Related to Shale Gas

Energy discoveries in the last two decades have triggered a paradigm shift that history has never seen. Shale gas production opens new opportunities for increasing energy security while lowering greenhouse gas emissions. Governments, nongovernmental organizations (NGOs), and academia working together on shale gas research have led to dramatic increase in the availability of data. Fracking, also known as hydraulic fracturing, involves drilling a deep well and injecting chemicals and liquids into the subsurface at high pressures (Guo et al., 2022). No matter how exciting shale gas production may be, there are inherent risks and the possibility of unexpected outcomes. These dangers have gotten worse over time for unknown reasons, and they can vary greatly depending on the situation and the location. The prospect of fracking has sparked heated debate in the Karoo. Shale gas drilling and hydraulic fracturing gives rise to environmental and water-use concerns (i.e., fluid migration and shale degassing are poorly or not well understood). This operation's environmental impacts include excessive water use and chemical leaks on the surface. When waste fluids are injected into deep disposal wells, it can cause earthquakes and have a negative impact on water quality both above and below ground. Residents and industries in the Karoo region rely heavily on groundwater.

Water scarcity is a major issue in the fracking industry, with each well requiring 20,000 m^3 of water. Methane may bubble to the surface when the shale cracks. Furthermore, the Karoo's unique subterranean structure, as well as other drilling activities such as well site construction, transportation of supplies and equipment, and waste disposal, produce additional air pollutants. Pollutants produced during drilling include particulate matter and dust, ground-level oxygen and nitrogen oxides, carbon monoxide

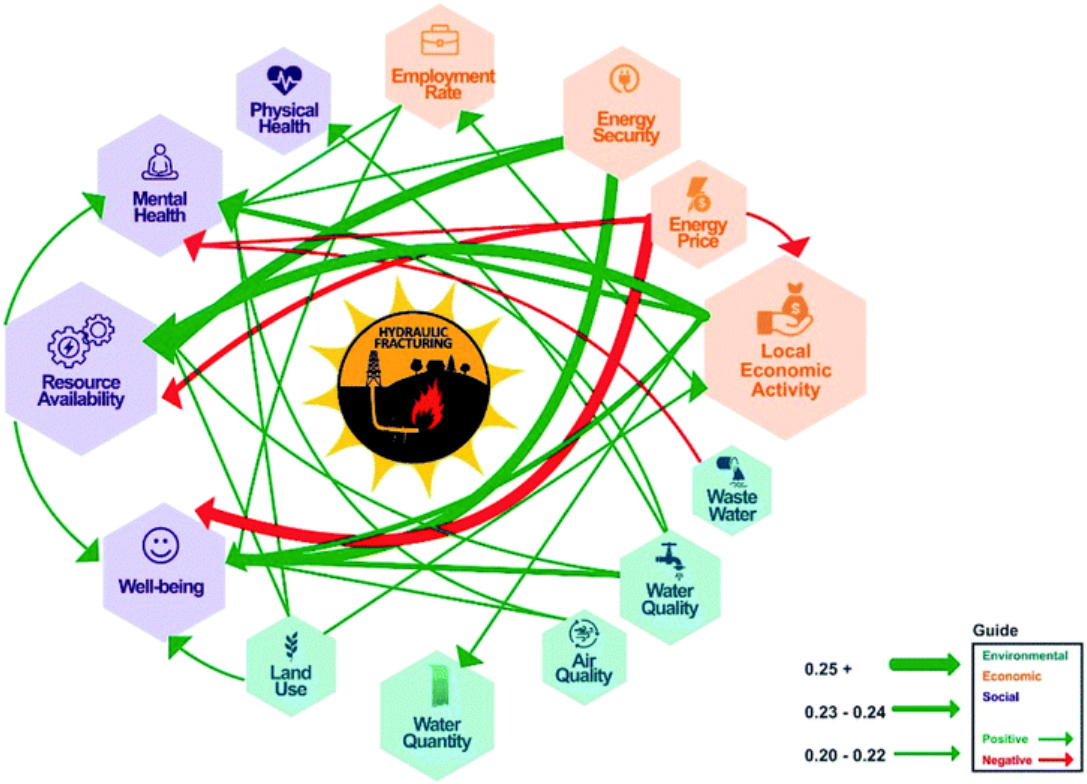
and formaldehyde, and metals found in diesel fuel combustion. Short-term illness, malignant tumor growths, organ deterioration and damage, neurological abnormalities, birth problems, and even death have all been linked to excessive exposure. Individuals who support fracking are opposed to global warming, they frequently oppose the theory that humans are to be blamed for several number of commercials reasons and drawbacks

This argument shows how difficult it can be to resolve scientific disagreements. Fracking's tipping point in the last decade has resulted in a massive increase in global oil and gas output, with the United States leading the way (Male & Duncan, 2022). Oil prices have had an impact in some cases, while environmental concerns have had an impact in others. The United States now produces nearly three times as much crude oil as it did in 2010. It played a smaller role in total US oil consumption. Price increases are also caused by an increase in supply. International collaboration has significantly reduced the risks in the early stages of shale gas exploration and extraction. When it comes to research, many scientists believe in the power of collaboration and in order to scientists must work together to advance to further the cause. With advancement in this area one hope to improve people's talents, knowledge, ideas, and information so that they can perform better in the future. Regional geology has complicated shale gas production, necessitating the cooperation of all parties involved.

2.2.7 Hydraulic fracturing resulting into energy security and economic prosperity

Hydraulic fracturing has improved the exploitation of natural gas and oil resources in the United States of America. Almost since the beginning of shale gas drilling, there has been considerable discussion about the potential environmental and health consequences. Drilling in shale resources has propelled the United States to the top of the world's natural gas production rankings because of hydraulic fracturing (Isser, 2022). It is necessary to establish adequate reporting/documentation systems for wastewater discharges and spills

at the federal, state, and industrial levels. Furthermore, because hydraulic fracturing can be done with or without diesel fuel, the SDWA Underground Injection Control (UIC) rules required the development of new guidelines.



Source 8 (Essien et al., 2022)
Figure 2.2.7 DEMATEL Model

The central hub of the diagram is labeled "Hydraulic Fracturing," and from it, arrows extend to and from various outcomes. The green hexagons are environmental factors, orange are economic factors, and purple are social factors. Green arrows indicate a positive relationship where hydraulic fracturing positively impacts or is positively impacted by the factor and red arrows indicate a negative relationship, showing negative impacts or relationships with the factor. The arrow thickness represents the strength of the relationship, with thicker arrows suggesting a stronger effect. Hydraulic Fracturing has both positive and negative impacts on factors such as local economic activity (positive)

and air quality (negative). The environmental impacts include adverse effects on water quality, air quality, and land use, often depicted with red arrows. Economic benefits such as energy security and employment rate are indicated with positive relationships, highlighted by green arrows. Social impacts, like well-being and mental health, show a mix of both positive and negative effects. This systems map shows how hydraulic fracturing affects and is affected by a network of interrelated factors, balancing the economic benefits against environmental and social costs.

The chemicals used in hydraulic fracturing are not well understood, making the technique difficult to implement. A federal statute required hydraulic companies to report the composition and concentration of fracturing fluids to federal and state regulatory bodies as well as health care specialists, which can speed up the procedure while maintaining environmental quality. If the chemicals used in the process are made public, the health and environmental consequences of hydraulic fracturing can be better understood. The US consumes nearly one-quarter of the world's total oil supply. We currently have control over only 2% of the reserves. The only way for the United States to achieve long-term energy security is to reduce its reliance on foreign oil sources. The United States, the world's most populous country, consumes more than 20% of the world's energy (Beckley, 2018). Their total resource consumption exceeds that of Germany, the United Kingdom (UK), China, Iran, and Canada combined (all combined). Shale gas production in the United States is expected to reach 385.1 million cubic meters by 2035, accounting for roughly half of total natural gas production in the country. A single year's consumption of natural gas could provide enough fuel for 15 million families, 100 million homes, or 12 million natural gas-powered vehicles.

Despite declining energy consumption, the state of Washington is committed to increasing its energy efficiency. "America's oil and natural gas resources are critical

components of our nation's energy portfolio," President Barack Obama said in a speech introducing the United States 2011 Energy Blueprint. "The advancement of these technologies contributes to our energy security and economic prosperity." The US consumed 735 billion cubic meters of natural gas, surpassing both Russia (464 billion cubic meters) and China (160 billion cubic meters). Despite environmental concerns, this administration recognizes the importance of alternative energy sources in meeting the demand for these fuels.

2.2.8 Shale Gas Extraction: International Perspective

To balance the clout of the United States and Europe, China and Russia recently agreed to a US$400 billion gas deal covering 38 billion cubic meters. As a result of this, Moscow gained a massive new market for its primary export, and two major powers that had previously been estranged by a turbulent history of alliances and rivalries were brought together (Kroenig 2020). As a result of the threat to the world's most important energy corridor, Russian President Vladimir Putin is strengthening diplomatic and bilateral ties with China. Despite recent US efforts to reorient its foreign policy toward the Asia-Pacific region, Russia and Uzbekistan have reached energy agreements. North American energy cooperation agreement, while Russia and China work to ensure Eurasia's energy stability it has the potential to strengthen US foreign policy in the region.

Obama have implemented an energy policy that would ensure global economic stability and security by 2020. Various documents show that global market trends are unstoppable and that America is on the verge of becoming the world's leading producer and consumer of energy. Reaffirming America's global leadership is a top priority for the US government in Washington, DC. Foreign policy has reduced military participation in certain regions, such as the Middle East, to accommodate these new energy options.

Meanwhile, the shale gas boom inspires visions of an American region that is both environmentally friendly and secure in terms of energy supply and distribution.

The US has relied on its natural North American allies, Canada and Mexico. Shale gas extraction could begin in the region, which is currently controlled by Canada and the United States, but only if the process is simplified for the operators involved. Shale oil and gas extraction in North America has the potential to propel the US to the top of the global economic rankings (Wang, Fan, et al., 2023). The impact of unconventional gas on Mexico, Canada, and the United States could be a critical first step toward establishing a North American energy superpower zone.

2.2.9 Investments for the Extraction of Shale Gas

It is critical to reduce the cost of shale gas extraction to increase supply. Vertical wells cost around $850,000, while horizontal wells can cost up to $2.5 million. Unlike other markets where monopolies frequently direct or are responsible for production, the oil extraction industry in the United States is primarily made up of small and medium-sized businesses. The federal government has come under fire for developing an energy independence policy since the Arab oil embargo of 1973. According to previous projections, natural gas production would decline significantly by 2025. Due to oil supply constraints, the EIA estimates that the country's energy needs were met domestically to an extent of 84 percent in recent years (Coady et al, 2019). At the microeconomic level, this is an important indicator to monitor. Shale gas, an unconventional natural resource, has increased the United States' energy power about domestic consumption, elevating the country to world leadership status. Shale gas has the potential to have an impact on emissions, according to the Massachusetts Institute of Technology Emissions Prediction and Policy Analysis environmental issues, the economy, and international relations (mit-eppa).

2.2.10 Potential of shale gas to contribute to a greener future

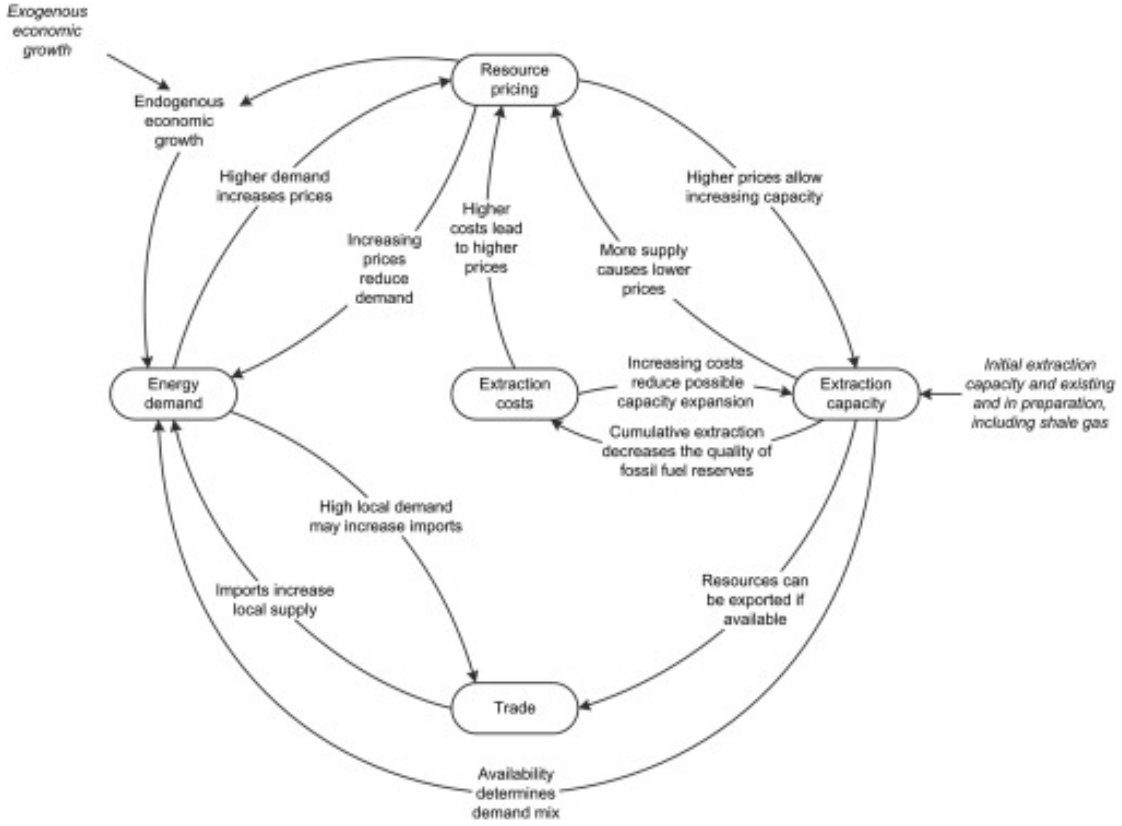
While carbon emissions are decreasing, concerns about methane leaks and water contamination meant that the Obama administration's claim that shale gas contributes to a greener future will remain unsubstantiated in the foreseeable future The procedure gained legal recognition as a legitimate procedure following the passage of the 2015 fracking rule in the United States. Shale gas, is now widely regarded as a critical link between traditional energy sources and long-term economic growth in the United States.

In the United States, technological advances and environmental legislation have enabled more controlled extraction of shale gas while adhering to the environmental paradigm of the twenty-first century. Obama claimed that natural gas has been "discovered" and that it can meet all of America's energy requirements. In the Marcellus Shale Play, for example, shale gas has increased efficiency while decreasing costs. Shale gas has made significant contributions to the United States' economic and industrial development (Mei et al, 2022).

2.2.11 Geopolitical policies related to shale gas extraction

Creating a trilateral energy alliance between the US, Mexico, and Canada appeared to be a viable option. Geographic and economic agreements such as NAFTA are more important than the amount of natural gas in North America. Although they are not currently cooperating, the three countries have the potential to form a strategic partnership that would transform them into the world's largest shale gas extraction, processing, and transportation center. Due to shale gas and its energy security, the US will increase its involvement in the Middle East and with OPEC members, rather than decrease it. The United States' energy diplomacy has remained unchanged since the discovery of a new fossil fuel that can be used to supplement domestic demand without being constrained by international oil diplomacy. However, there is still much work to be done in terms of American security.

Shale gas is important to the United States because it gives the country more time to develop a low-cost, long-term climate change strategy. In the twenty-first century, the goal of the United States' geopolitical policy is to ensure the security of the country's energy sources.



Source 9 (Auping et al., 2016)
Figure 2.2.11 Energy-mix model sub-system diagram

The diagram consists of several key elements connected by arrows, indicating the direction of influence. Each arrow represents a causal relationship, and the variables are interdependent. This causal loop diagram represents the complex and interrelated dynamics of energy markets. It shows how energy demand, resource pricing, extraction costs, extraction capacity, and trade interact with each other, forming feedback loops that can

amplify or dampen changes in the system. The diagram captures the complicated balance between supply and demand and the economic factors that influence energy production and distribution.

If more time is given to develop an affordable and environmentally sustainable energy strategy, shale gas may not be a long-term solution for the United States, but it is a step in the right direction. To ensure safety, the global geopolitical shifts proposed by Joseph Nye will be required. According to him, there is a shift in the global power because any conflict in Asia-Pacific can create an imbalance in the economy. An example of that is the Russia-Ukraine war. The US cannot show authority like it used to in the past. Shale gas helps to reduce the United States' reliance on imported oil while can help to stabilize financial markets by encouraging domestic energy investment (Husain et al., 2024). The United States may be able to increase its global influence by using shale gas as a political tool. As energy security becomes more important, the United States will continue to compete in the global political arena with other countries such as China and Russia for position of leadership.

2.2.12 Balance between extraction of shale gas and environmental protection

Several large corporations are conducting environmentally hazardous drilling operations to increase their natural gas supplies. The government must intervene if the environment is to be protected from excessive drilling. The regulation of hydraulic fracturing (fracking) has sparked heated debate in countries such as the United Kingdom, the United States, and the Netherlands. As a result, hydraulic fracturing must be used more widely, but only under strict supervision and per industry standards, because government officials are still unprepared to comprehend the scope of the problem. It is the environmental health authority's responsibility to keep the government informed about the

challenges it can face in this regard. Hydraulic fracturing can be managed to maintain a healthy balance between profit and environmental protection.

According to research conducted in this arena, the vast majority of primary energy consumption in the United States is accounted for by oil and coal, and as a result, carbon emissions in the country are increasing. Sustainability and the effects of climate change is becoming increasingly important concerns for all businesses in the future. The greenhouse's negative impact was also visible five years ago. Natural disasters are becoming more frequent and severe as global warming increases their frequency and severity. Because of the growing impact of "climate politics," Chevron and other large oil companies have had to drastically alter their business models and production techniques (Green et al, 2021). Every oil company in the world, for example, is working hard to establish a "green hydrogen" corporation. To do so, it is not necessary to dismiss new technologies that may be beneficial to the organization to simplify business operations and protect the environment.

The presence of this rare source of fossil fuels has piqued the interest of other countries, according to a variety of hopeful but highly speculative geological investigations. There are insufficient test wells and reliable and up-to-date geological data to evaluate recoverable resource potential outside the United States, a common comparison method was used where the American shale worked as a model. According to the International Energy Agency, the European Union has one of the world's largest (technically) recoverable shale gas resource potentials, with Poland emerging as the first E.U. country outside of the United States where an unconventional shale gas "revolution" may occur. Advanced Resources International discovered 5300 Bcm of unconventional gas. (ARI) in an Energy Information Administration (EIA) study for the United States Department of Energy led many to believe that shale gas could be produced in Poland

(EIA). As a result, multinational oil and gas companies like ExxonMobil, Shell, and ConocoPhillips, as well as domestic oil and gas companies like PKN Orlen and Lotos, increased their investment in prospecting and exploration. Poland has received more unconventional gas production and exploration licenses than any other country in Europe (MOS', 2016), making it the only European country with more than 100 such licenses (Cantoni, 2018). Unconventional gas was a major selling point for Poland, which had previously relied heavily on Russian gas supplies for most of its energy requirements.

2.2.13 Shale gas contributing towards national energy security

The Polish public saw the prospect of achieving gas independence, increasing national energy security, improving Poland's geopolitical position in the region, and even spurring economic development as an opportunity in response to the country's uncertain but optimistic prospects for commercial production of unconventional gas from shale. Polish citizens have high hopes that the public debate on energy security will reduce the country's reliance on Russian gas imports and lead to total self-sufficiency in the natural gas supply. The Polish Prime Minister Donald Tusk predicted in 2011 that Poland would achieve gas independence by 2035 and he got re-elected as the PM in 2023. He was, however, cautious in his predictions (Rucińska, 2021). According to some officials, the S'winoujscie LNG terminal could be used to export Polish shale gas to other countries, which would be beneficial, being the first. The former Polish Foreign Minister Radoslaw Sikorski compared Poland's potential as a significant natural gas supplier to Europe and being a "second Norway" for a long time. It was included in several national plan documents to increase shale gas production capacity and thus improve energy security. No estimates have been made as to the scope of the production activities required to implement these political claims about Poland becoming a gas exporter and becoming self-sufficient in natural gas. In terms of production, there are no specific methods or analyses to guide

us toward these goals. Shale gas production has yet to reach a commercially viable level. From 2010 to 2016, more than half of all shale-related operations in Poland were either suspended or ceased or completely shut down.

2.2.14 Critical evaluation of the literature

With a special emphasis on the UK, offers a thorough analysis of the advantages and difficulties of utilizing shale gas to produce energy independently. For countries to achieve economic stability, lower national debt, enhanced national security, and stable fuel costs, energy production self-sufficiency is extremely desirable. The work does, however, do a good job of highlighting the actual difficulties in accomplishing this goal, particularly in a global economy characterized by volatile oil prices and rising energy demands (Gatto, 2022). The discourse surrounding shale gas underscores its capacity to profoundly influence domestic economies through the mitigation of reliance on external energy sources. The UK's 2008 launch into the shale gas extraction industry is seen as a turning point, but there are still significant obstacles to overcome, including the high prices and environmental issues related to hydraulic fracturing (Szabo, 2022). There is a need for well-balanced regulations that cover both energy demands and environmental protection, as suggested by the well-articulated environmental discussion surrounding hydraulic fracturing, which includes the detrimental effects on ecosystems and popular opposition.

The global backdrop, which includes instances from China and the United States, emphasizes how widely used shale gas extraction is and how profitable it is. A possible example for the UK could be found in the United States, where shale gas has significantly reduced domestic gas prices and allowed for LNG exports. It also highlights the serious legal and environmental issues that come with hydraulic fracturing. To reduce hazards to human health and the environment, important issues including inadequate regulation of chemicals used in the process and a lack of transparency must be addressed (Woodruff et

al., 2023). A modest 10% recovery of the UK's shale gas reserves is projected to supply the country's energy demands for the next 50 years, indicating huge potential economic benefits. However, the careful strategic planning and cost management are necessary to realize this promise. A clear reminder of the worldwide issue and the necessity of strict environmental safeguards is provided by the mention of environmental prohibitions in France and Bulgaria.

The energy industry has greatly benefited from hydraulic fracturing, or "fracking," especially in the United States where it has significantly expanded the supply of natural gas and oil. By replacing coal in the production of power, this rise in energy resources has resulted in cheaper energy prices, improved energy security, and less air pollution (Jaiswal et al., 2022). These advantages have resulted in substantial economic growth, enhanced public health due to lower emissions, and general household affluence in the United States. Nevertheless, the sustainability of these advantages depends on local communities' acceptance of the fracking-related expenses. Communities must balance the benefits to the economy—more money, jobs, and property values, for example—against the costs, which include more truck traffic, possible rises in crime, and health hazards from air and water pollution. Studies have indicated that, in spite of these reservations, fracking frequently has a greater economic impact on the surrounding area (Donaghy et al., 2023). However, these advantages could be altered by shifting views about the health effects, highlighting the necessity for continual evaluation and control to guarantee fair results.

Because of the intricacy of its shale basins, the United Kingdom has a significant potential for shale gas extraction, but it will also be more expensive and difficult than in the United States. Appropriate tactics and manufacturing procedures might lessen these challenges and hence bring down natural gas costs in the United Kingdom. The comparison shows that the UK is behind because of ambiguous recoverable gas estimates and strict

regulations, whereas the US has benefited greatly from shale gas, turning into a net exporter and sharply lowering world gas costs. But the UK has the infrastructure and favorable geology to allow large-scale shale gas production, which may make it a major player in the world energy market. Studies show that US respondents are more in agreement than their UK counterparts about the advantages of shale gas, such as affordable energy and energy security (Bradshaw et al., 2022). The disparity between the two nations' regulatory frameworks and developmental stages is reflected in this gap in public opinion. Similar to the US, the UK may use its shale gas reserves to achieve economic growth and energy self-sufficiency with the help of supportive legislation and technological advancements.

Although shale gas production offers significant energy security and lower greenhouse gas emissions, it also has a number of health and environmental hazards. In order to perform hydraulic fracturing, high-pressure chemicals and fluids are injected into deep wells, which may contaminate water supplies and increase seismic activity and air pollution. In places like the Karoo, where water shortages and distinctive geological formations worsen the effects on the ecosystem, these dangers are especially noticeable (Hattingh, 2022). There are significant risks to the quality of surface and groundwater due to the intensive use of water and the possibility of chemical spills; these dangers could have a significant impact on the local communities that depend on these water sources. Furthermore, contaminants from drilling operations can cause a number of illnesses, including as cancer, neurological diseases, and respiratory troubles. Notwithstanding these worries, the fact that fracking has increased oil and gas production worldwide, particularly in the US, highlights the delicate balance that needs to be struck between the sustainability of the environment and economic gains. To reduce these hazards and grow shale gas production in a way that safeguards the environment and human health, cooperation among nations and ongoing scientific research are essential.

The United States has become the world leader in natural gas production through the use of hydraulic fracturing, which has completely changed how natural gas and oil resources are used in the nation. Although this method is profitable, there are serious concerns to the environment and human health. To reduce these dangers, efficient reporting and documentation procedures for wastewater accidents and releases are crucial at the federal, state, and industrial levels (Jiang et al., 2022). Because little is known about the chemicals used in hydraulic fracturing, notification to regulatory agencies and medical specialists is required in order to better understand the effects on the environment and human health. Since the US consumes a large amount of the world's oil and energy, it is crucial to lessen dependency on foreign oil sources in order to ensure long-term energy security. Hydraulic fracturing has several advantages, including increased economic growth and energy security, despite environmental concerns.

It is anticipated that the United States' shale gas production would rise dramatically, adding to the stability of the world's energy supply. Energy agreements, like the US$400 billion gas deal between China and Russia, impact the geopolitical landscape internationally and highlight the strategic significance of energy resources in foreign policy. The shale gas extraction industry is primarily made up of small and medium-sized businesses, and investments in this field are essential to lowering costs and increasing supplies (Daowei, 2022). The United States now holds a dominant position in the world energy markets as a result of the transition to energy independence, which has important ramifications for emissions, environmental regulations, and international relations. For policymakers and stakeholders, balancing the economic advantages of hydraulic fracturing with its social and environmental consequences continues to be a major problem.

Even with technological developments and regulations meant to lessen the impact on the environment, there is disagreement on whether shale gas can lead to a more

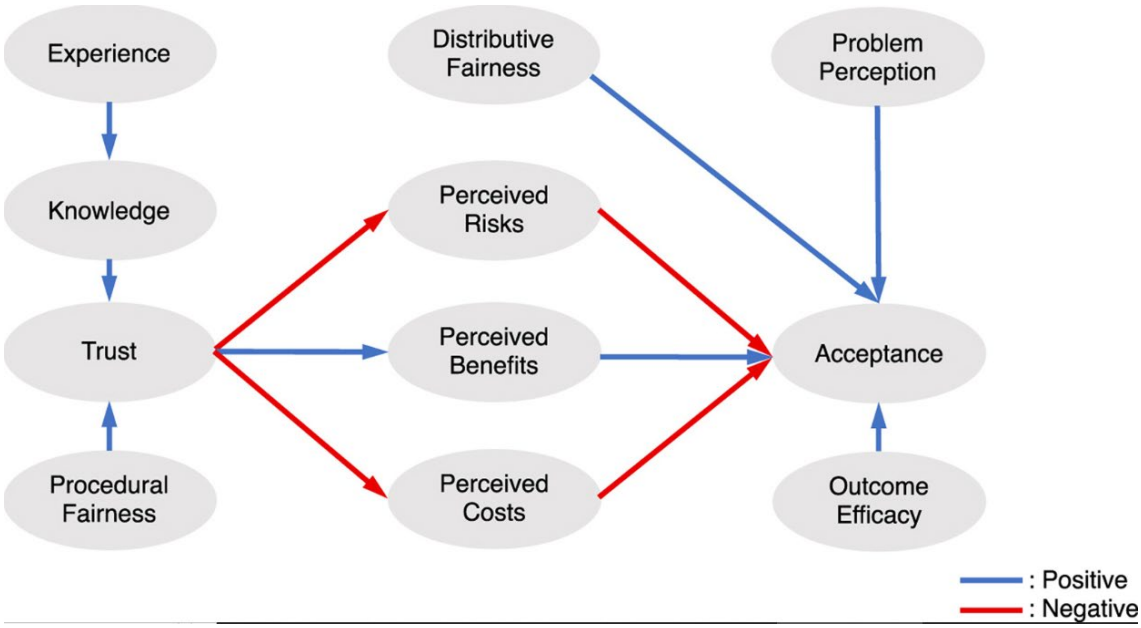
environmentally friendly future. The Obama administration's claim that shale gas is a fuel to bridge the transition to sustainable energy is undercut by persistent worries about water contamination and methane escapes. Hydraulic fracturing gained legal recognition in the United States in 2015 when the fracking regulation was passed, but the long-term sustainability of this green energy source is still under question due to the environmental dangers involved in the extraction process. The Marcellus Shale Play serves as an example of how technological advancements have increased the efficiency and economic viability of shale gas extraction, which has greatly accelerated industrial and economic expansion in the United States (Isser, 2023). But these developments haven't completely eliminated the threats that hydraulic fracturing poses to the environment and human health. The energy policy of the United States emphasizes the nation's continued reliance on fossil fuels, as it is dependent on the geopolitical power offered by shale gas. This dependence makes it more difficult to create an inexpensive, sustainable energy plan that complies with international climate targets.

Geopolitically, through strategic partnerships like a trilateral energy collaboration between the United States, Mexico, and Canada, shale gas has the potential to completely change the energy landscape of North America. With this partnership, the area might become known as a global center for the commerce and exploitation of shale gas. But the geopolitical forces go beyond North America; because of worries about energy security, the United States continues to be involved in OPEC and the Middle East (Fukutomi, 2024). Thus, shale gas serves to both strengthen the country's energy supply and increase American geopolitical dominance. It is still very difficult to strike a balance between environmental preservation and shale gas extraction. The United States, the United Kingdom, and the Netherlands have different approaches to the controversial topic of fracking regulation. To maximize the economic benefits of shale gas and prevent

environmental harm, effective oversight is essential. Even while shale gas seems promising, the larger trend toward sustainability demands a careful assessment of its environmental impact and the creation of greener energy alternatives.

2.3 Theory of Reasoned Action

For the purpose of this research it is important for the researcher to look upon the matters that can affect the development of hydraulic fracturing that is used for extraction of shale gas. On such matter is the behavior of country's population towards it. It is the reason behind making a plan to take a reasonable action. The below diagram suggests that building up trust is consequential for the growth of hydraulic fracturing in the UK. Another important thing is understanding the problem at hand. By building up trust, the perception of risks, benefits, and costs increases. When these are perceived and taken care of accordingly, only then it is acceptable by the nation and its population. This in return increases the efficiency of the outcome.



Source 10 (Kânoğlu-Özkan & Soytaş, 2022)

Figure 2.3 TRA

The image presents a conceptual model of the factors influencing the social acceptance of shale gas development. The model is based on the theory of planned behavior and suggests that individuals' attitudes towards shale gas development are influenced by their beliefs about the perceived benefits and costs, as well as their perceived social norms. Overall, the model suggests that individuals' attitudes towards shale gas development are influenced by a complex interplay of factors, including their experiences, beliefs, and perceptions.

2.4 Human Society Theory

The human society theory that has been focused upon is the rational choice theory. From the perspective of behavioral economics, it is understandable that people can make decisions based on the rationality. One such incidence can be looked here is that relying on shale gas is the only feasible solution to overcome the oil crisis due to the sanctions on Russia by European Union. According to this theory, people’s interests are turned upside down when they seek profit from the free economy market (Martín, 2021). They will make decisions in favour of the cause as they want that profit. Sometimes, the same cannot be said, the hidden forces can lead to an opposite decision-making. The hidden force in the case of hydraulic fracturing in northwest England is the environment. People stood against fracking because it was damaging the environment in more than way. Lancashire even voted against it which is an example of not making rational decisions based on profitability. They know that this measure can help the nation to become independent for renewable resources. However, the environment turned the tide to the other way.

This shows that making decisions based on this theory can be rather conflicting than profitabe as per this case. Something like this happened in 1973, when US decided to support Israel in the war against Arab. It is one of the topmost example of the failure of

rational choice theory. The decision made was rational, however, the hidden factor like oil embargo was never thought by them (Toomey, 2023). Due to that situation, being self-sufficient in the means of energy production became a priority for the US. Similar situation can be understood from the people's behaviour towards hydraulic fracturng, where they are not understanding the importance of the situation at hand. The fall in economy due to the sanctions on Russia is one story, however, the future propects of the method to extract shale gas are totally debauched by the population. It will impact them more than anyone else because finding measures to become self-sufficient requires something new and not changing will lead to more crisis in the future.

2.5 Summary

The theoretical framework of this literature review was focused on identifying everything about shale gas and hydraulic fracturing. On one hand, it is saving the countries from oil crisis and on the other, some countries are totally not accepting it due to the environmental concerns. The countries that are using the technique are finding their standing in geopolitical views. The reason behind that they are becoming self-sufficient and are able to help others because of that. Countries like Norway and Poland have found their grip on these matters related to the energy production as well as finding the alternative for the sanctions. Also, countries that have incorporated hydraulic fracturing are becoming economically stable with regard to the high oil prices. Because of the extraction of shale gas, they need less import of the oil and other natural resources that are used to produce energy. This means they buy less on the higher prices and finding their grip over the market because of that. After putting sanctions on the Russia, the reliance of the UK for the oil is on the Norway and the US, however, they are unable to make any long-term agreements for the same. The reason behind that is these countries are unable to provide these comodities like Russia.

The TRA focused on the population and researcher's point of view regarding the shale gas extraction in the UK by hydraulic fracturing. Mostly, the focus should be on the bahviours like the trust, risk perception, and acceptance when dealing with the UK population for hydraulic fracturing. The reasercher also focused on the same behaviour because they are the ones that connects to each other and acceptance cannot be their if risks are not percieved. Trust of the people comes from accepting what is going on and understading the importance of the situation.

Finally, the human society theory that has been used by the researcher is the rational choice theory. The theory emphasize on the people making decisions based on the rationality. This theory, however, can be considered as the contradicting one because the people do make decisions based on the rationality and where they can find economic profit. However, it does not address the hidden factors that can be considered as a risk. The issue of voting against the hydraulic fracturing in Lancashire is a decision taken based on the rationality with a hidden factor as environment. This disregards the actual importance of the measure that can save the energy production in the future without relying on other nations. It is not argued that it is not damaging the environment, but it can be made more efficient in the future and it is not possible without experimentation.

CHAPTER III: METHODOLOGY

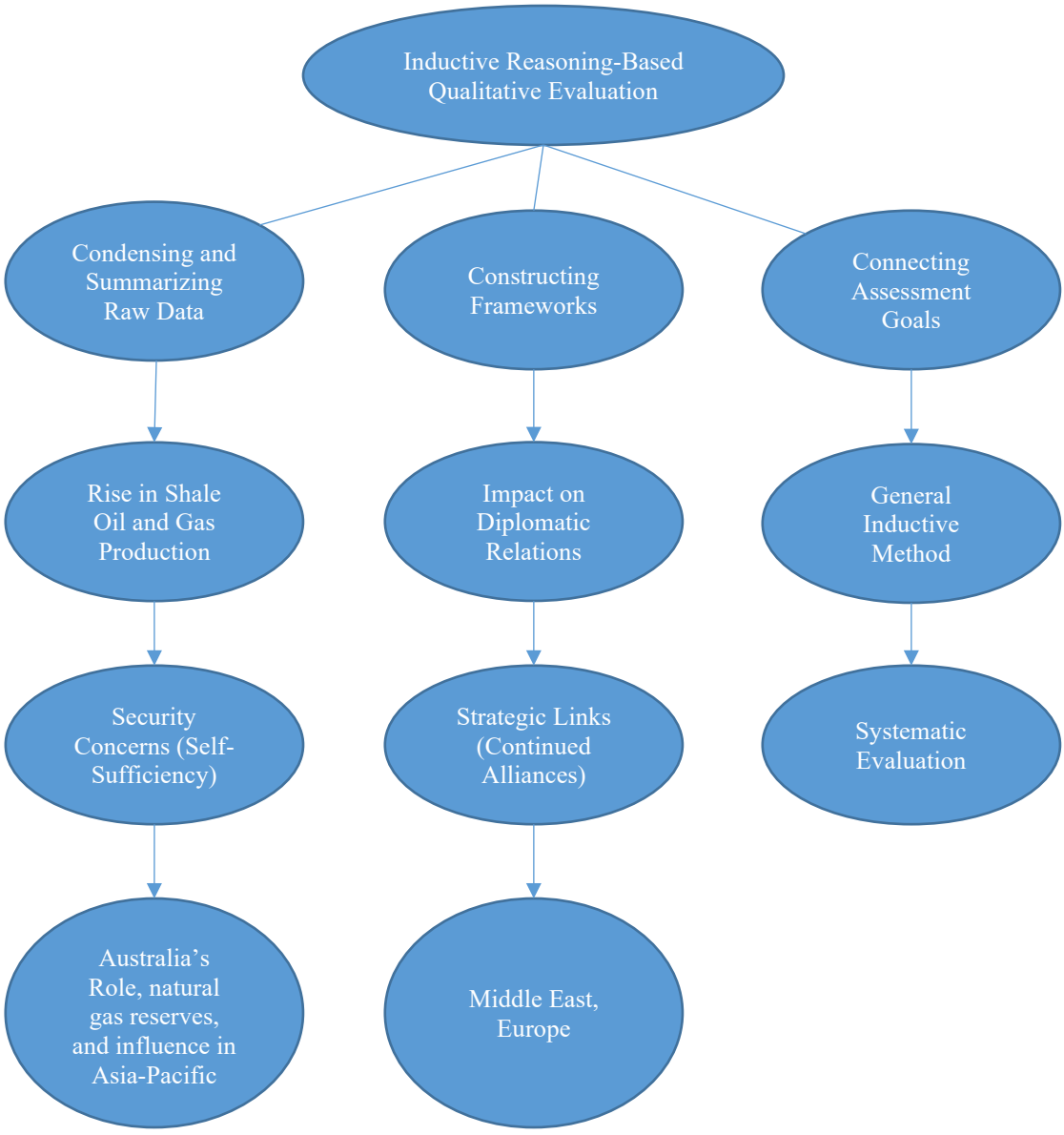
3.1 Overview of the Research Problem

The development and economic impact of the shale gas industry in the United States will be examined by the researcher to determine whether the United Kingdom can achieve energy self-sufficiency through hydraulic fracturing. A thorough review of the literature and primary data collection from specialists in the shale gas construction industry were required to form the basis of the study (Cooper et al, 2016). The information that were available were not sufficient to substantiate the thesis and its claim, hence the researcher needed to explore other sources of literature to draw comparison between two countries and the process of fracking for shale gas.

A literature review is essential to writing a thesis and it involves writing the critical analysis of data that are available to the researcher in the form of past studies (Hart, 1998; Cronin, et al., 2008). The reader, while reading the research report must read about the work that was done in this area by previous researchers. A good literature review consults several possible sources which are sources with a clear section strategy (Carnwell and Daly, 2001; Cronin, et al., 2008).

In this thesis, the researcher has considered several primary sources of articles that can provide a theoretical foundation for the study. These are mainly scholarly articles having adequate and relevant information and knowledge and significant synopsis of the previous work (Okoli & Schabram, 2010). As a researcher, those sources that help contribute to the research report from a scholarly and critical appreciation of the theory have been considered in the section on literature review. Listed below are the theoretical constructs that are relevant to this thesis.

3.2 Operationalization of Theoretical Constructs



Source 11: Self Made
Figure 3.2 Theoretical Construct

This paper intends to investigate an inductive reasoning-based qualitative evaluation data analysis technique. Use of an inductive technique is helpful for several reasons, including condensing and summarizing raw data, constructing an overarching

framework of processes that are reflected in data, and connecting the assessment's goals with the inferences made from raw data. The United States has enhanced its energy independence thanks to the rise in shale gas and oil production. This might have a significant impact on the nation's diplomatic relations, particularly with nations in the Middle East and Europe (Lee, 2021). In the face of international changes of the geo-political scenario in the Middle East, if the United States is self-sufficient and less concerned with its security the world's energy-rich regions will lose some of their strategic and political importance. On the other hand, it is improbable that the US and other countries' strategic links might be completely severed. Australia will continue to maintain a close security and economic relationship with the United States as one of its most dependable allies and a country with significant natural gas reserves and the potential to lower liquefaction costs, which could increase US influence on energy issues in the Asia Pacific (Mozaffari & Akbar, 2022) The general inductive method allows for the systematic and repeatable evaluation of the qualitative data. It is also true, , that the general inductive approach to theory or model construction lacks the potency of others although it does provide a fundamental, straightforward method to draw findings in the context of particular evaluation challenges. Many assessors would find the inductive approach to qualitative data analysis to be easier to understand than other approaches, and this approach is favored by others.

3.3 Research Purpose and Questions

1. Understanding the concept of energy production and supply, as well as the various methods for doing so, such as hydraulic fracturing.

This question will help the readers to understand the background context of the production and supply of energy in today’s world. It will help understand the dynamics of oil control and deficit and surplus nations.

2. Examining the history of using hydraulic fracturing to accelerate the growth of a country's energy economy, particularly in the United States.

The concept of hydraulic fracturing in central to this thesis and an overview of this production process and its successful use in the USA will help the readers to understand the ease of the process and its benefits.

3. Environmental research on hydraulic fracturing, such as the Cuadrilla experiments in the United Kingdom.

The process of hydraulic fracturing had come under some flak from environmentalists with issues about environmental pollution. This section will provide a correct perspective on the nature of the environmental impact that this process can create in the near future.

4. Investigating ways to reduce the negative environmental impacts of hydraulic fracturing so that it can be increasingly and permanently adopted by countries.

If the process of hydraulic fracturing is used by other nations to become energy self-sufficient then reducing the negative impacts is essential for the oil producers. This section will provide various ways through which these negative impacts can be mitigated.

5. Investigating the concept of hydraulic fracturing in conjunction with achieving self-sufficiency in energy supply and consumption.

The researcher would also delve into the benefits of the process and how this process can make nations self-sufficient and reduce their dependency on other oil-producing nations and talk about the merits of implementing this process.

3.4 Research Design

Secondary Data

Computer-based investigation based on previously acquired data which are available online as archived material and are relevant to the study is known as "secondary

research" (Adewove & Olaseni, 2022). Analyzing and combining earlier data can help advance research. Through scholarly papers and conference presentations, secondary research can be carried out. One can find these resources in public libraries as well as through exploring historical data from a number of public and private sources. Compared to new research, secondary research is more time and cost-effective. Organizations and businesses conduct their own research rather than relying on a provider of third-party data collection.

3.5 Population and Sample

The researcher used various sample techniques to accurately collect and analyze the data. Convenience sampling, judicious or purposeful sampling, snowball sampling, and quota sampling were used by the researchers to collect and analyze data for inclusion in this research. The researcher also used a population-based sampling method. From Lancashire, 10 participants were chosen.

Sampling is extremely useful in research. It is one of the most important factors influencing how accurately the study or survey results. If there are any errors in the sample, the outcome will be affected accordingly. There are various methods for collecting samples depending on the circumstances and needs. A population is a collection of items that share one or more characteristics. The number of elements in the population determines its size. The sample is a subset of the population. Sampling is the process of selecting a sample. The number of components in the sample is referred to as the sample size.

3.6 Participant Selection

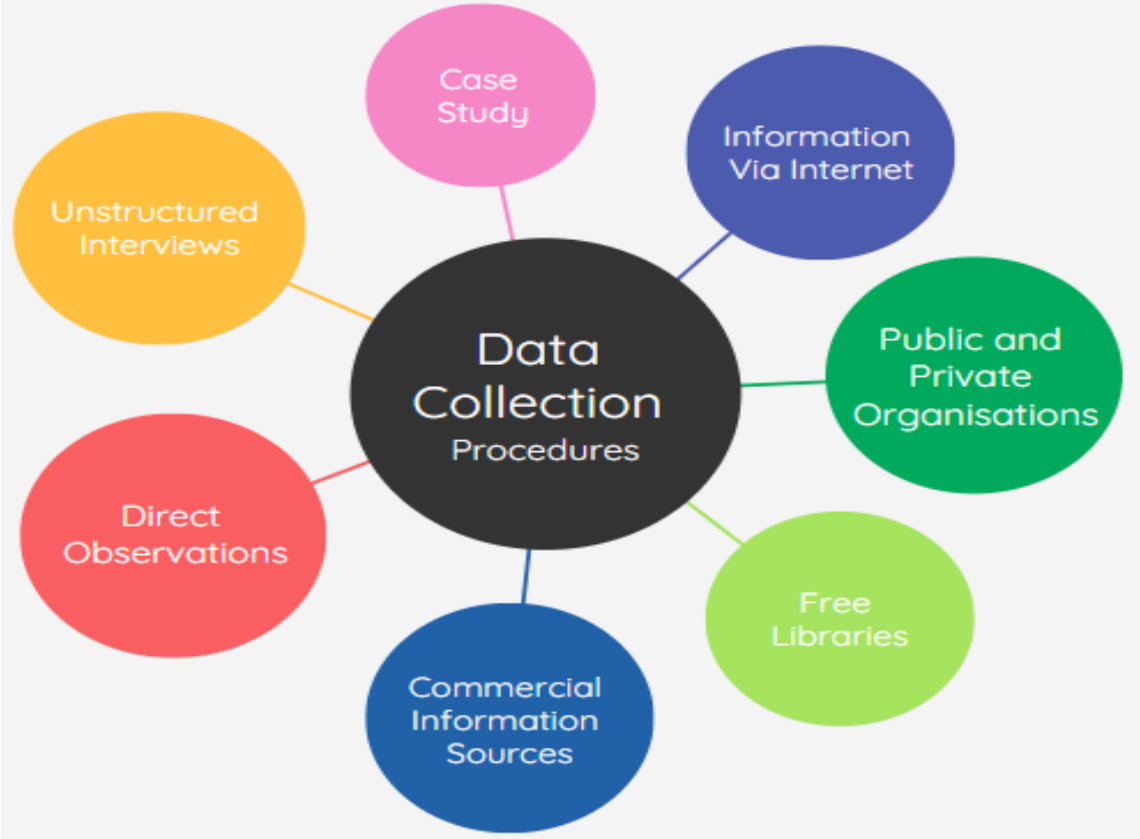
From those 10 participants, 4 will be from the general population, 3 will be the scientists, and 3 will be the managers from Cuadrilla Resources. Each of the participant will be interviewed with the same questionarre.They are chosen like this to have a nuance assessment of whether the UK is ready to change and implement measures like hydraulic

fracturing or not. Based on their responses, it will be easier to have an outcome that could be used by the UK authorities to explain the importance of such measures.

3.7 Instrumentation

There are many instruments used by the researcher to collect the data. These instruments are the internet, organizations, public libraries, direct observations, unstructured interviews, and case study. These instrument allowed the researcher to have a firm grip over the matter at hand. It also allowed the researcher to have different perspective without bias.

3.8 Data Collection Procedures



Source 12: Self Made
Figure 3.8 Data Collection Procedures

There are various through which the data was collected for this research. These sources with the type of data collected include information via internet (articles, research papers, reports, statistics, and other forms of digital content), public and private organizations (government reports, corporate publications, internal databases, industry statistics), free libraries (books, academic journals, historical records, government publications), commercial information sources (market research reports, business directories, financial records, advertisements), direct observations (behavioral patterns, interactions, physical environment details), unstructured interviews (responses, opinions, narratives, personal insights from interviewees), and case study (detailed contextual information about a particular case, including historical background, outcomes, and influencing factors).

3.8.1 Information received via the use of the Internet

Obtaining new information online is something that occurs frequently. The process of downloading content from the internet is easy. One might choose to get the information for free or pay a little charge to access it. According to Peddoju & Upadhyay (2020), companies and organizations have access to a vast amount of content thanks to web-based information sources. On the other hand, organizations are only allowed to get information from reliable sources. The researcher used this method and information to understand the work that is already done in this field. The information that are collected are from reliable and published sources. There are a lot of data available on the internet on every subject. It gives the researcher a global and updated perspective on the topic at hand. This method is used as it is cheap, time efficient and easy to access.

3.8.2 Organizations both public and private

Secondary research data can be obtained from a variety of public and commercial sources and used in several contexts (Alam, 2022). Data from government agencies

including the United States Census Bureau, the United States Government Printing Office, and Small Business Development Centers are a few examples. To use or download data from these organizations, one must pay a fee. They can provide with trustworthy information on the subject of interest. Data is available will little fees and does not consume much time. According to Jia *et al.* (2021), the details about the impact of Hydraulic fracturing like percentage increase in oil and natural gas production, and the year on year increase, future trends etc. were derived from these organizations. The surveys were authentic, and it was a reliable way of collecting this data. Information like changes in the prices of energy commodities in the domestic market and the impact of this process towards environment was also studied using this method.

3.8.3 Libraries that are free and accessible to the public

One needs to keep in mind that a public library might potentially be an important source of information for this kind of investigation (Swist et al, 2022). One can use the research that has already been published and is available in public libraries. They are a useful tool for academic researchers because data and articles are preserved there. The resources and services offered at these public libraries can vary greatly depending on their sources. Public libraries are more likely to have government publications including corporate directories, market information, and bulletins than private libraries. Educational institutions' data are frequently overlooked in secondary research. This is hardly unexpected given that academic institutions do the most amount of research in any industry. According to Mustapha *et al.* (2021), universities collect information primarily for the aim of research. Businesses or groups may, on the other hand, approach educational institutions and request information from them. For this kind of research, both public libraries and libraries of educational institutes are used. The researcher has used this source of information to get specific and reliable information on the topic which will help in

finding answers to the research questions. Academic institutes, research papers and academic article helps in understanding the research done to date and suggest further readings. They also indicated to future researcher findings that can happen in this field.

3.8.4 Commercial information sources

Local radio and television stations, journals, magazines, newspapers, and other secondary sources can also be used as sources for secondary research (Bangani et al, 2022). These for-profit information providers cover a wide range of topics, such as market research, demographic segmentation, and others. Organizations or businesses may submit requests for information regarding particular research. If businesses can figure out how to market their goods and services more effectively while also attracting new customers, they may benefit from exploiting these sources.

3.8.5 Direct Observations

In several ways, direct observation differs from participant observation. For starters, a direct observer does not usually attempt to become a participant in the context. The direct observer, on the other hand, strives to be as unobtrusive as possible to avoid biasness in the observation. Second, direct observation implies a more detached viewpoint. The researcher is observing rather than participating. As a result, technology can supplement direct observation. One can, for example, videotape the phenomenon or observe it through one-way mirrors. Finally, direct observation is more focused than participant observation. Rather than attempting to immerse himself in the entire context, the researcher observes specific sampled situations or people. Finally, direct observation does not take as long as participant observation. For example, one might observe child-mother interactions in a laboratory setting from behind a one-way mirror, paying particular attention to nonverbal cues.

The researcher has conducted direct observations of the various hydraulic fracturing processes that has been used for Shale gas extraction in the various regions of the world. The researcher collected the data that is related to the percentage of the shale gas extraction through the designated process. It has been evaluated that the companies are extracting a high level of shale gas and utilizing it for the production purpose. It is helping in increasing the self-efficiency of the production of those companies. The researcher has taken some focused group interviews which include the officers and employees of the natural gas extraction companies. Their actions were observed as to how they are using the hydraulic fracturing function to improve its production capacity. Direct observation is the gathering of information using your senses. The document activities, behavior, and physical aspects of a situation by observing rather than relying on people's willingness or ability to respond accurately to questions. Direct observation can be overt, when the subject and others in the environment are aware of the purpose of the observation, or covert, when the subject and others are unaware of the purpose of the observation. Structured direct observations are most appropriate when standardized information must be gathered and quantitative data is required. Unstructured direct observation examines natural occurrences and provides qualitative data.

This method was used as it can be considered a reliable method for information collection. The data is collected by observing the sample in the natural setting which gives a nonbiased and exact result. This is a standard method which is used around the globe. It does not need much input from the participants. The researcher makes notes which are apt for the study and relevant for answering the research questions. Due to less or no participation of anyone else, chances of manipulating and personal preference interfering with the results become less.

3.8.6 Unstructured Interviews were conducted

Unstructured interviews involve the researcher interacting directly with a respondent or group. It is distinct from traditional structured interviews in several ways. For starters, while the researcher may have some preliminary guiding questions or core concepts to inquire about, there is no formal structured instrument or protocol. Second, the interviewer is free to steer the conversation in any direction that arises. As a result, unstructured interviewing is especially useful for broadening the scope of a topic. However, this lack of structure comes at a cost. Because each interview is unique, with no predetermined set of questions asked by all respondents, analyzing unstructured interview data is typically more difficult, especially when synthesizing across respondents. The researcher conducted face-to-face interview with the various officers and the employees of the natural gas companies all over the world. The researcher has asked the following interview questions to them:

The researcher enquired about current strategies that are being used to extract high quantity of shale gas which would facilitate over production of companies

The researcher asked about the competitive strategies that are being followed for the shale gas extraction through hydraulic fracturing, so that more shale gas could be extracted and high profit margins could be earned in the market.

The researcher asked a particular candidate during interview to provide some feedback so that the hydraulic fracturing processes of the shale gas extraction could be improved in various companies.

3.8.7 Case Study

The methodology of using a qualitative method to conduct research helps in formulating an emerging field of research (Edmondson and McManus, 2007). The qualitative method uses case studies, grounded theories, and ethnography to create the field or area of research. The qualitative method helps in creating a new phenomenon

(Siggelkow, 2007), helps in describing a particular field (Dubois and Gibbert, 2010; Levy, 2005), negating an old theory and creating a new theory (Hirsch and Levin, 1999) formulate new theories (Eisenhardt, 1989; Gummesson, 2005).

One of the most used methods in a qualitative study is to take the help of a case study method. Creswell and Poth (2018) define a case study by emphasizing the identification of a case that has the commonality of sharing a culture. The case is generally cited by the researcher in a "real-life, contemporary context, or setting" (Yin, 2014, as cited in Creswell & Poth, 2018, p. 96). Studying a case requires the researcher to adopt multiple methods to accumulate data to substantiate the case. In most cases they are interviews conducted, observation methods, notes, and audio-visual mediums used to generate data to conduct the report (Creswell & Poth, 2018). A case study is generally one but at times multiple case studies are cited to create a robust understanding of the subject. A single issue or concern is often explained by a single case and would be known as an instrumental case study. A narrative case study looks closely at the uniqueness of the case based on its context and setting. A multiple or collective case study looks at several cases similar in nature which helps in analyzing the case from a multiple perspective.

3.8.8 Methods not Chosen for Data Collection

There are various data collection methods that have not been used for this research. These methods comprise experimentation, survey, ethnography, and archival research (Hurst, 2023). The methods selected—such as direct observations, unstructured interviews, and case studies—offer deep insights and are well-suited for understanding complex processes or contexts. On the other hand, experimentation, surveys, ethnography, and archival research might not have been used because they either don't align with the research goals, require more resources than available, or are not suitable for the type of data needed.

- The method of experimentation was not used because of study's nature, ethical considerations, and complexity. For this research, there is no specific hypothesis that needs to be tested as it is descriptive study (Scheel et al., 2020). Even if there was some experimental manipulation needed in this research, the social issues is one of the many ethical consideration that is required to be focused upon. Experiments can require significant resources, time, and logistical support to create and control experimental conditions, which may not be feasible in all research contexts.
- The survey method was not used because of the following reasons; depth of data, response bias, and relevance. Surveys are excellent for collecting data from large populations and for quantifying opinions, behaviors, or characteristics. However, they often lack the depth of qualitative methods like interviews or case studies, which may be more appropriate if the research aims to explore complex processes or contextual details. Surveys can suffer from response bias, where participants may not always provide accurate or honest answers, especially on sensitive topics (Ibbett et al., 2021). If the research required more in-depth understanding or direct observation, other methods might be preferred. If the research focuses on specific, detailed aspects of a process (like hydraulic fracturing in shale gas extraction), surveys might not capture the degree of information needed.
- The ethnography was not used as the method for collecting data because of time, focus of the research, and complexity. This method requires a researcher to fully involve in the field to observe as well as interact with the participant that consumes a lot of time. It is not good because the focus of this study is not on a specific group to understand social or cultural dynamics. The qualitative

data gathered using this method is in large amounts and interpreting that data is quite complex which is not suitable for this research.

- The archival research method is not used because of data availability, focus on contemporary data, and data specificity. This method relies on the existence of documents and records. For this research, there is no need of such data. The research is focused on recent trends, behaviors, or practices associated with hydraulic fracturing for which contemporary methods like interviews and direct observations are most suitable (Stretesky et al., 2022). Also, this method of collecting the data does not provide the data that is specific to answer the research questions.

3.9 Data Analysis

The data collected by the researcher for the preparation of this research proposal has been analyzed using various software programs. All collected data would be sorted and summarized in different Excel sheets before being thoroughly analyzed using various commands. The data gathered and retrieved through the analysis will be presented in power point slides and on various charts. Data analysis is critical in research because it simplifies and improves data analysis. It allows researchers to clearly evaluate the data, ensuring that nothing is omitted that would prevent them from drawing conclusions. Various kind of analysis will be conducted to draw a conclusion to the study. This research proposal includes the following methods of analysis:

3.9.1 Qualitative Data Analysis

The qualitative data analysis would consider non-textual data. Qualitative data is not text-based and can take the form of words or images. So, how can one evaluate this type of data? The application of this technique is helpful for analyzing data that consists of more than just numerical values. It is useful for comprehending and making informed

decisions about moods and behaviors. It is a versatile form since the researcher can alter the variables following the responses that are necessary (Rahman, 2020). This method is being evaluated as a potential tool for use in the process of measuring more qualitative factors such as productivity, influence, and beliefs.

3.9.2 Narrative Analysis

If the basis of the research is gathering responses from participants in interviews or other situations, this could be one of the most effective analytic strategies. The narrative analysis facilitates the examination of various people's narratives that are available in text form. The experiences, stories, and other responses of the respondents drive the study. Content analysis is a popular technique for analyzing quantitative data. This method is not limited to any data. Any kind of information, including text, photos, and even physical objects, can be used in this.

Knowing the questions to which one needs answers in this situation is critical. When one has the responses, it can be used to strategize or to analyze them and draw conclusions for the research. It is a methodology that is used exclusively in many analytical investigations. Participants are encouraged to open up and talk about their experiences while using this method, which takes place in a relaxed environment. Participants in this investigation are asked to reflect in-depth on their perspectives regarding the topic (Sony et al, 2020). There is room for a variety of viewpoints to be illustrated by examples, and the information that has been documented is comprehensive, well-explained, and extensive.

A number of excerpts from interviews about the effects of a pipeline for hydraulic fracturing project on farmers and rural landowners are included in the illustration. During the summers of 2020 and 2021, the following themes emerged from the interviews: loss of land and homes, failed land restoration, land with visible scars, loss of land rights and

trees, economic and emotional impact. These excerpts demonstrate the significant interruptions and psychological costs that major infrastructure projects, such as pipelines, have on rural communities.

We went to a farm auction, we walked from our house. It's a 10-acre farm, and there was a couple with a baby in their arm, and their family lives here. That's how people stayed there for generations. The auctioneer has the farm up for sale and it would have [gone] for $25 [thousand], because mine went for $20 [thousand], [but] the auction there starts [at] $150,000. [Gas company] raises their hand, auction over. They tear the house down, [they] just used [it] to go across [with the pipeline]. (Interview 16, summer 2020)

I had a hay field, can't make hay off it. Supposedly they restored it, but when they finished up, they planted hay and grass seed in July. It didn't rain. Nothing grew. And still nothing is growing. You know, it's been three or four years now. Still don't have no hay. (Interview 21, summer 2021)

You can see the wide swaths where the pipeline went through, and the rights of way are of course a great deal bigger than for a six and eight inch pipeline. And they are re-seeded. When the green grows, maybe they don't look bad to other people, but to me they're kind of a constant reminder of what's underneath there. (Interview 17, summer 2021)

They [gas companies] gave the loggers the trees, because they had the eminent domain right of way. So people, [landowners], didn't own the trees anymore. Now they have the land. (Interview 19, summer 2020)

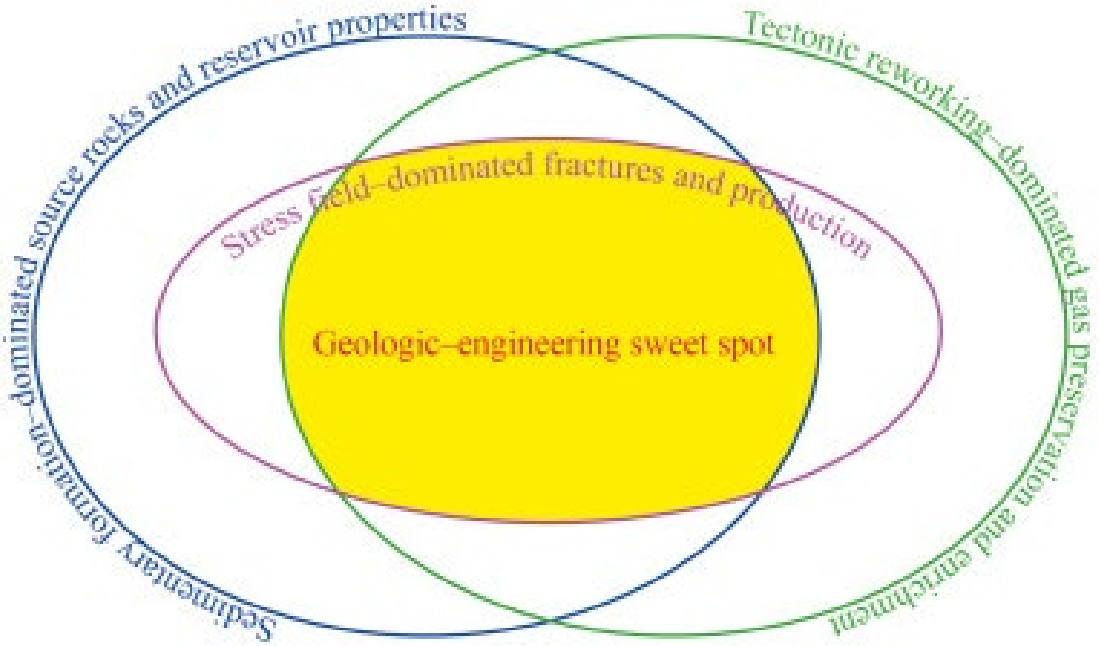
To us, it's farming ground, it's not out there for somebody to run over the rest of our lives. But they took it. Then they offered so much, and that day they put that in an account. They had our land, they took it, they paid this, and that was it. It was despair, because what we had farmed, and what other people we knew had farmed, this land, all these years, had put their heart and soul into it, and our blood, sweat, and tears are into it. We're just folks out here, that [they're] gonna run across. You're just dumb farmers, and you don't count pretty much. (Interview 6, summer 2020)

Source 13: (Caretta et al., 2024)

Figure 3.9.2 Narratives on Livelihood Impacts and Damages

3.9.3 Data Analysis would be done by using the grounded theory

When a researcher wants to understand the driving force behind an event, they utilize a grounded theory. Following this strategy one needs to go through numerous different use cases and compare them to one another. It is an iterative process, and explanations are changed or produced again and again until the researchers reaches a conclusion that is appropriate and meets their particular requirements. This theory is use to produce richer, more current, and more varied data. It brings to light areas of disagreement and conflict within the themes that have been explored (Guetterman et al, 2019). Its purpose is to amass a substantial amount of information and produce a comprehensive descriptive account of the nature of both practice and knowledge.



Source 14: (He et al., 2023)
Figure 3.9.3 Diagrammatic representation illustrating the three factors that dominated high production and enrichment of normal-pressure shale gas.

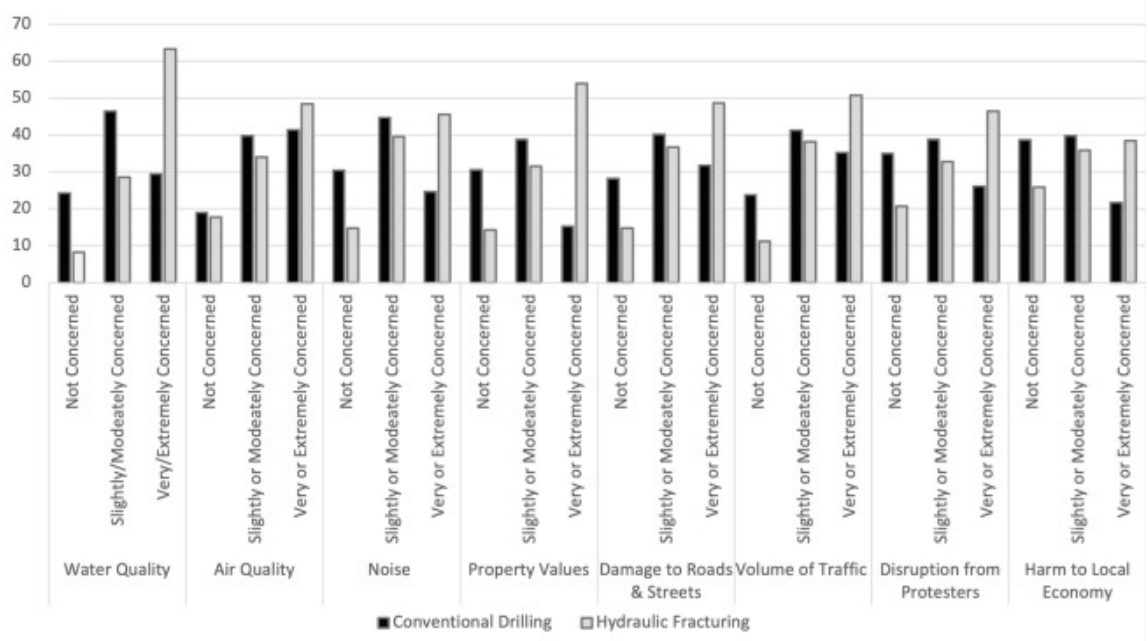
The above Venn diagram shows a geologic-engineering sweet spot as three distinct factors overlap. These three factors are sedimentary formation-dominated source rocks and reservoir properties, stress field-dominated fractures and production, and tectonic reworking-dominated gas preservation and enrichment. The yellow area where all these factors overlap is labeled as the "Geologic-engineering sweet spot." This area represents the optimal conditions where the properties and processes from all these domains come together, likely leading to the most favorable conditions for resource extraction or other geological engineering processes. After reiterative coding, the researchers found that such a region can exist where normal-pressure shale gas will be enriched and its production will be high in this region.

3.9.4 Discourse Analysis

Discourse analysis is similar to story analysis in that it uses interactions with people for analytical purposes. The only difference is that the focal point is different here. Rather than evaluating the story, the researchers focus on the setting in which the dialogue takes place. The research is conducted using the subject's entire background, including his regular surroundings. The use of discourse analysis helps decipher the real message as well as the data gathered from a variety of primary sources, such as interviews and observations (Jacobs & Tschötschel, 2019). It compares and evaluates other elements such as the social, cultural, or linguistic environment to gain more meaningful data from interviews and other activities that are carried out to extract the necessary information.

The bar graph below contrasts issues with hydraulic fracturing (fracking) with traditional drilling across a number of social and environmental issues. Each topic is divided into three levels of concern: "Not Concerned," "Slightly/Moderately Concerned," and "Very/Extremely Concerned." The data is displayed in columns. Concerns about water quality were higher among respondents regarding hydraulic fracturing, with a large

percentage expressing "Very/Extremely Concerned," compared to conventional drilling, when most indicated "Slightly/Moderately Concerned" or "Not Concerned." Similar trends are shown in the area of air pollution, as conventional drilling exhibited a more evenly distributed distribution across the three categories, while hydraulic fracturing once again sparked higher levels of worry. Regarding noise, the bulk of respondents expressed "Slightly/Moderately Concerned" feelings for conventional drilling, but more expressed "Very/Extremely Concerned" feelings toward hydraulic fracturing, suggesting a higher perceived impact. Concerns regarding property values also showed that more persons were "Very/Extremely Concerned" about hydraulic fracturing than they were about conventional drilling, which was a milder concern. Another area where hydraulic fracturing prompted greater concerns than conventional drilling was the harm to roads and streets, with more respondents expressing "Very/Extremely Concerned" rather than traditional drilling, where the majority expressed "Slightly/Moderately Concerned." This pattern was also followed by worries about traffic congestion, with hydraulic fracturing perceived as more harmful. Remarkably, both approaches raised concerns about protest disruption; nevertheless, hydraulic fracturing once more resulted in higher levels of "Very/Extremely Concerned" replies, indicating a greater sensitivity to social unrest surrounding fracking. Damage to the regional economy was also a major worry, with hydraulic fracturing again evoking more extreme fears than traditional drilling, which elicited more mild concerns.



Source 15: (Bradshaw et al., 2022))
Figure 3.9.4 Hydraulic Fracturing Eight Perceived Negative Impacts by Residents Percentage

3.9.5 Quantitative Analysis

Numerical data analysis is classified as quantitative analysis. Quantitative analysis approaches a wide range of methodologies, from the most basic to the most cutting-edge. If the study is based on numerical data, one can have an effective analytical techniques at one's disposal. The quantitative method of analysis is quick, trustworthy, and able to manage vast amounts of data (Ma & Nakab, 2020). This study could be carried out with the assistance of several statistical and analytical tools, which would assist in the analysis of the data and the presentation of the results in such a way that it would be simple for the researcher to draw a conclusion based on the findings.

3.9.6 Descriptive Analysis

Descriptive statistics are the most basic method that researchers can use to draw conclusions from data. It aids in pattern recognition and makes data more audible. In the

following section the researcher have explored some of the most popular methods for analyzing descriptive statistics data.

Mean

The mean is the average of all available data. The formula indicates the expected average value across all data points.

Median

The median is the value in the data that is in the middle. It allows researchers to pinpoint the midpoint of the data. It is critical to remember that the data must be sorted before calculating the median.

Standard Deviation

Knowing how widely distributed the data is important because numerical data is expanded It reveals the extent to which a typical data point deviates from the norm.

Mode

The mode is the most prevalent data in the dataset.

Summary Statistics	count	Mean	sd	Min	max	p25	p50	p75
Shale Gas Prod. Growth	180	0,19	0,22	0,00	0,72	0,00	0,12	0,30
Shale Oil Prod. Growth	180	0,18	0,20	−0,07	0,66	0,02	0,14	0,31

Source 16: (Özgür Speitmann, 2023)
Table 3.9.6 Descriptive Analysis of shale oil and gas production growth

The table provides summary statistics for the growth rates of shale gas production and shale oil production. Here, the number of observations (data points), mean is the

average value, sd is the standard deviation (a measure of dispersion), min is the minimum value, max is the maximum value, p25 is the 25th percentile (first quartile), p50 is 50th percentile (median), and p75 75th percentile (third quartile). There are 180 data points for both shale oil and gas. The average growth rate of shale gas is 19% and shale oil is 18%. The growth rates for both shale oil and gas can be highly variable due to the standard deviation of 0.20 and 0.22. The minimum growth rate of shale gas is 0% whereas shale oil is -7%. On the other hand, the maximum growth rates are 72% and 66%. For shale oil and gas, 25% of the periods had a growth rate of 2% and 0%. The median growth rate for shale gas is 12% and shale oil is 14%. The 75% of the periods had a growth rate of shale gas production of 30% or less. Whereas, for shale oil is less than or equal to 31%.

3.9.7 Questionnaire

Primary data is the firsthand data collected by the researcher to find answers to the research questions. This method provides highly relevant and accurate data to reach to a conclusion. There are various techniques that can be used for data collection like Interview. In this method questions can be asked directly or via email or telephonic conversation. Samples are selected and they are contacted to gather the required information. Projective data gathering is another technique that is used to understand topics that are sensitive and participants might be hesitant to give their opinions freely. In Delphi technique a panel of experts are selected and they answer the questions related to their expertise, once this is done all the responses are complied. Focus group is another technique where more than half a dozen selected participants are led by a moderator to discuss the topic. Researcher by observing their responses and body language takes note of the information required.

The questionnaire technique has also been used for the data collection.

A detailed questionnaire has been sent to the participants of the research process and they are asked to fill in the questions. The general questions were based on getting their feedback and are related to the information on how the shale gas extraction through hydraulic fracturing is beneficial in enhancing the productivity and efficiency of the various natural companies in the world. In this questionnaire, various open and close-ended questions were asked to the participants. The questionnaire was designed by experts and intellectual persons and this has helped in retrieving the bulk data. As it was an unstructured interview; a few examples of questions asked were:

What are the negative impacts of hydraulic fracturing technology on the environment?

What strategies are you using to extract a high quantity of shale gas?

What is the true meaning of being energy self-sufficient for a nation?

What competitive strategies to increase profit margins and achieve high efficiencies?

Feedback and recommendations to improve this technology?

3.9 Research Design Limitations

Due to a large population sampling that was conducted could have given rise to error or biasness in the technique. In this study, the researchers have used convenience and snowball sampling to select the participants from the experts in the shale gas industry which might lead to biasness. As mentioned earlier, the previous study on this topic was very limited. It could have created a theory or literature gap. In case of Shale gas extraction, the researcher has limited access to the data and even the participants were only a few. Another limitation was the time deadlines. In this field, technologies are ever-changing and so are the impacts. Due to time constraints, researchers were not able to monitor the impacts over a period of time. As stated earlier in US hydraulic fracturing sector, has made itself

self-sufficient although it has negative environmental effects. The participants as per their personal judgment and priority towards overall impact may have given biased responses rather than stating facts.

3.9 Conclusion

In order to determine whether hydraulic fracture may be leveraged to attain self-sufficiency in energy production in the United Kingdom, an exploratory study of the history and contributions of the US shale gas sector was conducted. According to Wachtmeister *et al.* (2021), these resources might be in public libraries and historical polling results. There are many locations where one can find the information, both paid and unpaid. Secondary research is more economical than conducting brand-new research from the beginning. Businesses and organizations can now conduct their research without the assistance of a third-party data collection service.

CHAPTER IV: LIMITATIONS AND CHALLENGES

4.1 Overview

There were a number of significant obstacles to overcome in conducting research on hydraulic fracturing-based shale oil and gas extraction, especially when using techniques like discourse analysis, narrative analysis, grounded theory, and descriptive analysis. These difficulties arise from a number of sources, such as the availability and quality of data, which can make it difficult to conduct a thorough analysis because it is hard to gain access to confidential information and secure trustworthy qualitative data from stakeholders. Because the consequences of hydraulic fracturing vary greatly depending on local conditions, assessing the environmental repercussions is difficult and difficult to come to a firm conclusion (Caldwell et al., 2022). Furthermore, the research is made more complex by the diversity and conflicting opinions of the various stakeholders, including those from local communities, environmental organizations, and energy businesses. This is particularly true when attempting to balance conflicting narratives and points of view. Methodological challenges arise when attempting to comprehend the strategic and economic ramifications of hydraulic fracturing since the energy sector is dynamic and necessitates complex analysis that is frequently outside the purview of straightforward quantitative techniques (Merzoug et al., 2023). Research is made more difficult by ethical and regulatory restrictions, especially when delicate topics like environmental justice and community effects are involved. In addition, because of the temporal and spatial heterogeneity of the effects of hydraulic fracturing, ongoing data collection and analysis—which can be resource-intensive—is necessary. It is necessary but difficult to integrate findings from other disciplines, such as geology, economics, and sociology, since it calls for rigorous methodological preparation to prevent oversimplification or oversight.

Overall, these constraints call for careful planning and execution of the research to ensure that the complexity of hydraulic fracturing are sufficiently addressed.

4.2 Data Availability and Quality

The restricted access to energy companies' confidential data is a significant obstacle. These businesses own a large portion of the quantitative data on manufacturing processes, environmental effects, and economic results; for competitive, legal, or regulatory reasons, there was limited access. This resulted in gaps in the data that can be analyzed, which led to biased or insufficient research findings. The available data can differ greatly in quality, particularly when discussing the effects on the environment (Wang, Liu, et al., 2023). For example, there may be disparities in data between different regions or time periods regarding the effects of hydraulic fracturing on air quality, water contamination, and seismic activity. Because of this diversity, it was challenging to derive findings that could be trusted, and the researcher needed to invest more time and money in standardizing and validating the data.

The lack of longitudinal data often impedes research on hydraulic fracturing's long-term impacts. Years after drilling started, many environmental effects, such as groundwater contamination or ecosystem damage, could not be noticeable. It is difficult to evaluate these effects thoroughly in the absence of long-term data, which could result in an underestimation of the hazards related to hydraulic fracturing. Gathering rich qualitative data from stakeholders is essential for techniques like grounded theory and narrative analysis (Chi-Kuan et al., 2023). But it was challenging to get truthful and in-depth stories from government officials, business employees, or impacted populations. Concerns about confidentiality, possible legal ramifications, or mistrust of researchers might make stakeholders hesitant to divulge information, especially in controversial areas like environmental degradation or economic implications.

Hydraulic fracturing data can be found in a variety of places, such as government publications, scholarly research, trade journals, and media coverage. The research process became more difficult as a result of this fragmentation since it takes a lot of work to gather, validate, and cross-reference data from several, frequently unrelated sources. Data inconsistencies resulted from differences in reporting requirements and regulatory frameworks between nations and regions (Bagepally et al., 2022). For instance, although some jurisdictions may have lenient standards or no reporting requirements at all, others may have strict legislation demanding full reporting of hydraulic fracturing activities and their environmental implications. This discrepancy made it difficult to compare data from other places and to build a thorough picture of the wider effects of hydraulic fracturing.

4.3 Assessment Complexity in Environmental Impact

4.3.1 Variability in local geology and hydrology

Hydraulic fracturing is the process of releasing natural gas or oil from shale rock formations by pumping a high-pressure fluid into them. There are wide regional variations in the geological features of these formations, including the kind of rock, depth, and presence of faults. This fluctuation influences the way fracking fluids interact with the subsurface environment, which can have a variety of effects on the environment, including the possibility of groundwater contamination or the risk of induced seismicity (earthquakes). The hydrology of a region, which includes groundwater flow and location, affects how fracking affects the environment (Dakheel Almaliki et al., 2022). Fracking fluids and methane have a greater chance of seeping into sources of drinking water in areas where aquifers are interconnected. Evaluating these hazards necessitates precise hydrogeological data, which is frequently hard to come by or impossible to collect.

4.3.2 Challenges in measuring long-term and cumulative impacts

Numerous negative effects of hydraulic fracturing on the environment, like soil erosion, groundwater pollution, and ecosystem change, may not show symptoms right away and may take years or even decades to show up. Because of this, it is difficult to test and evaluate these impacts in the normal research timeframes. Longitudinal studies are required to comprehend these effects completely, but they take a lot of time and resources (Rohrer & Murayama, 2023). Multiple fracking operations within a region can have considerable cumulative environmental consequences, although these are frequently difficult to measure. For instance, the cumulative effect of water withdrawals for hydraulic fracturing from several wells may cause the local water supplies to run out, impacting populations and ecosystems. In the same way, local air quality problems may arise from the combined effects of air pollution from multiple fracking sites. Comprehensive data and complex models are needed to assess these cumulative impacts, which may not always be possible sites that may be a factor in local problems with air quality.

4.3.3 Regulatory and methodological challenges

There are significant differences in the regulatory structure that governs hydraulic fracturing between different nations and areas. There may be limited oversight in some regions and strict laws in others, necessitating thorough environmental evaluations and ongoing monitoring. The reported results may differ significantly as a result of this variability, which also has an impact on the scope and quality of environmental impact assessments. Conventional environmental impact assessment (EIA) techniques might not be entirely suitable for addressing the unique difficulties presented by hydraulic fracturing (Guerrero-Martin & Szklo, 2024). For instance, while fracking frequently has long-term, diffused effects, environmental impact assessments (EIAs) usually concentrate on a project's immediate and concentrated effects. Furthermore, it is methodologically difficult

to combine the many environmental, social, and economic aspects into a single assessment framework, which might cause the results to be oversimplified or interpreted incorrectly.

4.3.4 Social dynamics and public perception

Environmental justice is raised by the fact that fracking activities frequently take place in rural or economically underdeveloped areas. Environmental assessments become even more challenging when evaluating the disproportionate effects on these populations, who do not have the political clout or means to oppose destructive activities. High-profile events, media attention, and environmental groups' activism are often what shape the public's impression of hydraulic fracturing's negative environmental effects (Williams et al., 2022). This may cause worries to grow, sometimes unnecessarily, but it may also increase the need for more thorough impact analyses. It is difficult for academics to strike a balance between the public's concerns and scientific conclusions, particularly when attempting to explain complicated environmental issues.

4.4 Diverse and Conflicting Stakeholder Perspectives

A major obstacle to research on hydraulic fracturing-based shale oil and gas extraction is the divergent and sometimes antagonistic viewpoints of different stakeholders. The economic benefits of hydraulic fracturing, according to energy companies and industry stakeholders, outweigh the environmental risks, which they believe can be reduced by technological advancements and regulatory compliance (Aczel et al., 2022). These benefits include increased profits, job creation, and energy security. On the other hand, environmental organizations and activists advocate for stronger laws or even the outright prohibition of hydraulic fracturing in some places due to the possible adverse effects, which include air pollution, groundwater contamination, and greenhouse gas emissions. In addition to immediate worries about noise pollution, air and water pollution, and possible health dangers, local populations close to fracking sites frequently

worry about long-term environmental damage that may affect their livelihoods and land. Tension between local communities and legislators often results from these concerns' frequent conflicts with national interests, which may emphasize larger economic and energy aims above local issues. Regulatory agencies have to strike a balance between environmental preservation and economic growth, but they frequently come under criticism from both the public and the industry, which wants stricter laws (Kastelli et al., 2023). The scientific community provides evidence-based insights by concentrating on facts and effect evaluations; yet, these conclusions can be complicated and occasionally contradict popular opinion, which is frequently shaped by advocacy organizations and media coverage.

Environmental groups contend that the short-term economic benefits of hydraulic fracturing do not outweigh the possibility of long-term environmental harm, while proponents of economic development emphasize the significance of fracturing in stimulating local economies. The matter is further complicated by legal and ethical issues, which give rise to disputes about property rights, environmental justice, and the propriety of placing particular communities at risk from the environment. Furthermore, disagreements between various scholarly viewpoints may arise from the interdisciplinary nature of hydraulic fracturing, which encompasses disciplines including geology, engineering, economics, and environmental science (Marshall, 2023). The argument over hydraulic fracturing is made more complex by the fact that different countries have different views on the practice. While some support it as a means of achieving energy independence, others forbid it because of environmental concerns. Managing these divergent and opposing viewpoints is essential to creating equitable and long-lasting policies for shale oil and gas production

4.5 Methodological Challenges in Understanding Strategic and Economic Implications

There are several methodological difficulties in figuring out the strategic and financial ramifications of shale oil and gas production, especially when it involves hydraulic fracturing. These difficulties arise from the industry's complexity, the wide range of variables influencing economic results, and the issue of precisely projecting long-term effects. First, it is challenging to model and forecast economic results due to the energy market's dynamic character. Numerous worldwide factors, including shifts in supply and demand, technical developments, and geopolitical events, have an impact on the price of oil and gas (Zakeri et al., 2022). Strategic planning and economic forecasting are made more difficult by this instability. The subtleties of these variations may not be fully captured by traditional economic models, which could result in predictions of the long-term sustainability and profitability of shale oil and gas operations. Second, there are a lot of difficulties with data quality and availability. To perform in-depth economic studies, one needs accurate and complete data on production costs, technology efficiency, environmental impact, and market trends (Kuzior et al., 2023). But such information is frequently confidential, lacking, or erratic, especially in a field that is changing quickly, like hydraulic fracturing. Accurate strategy model development and strong economic assessments may be hampered by this lack of transparency.

Third, the complexity is increased by the interdisciplinary character of the analysis needed to comprehend the strategic and financial ramifications. Integrating knowledge from geology, engineering, economics, environmental science, and public policy is necessary for effective analysis (Castro & Lechthaler, 2022). These fields all employ various techniques, which might not always coincide or might lead to contradicting outcomes. Divergent outcomes may result from, for example, environmental models

prioritizing sustainability and long-term ecological repercussions while economic models may concentrate on cost-benefit evaluations. Fourth, it is challenging to measure and account for the long-term environmental and social consequences of hydraulic fracturing in economic models (Erickson et al., 2022). These expenses include possible harm to ecosystems, hazards to the public's health, and effects on nearby populations. These externalities are frequently difficult for traditional economic models to account for, especially when the costs are unknown or may not be felt for some time. This restriction may cause the actual costs of producing shale oil and gas to be underestimated. Finally, the strategic and economic analysis is complicated by the multiplicity of stakeholders and competing interests (Lami & Todella, 2022). The goals and priorities of various stakeholders, such as governments, energy firms, environmental organizations, and local populations, differ. It can be difficult to balance these objectives in strategic plans and economic models when stakeholders have competing interests, like maximizing profit vs limiting environmental effects.

4.6 Personal and Anecdotal Evidence

When conducting research on hydraulic fracturing-based shale oil and gas extraction, personal and anecdotal evidence is essential, particularly when employing narrative analysis. These kinds of evidence capture subtleties that can only be expressed by quantitative data, offering insightful information about the real-life experiences of people and communities impacted by hydraulic fracturing. To guarantee the validity and trustworthiness of their conclusions, researchers must overcome a number of obstacles when depending on anecdotal and personal data (Cheong et al., 2023). Subjectivity in personal and anecdotal reports is one of the main obstacles to using them as proof. Due to a person's prejudices, feelings, and particular situations, their experiences and perceptions can differ greatly from one another. It is challenging to generalize findings and draw broad

conclusions because of this diversity. In order to provide a more thorough and fair view, researchers can address this by triangulating human narratives with data from other sources, such as economic reports, environmental monitoring results, and scientific studies. The possibility of incomplete or biased reporting of anecdotal evidence is another difficulty. People tend to highlight some parts of their experiences and leave out others, either intentionally or inadvertently (Schoenherr et al., 2022). Scholars need to analyze these stories critically, looking for contrasting viewpoints and supporting evidence wherever they can. This problem can be addressed and a more accurate and representative representation of the effects of fracking can be achieved by conducting in-depth interviews and interacting with a wide range of stakeholders.

The use of anecdotal and personal information is further complicated by the temporal and spatial heterogeneity of fracking effects. Hydraulic fracturing can have varying consequences in different areas and over time, depending on a number of factors including geology, regulations, and technological developments. When examining and evaluating personal narratives, researchers need to take these contextual variations into account. This diversity can be captured through longitudinal study following changes over time and comparative studies across various geographies (Coelho et al., 2023). Notwithstanding these difficulties, anecdotal and personal data is crucial for comprehending the human aspect of hydraulic fracturing. These personal accounts shed light on issues that may not be apparent from quantitative data alone by highlighting the perspectives of those who are directly impacted. Personal accounts, for instance, might highlight the negative social and psychological effects of hydraulic fracturing, including disturbances to communities, health issues, and reduced quality of life (Kronenberger, 2024). Additionally, they can provide context-specific insights that are essential for

creating successful and culturally relevant policies and interventions by illuminating local knowledge and practices.

For this research, few crucial tactics were used to optimize the value of anecdotal and personal evidence. They should first give ethical issues first priority, making sure that participants' identities are kept private and their opinions are heard. Second, a more comprehensive knowledge of the effects of fracking may be obtained by using a mixed-methods approach that incorporates both qualitative and quantitative data (Caretta & Emanuel, 2023). Third, by creating a sense of ownership and trust, including community people in the research process can improve the findings' relevance and trustworthiness. In summary, anecdotal and personal evidence is an essential part of research on hydraulic fracturing-based shale oil and gas extraction. Even if it raises issues with subjectivity, completeness, and variability, these can be resolved by using meticulous and exacting research procedures. Researchers can obtain a greater understanding of the complex effects of hydraulic fracturing by incorporating personal narratives with other data sources and taking contextual aspects into account. This will ultimately lead to more informed and efficient decision-making.

CHAPTER V: RESULTS

5.1 Research Question One

What are the negative impacts of hydraulic fracturing technology on the environment?

What strategies are you using to extract a high quantity of shale gas?

5.2 Research Question Two

What is the true meaning of being energy self-sufficient for a nation?

What competitive strategies to increase profit margins and achieve high efficiencies?

5.2 Summary of Findings

New technologies, such as hydraulic fracturing, have a substantial impact on the energy production and the environment, as noted earlier. While hydraulic fracturing have increased oil and gas output and reduced energy costs, it also has a number of environmental hazards, including the contamination of soil and water and seismic vibrations. By using sound operational procedures and collaborating effectively with environmentalists and the gas sector, these risks can be reduced.

Fracking has completely changed the energy industry by making previously unreachable large deposits of natural gas and oil available. This has led to a notable increase in energy production, especially in areas like the United States where domestic oil and gas output has surged. The financial advantages are obvious: more output has resulted in cheaper energy prices, less dependency on foreign oil, and the creation of jobs in regions with abundant energy resources. These advantages do, however, present serious environmental risks. In order to release hydrocarbons that have been trapped underground, a high-pressure mixture of water, sand, and chemicals is injected into rock formations by

hydraulic fracturing. This technique has been connected to numerous environmental risks. The main worry is that the chemicals in the fracking fluid are contaminating the soil and groundwater. Although businesses frequently claim that these dangers are negligible if wells are built and maintained correctly, recorded cases of contamination have raised questions about the long-term effects on the environment and public health.

Furthermore, fracking's high water requirements present a problem in areas with limited water supplies. Depleting the region's water supplies during the extraction process may have far-reaching effects on ecosystems and human populations. Another problem is the disposal of wastewater, which may contain radioactive elements and dangerous substances. Surface water bodies may get contaminated as a result of improper disposal techniques, hence increasing environmental dangers. Seismic activity is another significant concern associated with hydraulic fracturing. The injection of wastewater into deep underground wells has been linked to an increase in the frequency and magnitude of earthquakes in some regions. Although these earthquakes are typically minor, they have the potential to cause damage to infrastructure and raise public safety concerns. The relationship between fracking and seismicity is complex and not yet fully understood, necessitating further research and regulation.

The worldwide movement towards sustainability and energy independence has underscored the significance of renewable energy sources, even if hydraulic fracturing has contributed significantly to increased energy output. Particularly, solar and wind energy have become important components in the shift to a low-carbon energy system. These technologies present a competitive substitute for fossil fuels, which have limited supply and greatly increase greenhouse gas emissions and the effects of climate change. There are many benefits to using renewable energy sources. They are becoming more and more affordable when compared to conventional energy sources, plentiful, and clean. For

example, electricity produced by wind and solar power emits no greenhouse gases or other pollutants. They are therefore essential in the fight against climate change and the reduction of the environmental effect of energy production. Furthermore, by diversifying the energy mix and lowering reliance on imported fossil fuels, renewables can improve energy security.

Nonetheless, there are a number of obstacles in the way of the broad use of renewable energy. The requirement for large investments in technological development and infrastructure is one of the most important. Scaling up these technologies requires, according to Mayyas et al. (2019), creating a strong supply chain for raw materials and manufacturing components, like solar panels and wind turbines. In addition to financial resources, technological innovation and policy support are also necessary for this. To achieve energy independence and lessen reliance on fossil fuels, emerging technologies like renewable energy sources like wind and solar power can be very helpful. According to Mayyas *et al.* (2019), substantial investment is required to build the raw material supply chain and turn these energy sources into a widely accessible public good. In general, the interplay of new technologies and the environment is a crucial issue in the quest for energy self-sufficiency, and the environmental impact of energy production techniques must be carefully considered.

5.2 Conclusion

This research report provides a complete explanation of the data gathering and analysis procedures used to examine hydraulic fracturing for the extraction of shale gas. Although the research has its limitations, the results shed light on the subject and add to the body of knowledge in this area. According to Archibald *et al.* (2019), the effects and prospects of hydraulic fracturing for reaching energy self-sufficiency can be better

understood through additional research and studies with larger and more diversified samples, longitudinal data, and rigorous techniques.

CHAPTER VI: DISCUSSION

6.1 Discussion of Results

According to Fu and Liu (2019), the technology of hydraulic fracturing, which is used to extract oil and gas from shale rock formations, is covered in the passage. To induce micro-fractures and liberate trapped gas and oil, high-pressure injection of a solution of water, sand, and additives into the rock is required. Even though hydraulic fracturing has significantly increased domestic energy output, it is still contentious because of the short-term harm to the environment it may do. The section also explains the history of hydraulic fracturing, including its effect on global energy output and any problems related to it, and defines important concepts like self-sufficiency, energy production, and shale gas.

The literature study emphasizes how crucial it is for a country to become energy self-sufficient because doing so one can boost the economy, prevent financial crises, and enhance national security. As per Clapp & Moseley (2019), because of oil price surges and the fragility of the world economy, obtaining energy independence through oil output can be difficult. The study contends that a shift away from shale gas development in favor of alternative energy sources could prevent disputes over oil access.

According to Sun *et al.* (2021), shale gas is a cutting-edge energy source with tremendous potential to benefit nations through reserves and trade. Shale gas reserves in abundance in the United Kingdom could contribute to the nation's transition to energy production self-sufficiency. Shale gas drilling can be expensive, and its effects on the environment are up for debate. Despite this, shale gas production has the potential to benefit the economy and help the country meet its energy needs.

Although the UK has several advantages from using shale gas for energy self-sufficiency, such as improved energy security and economic gains, there are also many

drawbacks. These include threats to the environment and public health, obstacles to regulations, and public opposition. To tackle these issues, a well-rounded strategy that takes into account public participation, strong regulatory frameworks, and technological improvements is necessary (Lawal et al., 2024). While there are many significant lessons to be learned from the global experiences of shale gas development—particularly in the United States—the specific economic, environmental, and social context of the United Kingdom demands a customized approach to shale gas policy. In the UK, shale gas production can be matched with national priorities and sustainable energy targets to maximize advantages and minimize hazards.

6.2 Discussion of Research Question One

According to experts, 10% of the gas found in the shale basins in the UK can be easily harvested, which could supply all the nation's energy requirements for the next 50 years. According to Yadav *et al.* (2020), the UK may become one of the most flourishing economies in the world in the energy sector thanks to the potential for shale gas extraction. But because of the country's stricter regulations, more expensive extraction methods, and intricate shale basins, the situation in the UK is more complicated. To duplicate the success shown in the United States, these variables provide formidable obstacles that need to be surmounted. Furthermore, the economic stability that shale gas could offer may be jeopardized by the volatility of the global energy market, which is typified by varying oil prices and rising energy demands. Shale gas has significant potential economic benefits, but in order to fully achieve these gains, the UK must embrace this opportunity with strategic planning and efficient cost management.

The production of energy and the environment have both been significantly impacted by the hydraulic fracturing of shale gas. On the one hand, shale gas reserves that

were previously inaccessible to nations like the United States, China, and others are now accessible and can be extracted, which has increased energy production, enhanced financial stability through exports, and decreased domestic gas prices. According to Weijers *et al.* (2019), countries like the United Kingdom have been able to boost their oil production more quickly than ever before because of the usage of horizontal drilling and hydraulic fracturing.

Concerns have been raised about hydraulic fracturing's effects on the environment. Lack of openness regarding the ingredients in the fracturing fluid, which is pumped into the rock formation to fracture it and liberate the gas, is one significant problem. There are worries about the emission of methane, a powerful greenhouse gas, during the extraction process as well as the potential for these compounds to contaminate groundwater and surface water. , the considerable amounts of water needed for hydraulic fracturing can put a burden on nearby water supplies, especially in arid areas, and cause water pollution through the discharge of effluent. Numerous studies have brought attention to these issues, emphasizing the impact on water quality and the consequences of chemical leaks. Environmental concerns are exacerbated by health dangers associated with hydraulic fracturing (fracking), which include cancer, neurological diseases, and respiratory ailments brought on by exposure to chemicals used in the process. Despite these difficulties, supporters contend that these threats to the environment and public health can be efficiently addressed with strict laws and technical developments. Some believe that the advantages for the economy and energy security—such as lower greenhouse gas emissions when compared to coal—outweigh the disadvantages for the environment. Local communities frequently embrace fracking's economic benefits in spite of its environmental hazards, suggesting that public acceptance could lessen opposition on environmental grounds. This demonstrates how divisive the discussion surrounding shale gas production is. A well-

rounded regulatory strategy that takes into account the necessity of environmental preservation as well as energy security is crucial for the UK.

According to Moore *et al.* (2018), to reduce these environmental dangers, the hydraulic fracturing business needs more transparency and oversight. This entails monitoring and controlling water use and wastewater disposal practices, as well as mandating hydraulic businesses to disclose the composition and concentration of fracturing fluid to healthcare professionals and regulatory agencies. Hydraulic fracturing can have severe effects on the environment and human health, but they can be kept to a minimum with the help of proper legislation and control.

Despite its detrimental effects, hydraulic fracturing investment is crucial for various reasons:

1. According to Kumari *et al.* (2018), hydraulic fracturing has considerably expanded the availability of energy resources, such as shale gas and oil, in the United States and decreased energy prices. Lowering reliance on foreign energy sources, has led to lower energy prices, putting more money in the hands of American households and businesses and enhancing energy security.

2. Reduction of air pollution and carbon emissions: Hydraulic fracturing has expanded the usage of natural gas, which, when used to generate power, emits fewer carbon emissions than coal. As a result, air pollution and greenhouse gas emissions have decreased, improving air quality and possibly lessening the effects of climate change.

3. Economic advantages: According to Xue *et al.* (2023), it has been demonstrated that hydraulic fracturing has a positive effect on regional economies, leading to an increase in income, employment, economic activity, and home values. By generating jobs and fostering economic growth, these benefits can help local communities expand and prosper.

4. Energy independence: According to Xue *et al.* (2023), Hydraulic fracturing may help a nation become less reliant on imported energy, which could increase its energy security and independence. Reducing sensitivity to changes in energy prices and supplies can have positive geopolitical and economic effects.

5. Development and innovation in technology: According to Suboyin *et al.* (2020), drilling methods, equipment, and environmental practices have all advanced thanks to hydraulic fracturing. This has enhanced the energy sector's effectiveness, safety, and environmental performance, which can be helpful to other businesses.

6.2 Discussion of Research Question Two

Despite these advantages, hydraulic fracturing also has drawbacks, including increased truck traffic, potential health risks from air and water pollution, as well as other issues related to society and the environment. It is crucial to carefully balance the costs and advantages and to take the necessary steps, such as laws, monitoring, and best practices, to lessen the negative effects. According to a comparison of the US and UK's shale gas output, both nations have sizable shale gas reserves with the ability to produce energy and gain economically. According to Suboyin *et al.* (2020), the viability and possible effects of shale gas production could be impacted by variations in geology, laws, and technological developments.

Shale basins in the UK are complicated, which could increase the cost of shale gas drilling compared to other nations. The UK also offers advantageous geological features that could help shale gas to be successfully commercialized, including as high natural gas prices, private property ownership, and already-existing infrastructure. To control shale gas production and guarantee that social and environmental safeguards are in place, the UK government has also introduced legislation. In order for shale gas projects to be feasible, public opinion and regulatory obstacles are important considerations. While in the

US, a more lax regulatory framework has allowed for rapid growth, in the UK, stringent rules and strong public opposition have hampered the advancement of shale gas exploitation. Environmental concerns frequently shape public opinion in the UK, sparking protests and opposition to hydraulic fracturing. Public opposition might lessen, though, if the UK can guarantee strong environmental regulations and show that there are significant economic benefits. Although the potential economic gains may not materialize right away, the UK's cautious regulatory approach is in line with wider sustainable energy policies and indicates a commitment to environmental standards and public concerns. Managing the hazards involved with shale gas extraction while maximizing its benefits requires effective regulation. Gaining public support and achieving the promise of shale gas will depend on establishing public confidence via openness and continuous implementation of regulations.

Le (2018) states that the US have already gone through a shale gas revolution. Resulting in large production increases and changes to the energy market. Shale gas has facilitated economic expansion and US energy independence, and the US has turned into a net exporter of natural gas. Hydraulic fracturing methods have seen major technological developments in the US that have increased their effectiveness and environmental performance.

Fracking, commonly referred to as hydraulic fracturing, has significantly impacted American economic growth and energy security. The United States has risen to the top of the global natural gas production rankings thanks to the exploitation of natural gas and oil resources through hydraulic fracturing, reducing its dependency on foreign oil supplies and boosting its energy independence. Hydraulic fracturing has several advantages, one of which is that it has boosted the supply of natural gas, resulting in cheaper energy costs for consumers and companies, promoting economic growth, and generating employment in

the energy sector. By lowering the need for gas and oil imports from other nations, the increased production of natural gas has also improved the trade balance of the United States, which benefits the economy.

By lowering the reliance on foreign oil and gas sources, hydraulic fracturing has improved the United States' energy security. As a result, the geopolitical dangers brought on by reliance on imported energy resources from politically dangerous parts of the world have been lessened. The United States' energy security has been improved, and its susceptibility to untoward incidents in the world energy markets has decreased, thanks to increased domestic production of natural gas and oil through hydraulic fracturing.

According to Zuhaira *et al.* (2022), by analyzing the growth and economic effects of the shale gas industry in the United States, the study seeks to ascertain if the United Kingdom can attain energy self-sufficiency through hydraulic fracturing. The research philosophy takes technique, epistemology, and ontology into account and is founded on the scientific paradigm. Inductive reasoning-based qualitative evaluation data analysis, which condenses and summarizes raw data and builds a broad framework, is used. According to Chen *et al.* (2022), primary data is gathered from experts in the shale gas construction business, and secondary data is gathered from sources including academic papers and computer-based research. Through the internet, credible and published sources are used to gather information, as well as data from public and private organizations, such as small business development centers and governmental agencies.

Direct observations of various hydraulic fracturing techniques utilized for shale gas production in various parts of the world were made by the researcher. It was discovered that enterprises were extracting a significant amount of shale gas, which increased their production efficiency, based on the data gathered regarding the percentage of shale gas extraction using these techniques. According to Bhatia, A., & Makkar (2020), officers and

staff from natural gas extraction corporations were among the focused groups that were studied to learn how hydraulic fracturing was being employed by them to increase production. The data was gathered through direct observation, which is a trusted way for gathering information, there was less potential of manipulation or personal preference influencing the outcomes. According to Zuhaira *et al.* (2022), this provided for objective and accurate results.

The researcher also performed face-to-face, unstructured interviews with a variety of officers and workers from natural gas firms all over the world. The researcher solicited suggestions for enhancing the procedures as well as information on the current methods employed for hydraulic fracturing and shale gas extraction. According to Chen *et al.* (2022), without a specific organized instrument or protocol, unstructured interviews allowed for flexibility in the dialogue and the investigation of a wide range of themes. As each interview is distinct and as results must be compared among respondents, analyzing unstructured interview data can be difficult.

A case study approach was also applied, which entailed a thorough investigation of certain people or circumstances. According to Bhatia, A., & Makkar (2020), data for the case study were gathered by the researcher using a combination of techniques, including direct observation and unstructured questioning. Data was sorted and summarized in excel sheets, and different commands were used to analyze the data while using a variety of software programs. PowerPoint slides and charts were used to present the findings to make them easier to grasp and analyze.

According to Archibald *et al.* (2019), the researcher also acknowledged that there were drawbacks, including time restraints, limited access to individuals and data, and potential bias in participant responses. Conducting thorough and protracted investigations is difficult due to the shale gas industry's dynamic nature and evolving technologies. The

validity of the results may also be impacted by the possibility of skewed responses from participants based on individual priorities and judgments.

Murtazashvili & Piano (2019) stated that despite these drawbacks, the study offers insightful analyses of the development and contributions of the US shale gas industry, which may help in talking about how hydraulic fracturing might make the UK energy independent. Direct observation, unstructured interviews, and a case study methodology were used to gain a thorough grasp of the subject. The research's conclusions assimilate the body of literature, fill knowledge gaps, and lay the groundwork for more studies in this area.

This research report provides a complete explanation of the data gathering and analysis procedures used to examine hydraulic fracturing for the extraction of shale gas. Although the research has its limitations, the results shed light on the subject and add to the body of knowledge in this area. According to Archibald *et al.* (2019), the effects and prospects of hydraulic fracturing for reaching energy self-sufficiency can be better understood through additional research and studies with larger and more diversified samples, longitudinal data, and rigorous techniques.

CHAPTER VII: SUMMARY, IMPLICATIONS, AND RECOMMENDATIONS

7.1 Summary

This paper explores the effects of hydraulic fracturing, or fracking, on the environment and the generation of energy. By injecting water, sand, and chemicals into shale rock formations under high pressure, fracking is performed which is a technique for removing oil and gas. Fracking has increased oil and gas production and decreased energy costs, but it also poses environmental risks like contamination of the soil and water and seismic vibrations.

The application is a cutting-edge technology like other renewable energy sources such as wind and solar power in order to attain energy independence and reduce reliance on fossil fuels. Building the raw material supply chain and making these energy sources a broadly available public good need a considerable investment. In the quest for energy independence, the interaction between modern technologies and the environment is a critical issue. According to Ba Geri *et al.* (2019), fracking, also known as hydraulic fracturing, is one such technology that has gained popularity in recent years. It is used to extract oil and gas from shale rock formations. As per the view of Rubin *et al.* (2019), hydraulic fracturing has enhanced energy security, cut energy costs, and increased oil and gas output, it also has serious environmental risks that must be carefully evaluated.

To create micro-fractures in the rock and release trapped gas and oil, hydraulic fracturing entails pumping a high-pressure mix of water, sand, and additives into the rock. Rubin *et al.* (2019) stated that in nations like the United States, this method has significantly increased domestic energy production while reducing reliance on foreign energy sources, which has reduced energy prices and improved energy security. Compared to coal, the increased use of natural gas, which is frequently obtained through hydraulic

fracturing, has reduced carbon emissions, which has improved air quality and may help to mitigate the short-term effects of climate change.Gearhart *et al.* (2019) argued that energy independence is a potential advantage of hydraulic fracturing. Countries can improve their energy security and become less sensitive to variations in energy prices and availability by lowering their reliance on imported energy, which can have advantageous geopolitical and economic repercussions. Nations with large shale gas reserves, like the United Kingdom, view hydraulic fracturing to shift to energy production self-sufficiency and lessen their reliance on imported energy supplies.

7.2 Implications

Despite those benefits, hydraulic fracturing has serious environmental hazards that must be taken into consideration. Lack of openness on the makeup of the fracturing fluid, which is injected into the rock formation during the hydraulic fracturing procedure, is one of the key issues. Concerns have been expressed concerning possible groundwater and surface water contamination as well as the release of methane, a powerful greenhouse gas, during the extraction process.Gearhart *et al.* (2019) further stated that hydraulic fracturing uses a significant amount of water, which can put a burden on nearby water sources, especially in arid regions, and cause water contamination through effluent discharge.

As per the view of O'Connor & Fredericks (2018), the hydraulic fracturing business needs to be subject to more openness and regulation to reduce these environmental dangers. Rubin *et al.* (2019) expressed that in addition to requiring disclosure of the composition and concentration of fracturing fluid to healthcare experts and regulatory bodies, this also entails monitoring and managing wastewater disposal and water consumption practices. The negative effects of hydraulic fracturing on the environment and public health can be reduced with the right regulations and controls.

To address the environmental issues related to hydraulic fracturing, it is also crucial for the industry, environmentalists, and other stakeholders to work effectively together. This entails actively including environmental organizations in hydraulic fracturing-related decision-making processes and taking their input into account when formulating rules and policies. Working jointly, energy production and environmental protection can be balanced. According to O'Connor & Fredericks (2018), hydraulic fracturing's negative environmental effects can be reduced by implementing best practices and technologies. Zanocco *et al.* (2018) said utilising cutting-edge drilling methods like horizontal drilling can lessen the surface impact of drilling operations and minimize disruption to ecosystems and wildlife habitats. Hydraulic fracturing-related greenhouse gas emissions can be reduced by taking steps to capture and minimize methane emissions during drilling and extraction. Water resources in the area can be less stressed and water bodies can be kept clean with the proper treatment and disposal of wastewater, which includes recycling and water treatment.

The effects of hydraulic fracturing on social issues and health should be considered in addition to the environmental dangers. According to studies, drilling operations may hurt nearby populations' quality of life by contaminating the air, and water, and increasing noise and light pollution. According to Badri *et al.* (2018), to safeguard the health and safety of workers and neighboring populations, appropriate health and safety measures should be put in place, including air quality monitoring, worker protection training, and the creation of buffer zones between drilling sites and residential areas.

Sangaramoorthy (2019) explained that involving the public and the community in decision-making on hydraulic fracturing is also essential. Participating in the planning, development, and monitoring of hydraulic fracturing activities can help all parties involved—local communities, indigenous peoples, and other stakeholders—address their

concerns, make sure their rights are upheld, and advance sustainable and responsible development. To inform the public on the advantages and dangers of hydraulic fracturing and to encourage an open and transparent debate among all stakeholders, appropriate communication and education programs should be undertaken. Griffiths (2019) said that efforts should be made in research and development to enhance hydraulic fracturing's environmental performance. This includes funding technological advancements for improved water resource management and monitoring, creating alternate fracturing fluids with lesser environmental concerns, and improving methane collection and emission reduction methods. The development of more sustainable practices can be aided by ongoing research, which can assist identify and solve any environmental and health issues related to hydraulic fracturing.

Shale gas has important geopolitical ramifications. The US experience demonstrates how shale gas may change the balance of power in the world by lowering dependency on foreign oil and changing ties with major energy producers like OPEC in order to achieve energy independence. Similar advantages might be experienced by the UK if shale gas extraction continues, as it might lessen reliance on imported gas from politically unstable areas and improve national security. The size of the world's energy demand and the volatility of energy prices, however, may restrict the UK's influence on the closely interconnected global energy market (Atherton et al., 2023). Furthermore, as international energy policies increasingly favor sustainable and low-carbon solutions, the worldwide transition towards renewable energy sources may eventually lessen the strategic significance of shale gas. Even if shale gas presents a route to increased energy security and independence, the UK's strategic choices must take into account both the geopolitical landscape of today and the direction that sustainability is taking in the future. Although the

overall trend towards renewable energy may limit shale gas's long-term potential, it might be used as a temporary energy source.

7.3 Recommendations for Future Research

1.To conceptualize factors that may contribute towards achieving self-sufficiency in the energy production of a particular country to meet its energy demand. To enlist the importance about its economy, the researcher explored the cases of the USA and then that of the UK and discussed the merits and demerits of the process. The context of energy-dependent nations on surplus energy producers is a reality and any alternate means of energy is going to reduce the pressure and dependency on oil-producing countries.

2. The new technologies like hydraulic fracturing interact with energy production and consumption, Hydraulic fracturing helps reduce the burden on other fossil fuels and thus helps nations to become self-sufficient in their energy consumption and production.

3. The global environmental impact of hydraulic fracturing, particularly in the United States, where there has been a massive energy boom primarily due to the use of hydraulic fracturing. The global impact has been both positive and negative, while an increase in production has helped the economy to boom, bringing in more cash flow it also had a negative environmental impact causing severe pollution and some dreaded diseases in the vicinity. Scientists need to work on mitigating these negative impacts and make this process work for all.

4. The countries should increase their investment in hydraulic fracturing in the future, despite its current negative environmental impacts. The researcher concluded that despite negative environmental impact countries must replicate the model of the US and delve more into producing energy by adopting this method. Once used effectively it can

help in conserving other fossil fuels and make countries less dependent on oil-producing countries.

5. Other countries such as the United Kingdom replicate the 'shale gas boom' experienced by the United States and learn from its example. The researcher through the help of data analysis explained that countries like the UK, who may have had a setback in the past can still benefit from such a process like that of the US and give a boost to its economy in the future.

7.3.1 Policy recommendations

- Business-Level: To minimize their impact on the environment, companies should follow industry-leading best practices, like using greener fracking fluids, reducing methane emissions through better well integrity, and utilizing cutting-edge water recycling technologies. It is advisable to promote adherence to global environmental standards, such as ISO 14001 (Nega et al., 2024). Companies should actively involve themselves in the community by arranging frequent public gatherings, disclosing details about their operations, and being open and honest about the outcomes of environmental monitoring and incident reports. Establishing community liaison offices can aid in resolving issues and fostering confidence. Businesses should set aside funds for R&D to increase the effectiveness and security of shale gas extraction. Prioritizing innovations like improved methane collection devices and waterless fracking is a good idea. Technological advances can be accelerated by partnerships with research institutions and universities. Create comprehensive CSR initiatives that assist neighborhood communities, such as funding for infrastructure, healthcare, and education. The social license to operate can be strengthened by revenue-sharing

programs that provide a percentage of profits to community development initiatives.

- National Government: Create and implement strict rules that cover land use, health and safety, and environmental protection in relation to shale gas extraction. Mandatory environmental impact assessments (EIAs) and routine audits to guarantee compliance should be part of this framework. Provide grants, subsidies, and tax breaks to businesses that meet or beyond safety and environmental regulations. Impose fines for breaking the law in order to discourage bad behavior and promote following the rules. To inform the public about the possible advantages and disadvantages of shale gas extraction, launch nationwide public awareness campaigns (Li, 2023). These advertisements ought to focus on presenting fair and impartial information that takes into account both environmental and economic factors. Finance the construction of energy distribution networks and other infrastructure, such as transportation networks, that bolsters the shale gas sector. Make ensuring that investments in infrastructure are sustainable and do not negatively impact local communities disproportionately.

- Local Government: Give local governments the capacity to control and keep an eye on shale gas operations that fall under their purview. Create local regulatory organizations to monitor adherence to federal laws and handle particular regional issues. Require community consultation when shale gas project permits are being obtained. Local governments ought to set up forums where locals may express their worries and offer suggestions for planned developments. Create regulations that guarantee local communities receive a percentage of the money extracted from shale gas (Musoma et al., 2023). Money can be allocated to public service

enhancement, environmental restoration, and neighborhood development initiatives.

- International-Level: Work together to create worldwide environmental standards for shale gas extraction with agencies like the United Nations and the Worldwide Energy Agency (IEA). Methane emissions, chemical disclosure, and water management are a few of the topics that these regulations ought to include. Provide global forums for the exchange of best practices and information about shale gas extraction. Developed nations, such as the United States, possess the ability to provide knowledge and insights to nascent producers on shale gas production (Marcel et al., 2023). Promote international research partnerships to tackle shared issues in the exploitation of shale gas. Collaborative research projects may concentrate on environmental monitoring, health effect evaluations, and technology advancements. Offer financial aid, capacity-building help, and technical support to developing nations investigating shale gas prospects. With this assistance, these nations can develop their resources responsibly and stay clear of the social and environmental traps that have been seen elsewhere. Strive to include shale gas into more comprehensive international frameworks for climate policy. As a possible transitional fuel, shale gas can assist in lowering greenhouse gas emissions and dependence on coal. But in order to achieve long-term sustainability and satisfy global climate targets, its function needs to be made very clear.

7.4 Conclusion

In conclusion, hydraulic fracturing could help increase economic growth, reduce energy costs, and promote energy self-sufficiency. It does, however, also provide important environmental dangers that require careful consideration. To lessen the environmental risks connected to hydraulic fracturing, transparency, cooperation, and appropriate practises are

crucial. According to Aczel & Makuch (2018), to guarantee that hydraulic fracturing activities are carried out safely and responsibly, strong rules, appropriate monitoring, and enforcement measures should be in place. Sustainable energy production can also be attained by investments in renewable energy sources and research and development projects to enhance hydraulic fracturing's environmental performance. Finally, it is critical to promote a balanced strategy that takes into account the economic, social, and environmental components of hydraulic fracturing. According to Reed *et al.* (2018), these include public engagement, community involvement, and stakeholder participation. Hydraulic fracturing can be a component of a comprehensive and sustainable energy plan that encourages energy self-sufficiency while safeguarding the environment and the general population by carefully controlling the risks and benefits. Encouraging decision-makers at all levels to implement these policy proposals will contribute to the responsible and sustainable production of shale gas. International collaboration is necessary to create global standards and encourage knowledge exchange. National and local governments must create and enforce comprehensive rules. Businesses must implement best practices and communicate openly with the public. These measures, which tackle the economic, environmental, and social aspects of shale gas extraction, can contribute to the UK's and other nations' energy self-sufficiency while reducing risks and building public confidence.

The thorough examination and disclosure of the fracturing chemicals employed in hydraulic fracturing constitute this dissertation's most important contribution to the literature and practice. At the moment, a great deal of information is unknown about the particular chemicals used in the process and how they might affect the environment and public health. This study will make it possible for future research to more precisely evaluate the dangers and impacts of hydraulic fracturing by fully disclosing these substances. Establishing efficient regulations, enhancing safety procedures, and building public

confidence in the sector all depend on this openness. This dissertation is significant from a commercial and professional standpoint since it tackles a vital topic that may have an impact on the industry's sustainability and public image of hydraulic fracturing. Concerns about the environment and public health frequently result in intense scrutiny and criticism for businesses that use hydraulic fracturing. Through advancing our knowledge of the chemicals used and their possible effects, this research can help businesses reduce risks, boost regulatory compliance, and improve operational procedures. Additionally, it can help the industry's long-term survival and social license to operate by contributing to the development of safer and more sustainable hydraulic fracturing procedures.

This dissertation is vital for the scientific community since it closes a large information gap about hydraulic fracturing. Researchers' capacity to carry out exhaustive and precise risk assessments is hampered by the current lack of comprehensive information on the chemicals employed in the process. This research will enable more thorough scientific investigations on the effects of these chemicals on the environment and human health by offering a comprehensive inventory of these substances. In the end, this will strengthen our understanding of the intricate relationships that exist between natural systems and hydraulic fracturing operations, which will help us develop more sensible and successful environmental management plans and policy. In conclusion, the full disclosure of fracturing chemicals will be the subject of this dissertation, which will greatly enhance the scientific and practical domains by improving transparency, guiding better practices, and assisting in the development of more thorough and precise risk assessments.

APPENDIX A

SURVEY COVER LETTER

Dear Sir/Madam,

I am a research student and I would like your opinion on the matter of extraction of shale gas using the hydraulic fracturing North-West England. I am writing this to you because I want your opinion through the survey that is based on the questionnare that I will be sending you. I would like to request all of you to answer the questions to the best of your understanding.

There have been studies conducted on this topic, however, there is no such study like this where your responses could help in resolving the issue as well as finding new methods for the extraction of shale gas. It has been found through the research that environmental issues that are caused by hydraulic fracturing can be overcome with the help of experiments. This research could help in finding such factors that can make it more smooth.

I humbly request all of you to complete the questionnare, the personal data that I will gather will be kept confidential, however I will be using the data that is required for my research.

Thanks for co-operation in advance

Yours sincerely

Student Name:

APPENDIX B

INFORMED CONSENT

The present research is not completely able to provide an essential advantage for me and my participation is voluntary. There are many steps that have been accepted to reduce the risk factors in addition to this present research. Furthermore, there are many insurance arrangements that have emerged about public liability. I have obtained the ability to ask for a copy concerning the major findings and statements of the entire research. I have protected all my subjective information with the application of security measurements and confidentiality. There are many risk factors such as inconvenience, distress, or liability as an effect in addition to my involvement in this research project. The consent for effective engagement in this research needs the essential process of informed consent. Furthermore, this procedure typically involves exchanging the statement and proceeding with communication that happens between the researcher and the subject of the potential research. The procedure of consent for this research normally starts with the proper presentation that determines the major activity.

Furthermore, I approve to of the recording of audio-visual in any aspect or all the activities of the research (if relevant). The broadcasting of major outcomes from this research is the purpose that my self-identity will not be disclosed.

Name:

Signature:

Date:

APPENDIX C

INTERVIEW GUIDE

Focus Area	Questions
Types of pollution caused by it. Long-term Impacts of it on the ecology.	What are the negative impacts of hydraulic fracturing technology on the environment?
Horizontal Drilling Hydraulic Fracturing Other ideas	What strategies are you using to extract a high quantity of shale gas?
Focused on energy production and consumption. Ways through which nation fulfills it energy requirements	What is the true meaning of being energy self-sufficient for a nation?
Location Population Who to sell When to sell	What competitive strategies to increase profit margins and achieve high efficiencies?
Hydraulic Fracturing	Feedback and recommendations to improve this technology?

Table 1

Interview Guide

Source 2 Self Made

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