University of Tehran

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U.S. National Security and Energy self-Sufficiency: the Case of Shale Gas and Tight Oil

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A thesis submitted to the Graduate Studies Office

In partial fulfillment of the requirements for the degree of Master in

North American Studies

February 2015

Dedicated to

The Martyrs of the Islamic Iran

With

Special Thanks to Dr. Hosseini, the Honorable Professor

Abstract

Since 2005, energy outlook has changed in the United States due to development of shale resources and hydraulic fracturing. This development has led to increase of oil and gas production to the extent that some U.S. officials expect the United States to be a net energy exporter soon. However environmentalists emphasize the disadvantages of hydraulic fracturing which pose risks for the environment and human health. This thesis is an attempt to investigate U.S. potential of being energy self-sufficient by means of shale resources. The thesis supposes that while shale oil and gas development and hydraulic fracturing can reduce U.S. imports nonetheless it is unlikely that U.S. shale can bring energy self-sufficiency by itself in a long term due to environmental and economic barriers and structural impediments. The research has been conducted based on a qualitative analysis of available documents by both opponents and proponents of shale development. The main concepts of the thesis have been outlined in three chapters: First, unconventional resources, hydraulic fracturing, and environmental impacts; second, trend of energy production and consumption in the United States; third, consequences of "shale statecraft" on U.S. national security.

Key Words: shale gas, tight oil, hydraulic fracturing, energy self-sufficiency, shale statecraft

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Chapter One: Introduction

Statement of Purpose

For the most part in Twenty First Century energy is going to be a critical factor in the economy of most societies. Accordingly energy security appears to be the main concern of policy-makers in the pursuit of their national interests. On the one side there is a perception of energy scarcity or theory of peak oil that implies the era of abundant cheap oil is over, and on the other side there is an increasing demand for energy; these two issues have spurred policy-makers and commercial actors to seek for other sources of energy in order to ensure the stable flow of energy. Among different sources of energy unconventional resources have come into focus. Unconventional resources are those hydrocarbons that are not easily accessible in comparison with conventional resources.

Geologists have always known that a huge amount of oil and gas is trapped among impermeable sediments, but for many years a method to exploit such resources had not been developed. Later, some companies started to make hard endeavor in order to improve a technology so that they can provide access to unconventional hydrocarbons. The endeavors led to development of a technology called hydraulic fracturing and horizontal drilling.

Hydrocarbon resources are classified into conventional and unconventional types because there are disparate formations and processes to capture them. In conventional resources, oil and natural gas are formed in permeable rocks underground that naturally flow through the rocks and are easily accessible. However unconventional resources are located in impermeable or low permeable rocks that cannot be easily pumped to the surface, but rather they require an advanced technology to be extracted. In short, the difference between conventional and unconventional resources mostly pertains to the methods and technologies of extraction, while the formation is basically similar. Unconventional resources are consisted of different types such as sandstone, siltstone, shale, and carbonate. Among them shale formations have achieved prominence due to the abundant available resources and the advanced technology that make commercial production of these resources more possible.

Ever since the U.S. moved toward industrialization energy security or energy independence has become a longstanding concern of U.S. policy-makers because it has been considered an effective component of a strong national security. Meanwhile instability in oil producing countries and the subsequent disruption to the oil market as the result of the instability has convinced U.S. decision-makers to pay more attention to the discovery of new sources of energy and the possibility of being energy independent. For example, on January 31, 2006, President George W. Bush in the State of the Union Address declared that America is going to remove its addiction to oil by moving toward the alternative sources of energy:

> America is addicted to oil, which is often imported from unstable parts of the world. The best way to break this addiction is through technology. Since 2001, we have spent nearly $10 billion to develop cleaner, cheaper and more reliable alternative energy sources. And we are on the threshold of incredible advances.

Afterwards on January 24, 2012, President Obama in the State of the Union Address enunciated: “We have a supply of natural gas that can last America nearly 100 years, and my administration will take every possible action to safely develop this energy.”

Shale resource has enhanced the prospect of energy independence insofar as it has been called “shale renaissance”, “shale revolution”, “game changer”, “energy boom”, or “a new outlook for a hundred years of natural gas”. The National Intelligence Council in *Global Trends 2030* has anticipated that shale resources would pave the way for U.S. energy exports: “By the 2020, the US could emerge as a major energy exporter.” (p. 35)

Moreover the Energy Information Administration in *Annual Energy Outlook 2013* has estimated: “With relatively low natural gas prices in the AEO2013 Reference case, the

United States becomes a net exporter of natural gas in 2020." (p. 79) Likewise this issue has been acknowledged in *Annual Energy Outlook 2014*: "The growth in production meets increasing demand and exports (liquefied natural gas [LNG] and pipeline exports), while also making up for a drop in natural gas imports. The United States becomes a net exporter of natural gas before 2020." (p. 107)

Quadrennial Defense Review 2014 released by the Department of Defense has also counted shale resources among U.S. elements of power that would turn America into a net energy exporter of oil and gas, the report has explained: "Shale gas discoveries and new technologies allowing access to hydrocarbon deposits appear likely to enable the United States to be a net energy exporter in the coming decades. Overall, future prospects for the U.S. economy are strong."(p. 9)

Jan H. Kalicki and David L. Goldwyn in *Energy and Security: Strategies for a World in Transition* have called to attention the importance of U.S. energy security and possibility of being energy independent. The authors have noted: "The United States has also become a net exporter of petroleum products and, if policy permits, may become a net exporter of natural gas and a limited exporter of crude oil." (2013, p. 3)

Put aside the bright energy outlook that has been improved by some agencies, numerous books and articles have been written about shale potential for mass production. Writers of these books and articles have called into question the opportunities of shale resources and have emphasized the impediments. They argue that financial affairs, environmental consequences and public health would influence the outspread of hydraulic fracturing. Opponents and proponents have opened lengthy debates about prohibition or promotion of this technology. Fracking proponents assert that shale resources coupled with hydraulic fracturing will bring energy self-sufficiency for the United States. Fracking opponents take the opposite

position and believe that it is an unrealistic expectation to be self-sufficient in energy just by means of shale resources.

In addition to technical and environmental obstacles that exist in the way of shale development, there are also political and economic uncertainties over the accessibility of cheap oil (conventional oil). These uncertainties have called into question whether shale resources would pave the way for a cost-effective production and bring energy self-sufficiency to the United States or it would be a temporary upsurge in production that remains as a powerful tool of foreign policy at the hands of U.S. policy-makers.

Research Questions

The major question this research aims to investigate is:

I. Would shale resources bring energy self-sufficiency to the United States?

The minor questions are:

I. Would "shale statecraft" strengthen U.S. energy security in the long-term?

II. What would be the geopolitical consequences of "shale statecraft" on U.S. national security?

Hypothesis

According to the open-sources and available data at the present time, it is unlikely that shale resource by itself can bring energy self-sufficiency to the United States in the long-term. This is because of the environmental and economic barriers such as water consumption and contamination, air pollution, or a rapid downtrend of production which needs high expenditure in order to offset the rate of production.

Methodology

This study is conducted based on a qualitative research and analysis of some texts and documents that bring into focus a textual description of an event or phenomenon and create narrative. According to Vanderstoep and Johnston (2009), a qualitative research is a descriptive and interpretive research that aims to describe, but not to predict. The authors explain that "the goal is to understand, in depth, the viewpoint of a research participant." (p. 167) In a qualitative research a researcher does not intend to generalize the finding of a research and applying it to a large population, but rather he or she uses an inductive approach to present the research findings. It needs to be noted that an inductive approach is "a process of reasoning that follows a reverse path — observation precedes theory, hypothesis, and interpretation. Qualitative researchers let the data "speak" to them and try to avoid going into a study with a preconceived idea of what they will find" (Vanderstoep & Johnston, 2009, p. 168). In other words in an inductive analysis a researcher does not start the study with a theory that aims to prove or disprove it (Woods, 2006, p. 4).

Moreover a qualitative researcher aims to conduct the findings based on typology or contrast, but not based on common features. Paul Have describes:

> The crucial feature of qualitative research, then, is to 'work up' one's research materials, to search for hidden meanings, non-obvious features, multiple interpretations, implied connotations, unheard voices….qualitative research offers complex descriptions and tries to explicate webs of meaning. (2004, pp. 4-5)

The procedures that a qualitative researcher follows are included: framing a research question, identifying theoretical framework coupled with dependent and independent variables, developing hypothesis, collecting and analyzing data (Vanderstoep & Johnston, 2009, p. 182). A qualitative research makes use of varied and extensive methods of data collection such as observations, interviews or analysis of texts and documents (Vanderstoep & Johnston, 2009, p. 169).

This study uses document analysis as a method of data collection which is called "document-based research". These documents are comprised of primary and secondary sources. Primary sources are consisted of reports, speeches, hearing session, documentary, or scholars' presentation in conferences. Secondary sources are consisted of books, articles, and websites.

Limitation of Study

The first limitation is unavailability of reliable data. At present, hydraulic fracturing is experiencing changing and ongoing improvements to the point that it seems unlikely to foresee the precise impact of this technology on the environment, or it is improbable to estimate the magnitude of shale resources or volume of production. Meanwhile there is no national shale policy or united regulatory system to be studied, for example, there are moratoriums on hydraulic fracturing in some states and commercial incentives to promote it in other states. The point is that due to the all factors it is unlikely to discuss precisely the U.S. capacity for self-sufficiency in energy, or address properly the issue of shale impact on U.S. national security.

Instability in international relations and interdependence feature of the energy market impose another limitation to findings of the research. In general there are many technological, political and economic uncertainties that change shale outlook to an unreliable and changeable issue; consequently this matter makes findings of the thesis more tentative.

Theoretical Framework

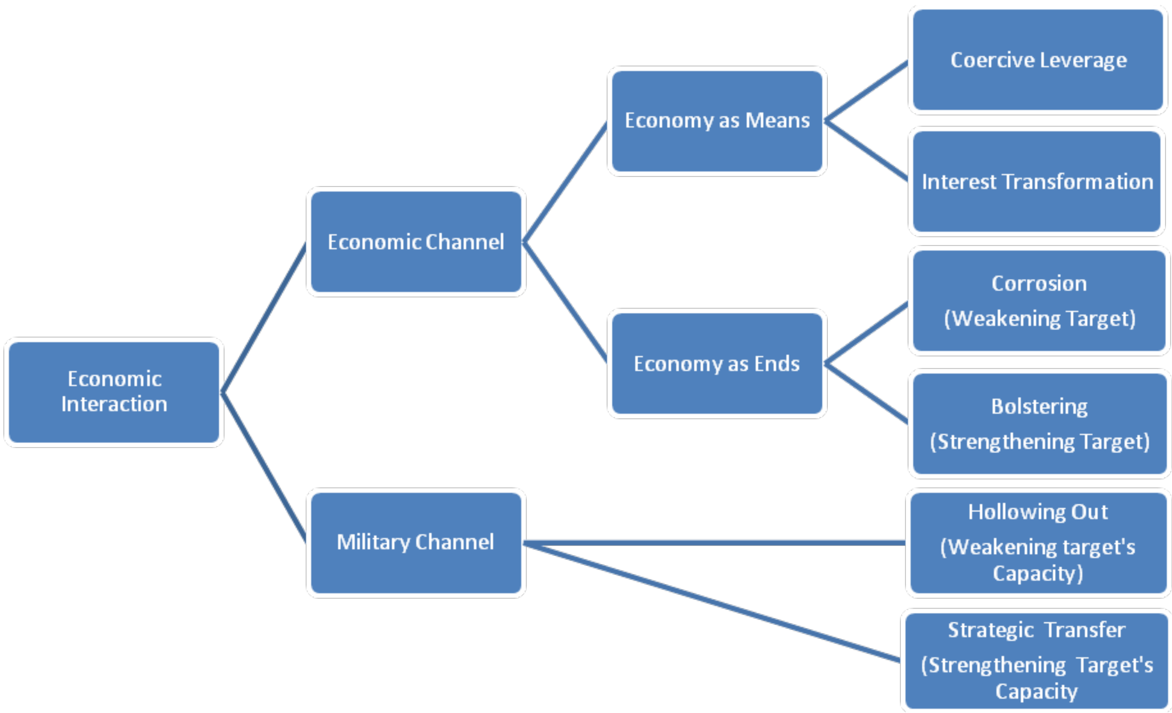
William Norris explains the concept of economic statecraft and the consequences it has on security. In a typology he shows how states use economic interaction to influence national security and under which condition economic statecraft would be successful. He illustrates the relationship between economy and security, in other words between commercial actors and a government. Norris explains how states use economy to achieve strategic objectives. He (2010) notes:

> When states seeks to encourage or discourage commercial actors to behave in ways that will generate the types of economic patterns that result in security externalities, states are engaging in what is known as *economic statecraft*. Economic statecraft is an important tool that states can use to pursue their strategic objectives. (p. 48)

William Norris states: "The concept of externalities captures the notion that a given transaction may also produce effects that are not fully internalized among the parties that are directly conducting the transaction." Security externalities mean "those security effects that are not fully internalized among the parties directly conducting any given economic interaction."(2010, p. 48) He defines economic statecraft as "the state manipulation of economic interaction to capitalize on or to reduce the associated security externalities." Then he describes "when states seek to manage security externalities they are engaging in what is known as economic statecraft." (2010, p. 19) Norris argues that economic statecraft "has its roots in the concept of security externalities. These externalities are the security consequences that result from the commercial activity of firms or other entities that conduct international economic transactions." (2010, p. 305)

In other words economic statecraft is a state's attempt to encourage commercial actors to behave in a manner that results in security externalities, and security externalities are the result of measures by commercial actors who seek more profits (Norris, 2010, p. 20).

Figure1: Security Effects Stemming from Economic Interaction: A Typology of Security Externalities



Source: Economic Statecraft with Chinese Characteristics: The Use of Commercial Actors in China's Grand Strategy, by William J. Norris, 2010

In this typology, there is an economic interaction that is divided into two categories: military channel and economic channel, together both channels make six types of security externalities.

First, the military channel includes two security externalities: one is *Hollowing Out*, which means weakens military capabilities of a target state. Weakening military capability occurs when economic interaction threatens the viability of those industries and sectors that are directly related to the military power and subsequently affects defense power of a target state. Another one is *Strategic Transfer*, which means enhances military capability. This security externality by means of strategic goods, resources, knowledge or technology, enhances military power of a target state. Norris sets out: “In the cases of *Strategic Transfer* and *Hollowing Out*, the economic interaction directly contributes or detracts from military capabilities. For the four other types of security externalities, firm’s activities affect the economy which, in turn, carries consequences on security.” (Norris, 2010, p. 51)

Second, the economic channel is divided into two categories of economy as an ends with two subdivisions of *Corrosion* and *Bolstering*; and economy as a means with two subdivisions of *Coercive Leverage* and *Interest Transformation*. “*Corrosion* is the security externality resulting from a weakened domestic economy”, in the case of *Corrosion*, economic interaction undermines the health of the economy of a target state “as a result, the target is less able to defend itself and its strategic interests.” (Norris, 2010, p. 52) Conversely, *Bolstering* is the result of a strong domestic economy, in which economic interaction creates improvement in the economy of a target state. Norris remarks: “Historically, states that consciously chose to pursue such strategies generally used economic interaction to strengthen and support allies.” (Norris, 2010, p. 54) The last security externalities are *Coercive Leverage* that is the result of economic dependence; sanction, embargo, and freezing bank accounts are examples of *Coercive leverage*. On the subject of *Interest Transformation* Norris (2010) notes:

> Whereas *Coercive Leverage* is employed to enforce State A’s *compliance* with State B’s interests, *Interest Transformation* actually seeks to *alter* States A’s goals and objectives to bring them into closer alignment with State B’s interests. The objective of *Interest Transformation* is not only to force State A to behave in a manner that is conducive to State B’s interests, but rather to redefine States A’s interests, goals and objectives in such a way that States A then actually wants the same thing as State B. (p. 56)

As it is noticed these are six security externalities resulting from economic interaction. Norris continues to explain that “economic statecraft occurs when states deliberately seek to manipulate economic interaction in order to generate the types of security externalities categorized above.”(2010, pp. 47-58) He says in order to have an effective economic statecraft the state requires spurring and controlling commercial actors so that they can produce a security externality that is compatible with strategic interests of the state, indeed “state control of commercial actors is crucial for economic statecraft to occur”. William Norris defines commercial actors as “those entities that actually carry out international economic transactions (e.g. buying and selling commodities, making investments, selling products, building factories, purchasing assets, employing workers, etc.)”(2010, p. 65)

Following the concept of security externalities, Norris takes into account five factors that determine the magnitude of a state ability to control commercial actors: First, there should be an agreement and harmony between a government and commercial actors. Second, there should not be inordinate number of commercial agents in the market. Third, there should be unity and oneness in a government; it means a disunited government can hardly control actors. Fourth, there should be a direct relationship between a government and commercial actors to have an effective control. Fifth, there should be resource commensurability between a government and commercial actors; it means if an actor accesses more resources than a government, it would be more difficult for the government to control the actor (Norris, 2010, p. 59).

The effectiveness of economic statecraft pertains not only to a government’s ability to control commercial actors, but also to other factors that are required to be observed by the government. These factors can be listed as: First, commensurability between the ends and the means; second, the extent of state economic interaction, for example, a country whose trade represents 80% of its GDP, would be at risk of disruptions of that trade in comparison with a country for whom trade has minimum influence in its economy. Third, the ability of a government to manage its economic interaction; fourth, the elasticity of demand for energy, it means if a country is dependent on light and sweet crude oil for meeting energy demand and there is no proper substitute for this commodity, then the demand will not be elastic. In this case, use of economic statecraft against this country would be more effective and successful. Norris explains: “Elasticity will be used to refer to how badly something is needed and how easily this need can be met by some substitute.” (Norris, 2010, pp. 65-7)

Today energy is considered not only a driving factor behind the industry but a strategic commodity that policy-makers use it to pursue their political and economic objectives. In fact, energy has transformed from an industrial commodity to a strategic commodity that influences both economy and politics of states. Klaus Guimarães Dalgaard says: “having access to energy supplies is crucial for the survival of a state both in security and in economic terms….” This implies that energy has the same meaning and role as the economy thus in this context it is plausible to interchange energy statecraft, or more specifically shale statecraft, with economic statecraft. In short economic statecraft is a general term which comprises a more specific term called energy statecraft.

Carlos Pascual, the former U.S. Ambassador to Mexico and Ukraine said: “Energy, politics and power have been clearly intertwined as a force in international security”, he remarked: “Energy as an instrument of foreign policy is a more specific form of economic statecraft, for energy resources are economic resources, after all. As such, they have essentially similar conceptual characteristics.”(as cited in Dalgaard, 2012, p. 59) According to him energy resources are strategic commodities that are vital to all industrial countries.

This research seeks to investigate U.S. shale potential of energy self-sufficiency in a long-term and its effects on U.S. national security. For this purpose the research implies theory of economic statecraft, hereafter is called “shale statecraft”. Through document analysis it examines the actual capacity of the United States for being energy self-sufficient, then based on theory of “shale statecraft” it reviews how the United States would interact with its allies and adversaries by use of this opportunity.

Literature Review

The current literature on U.S. shale indicates that there is no consensus on energy perspective. Opponents call into question an unorganized regulatory system, the negative and uncertain effects of shale gas and tight oil on the economy, or on the environment and public health. Proponents take into consideration the effect of shale resource on energy self-sufficiency that results in boosting of the economy, and making of a more powerful national security. They pay more attention to the increase of shale production, to the effects it has on economic growth, and more important to the effect it has on the U.S. role in global leadership and energy market. Literature review of this study consists of two parts: The first part deals with the main question of the thesis, it reviews works on the availability of shale resources, the process of hydraulic fracturing, the environmental consequences, and the cost-effective production of shale gas and tight oil in the United States. The second part reviews books, reports, documents, or speeches by official or independent agencies in order to present the concept of energy security and indicate the consequences it has on U.S. national security.

Literature Review on Shale Resources and Hydraulic Fracturing

Literature on shale advantages and disadvantages has been presented both by opponents and proponents. Opponents pay attention to the environmental impact or high expenditures; and proponents pay attention to the economic advantages.

Hydraulic fracturing What Everyone Needs to Know (2013) which has been written by Alex Prud'homme is a well-written book that is available for those who are not experts on energy issues, but are interested to have knowledge on shale resources and fracking technology. The author has structured the book in three main parts: part I presents a comprehensive introduction on fossil fuels including conventional and unconventional types, shale geology, hydraulic fracturing, and engineering operations. Part II which is the main part of the book presents arguments about the advantages and disadvantages of fracking. Part III provides a perspective on fracking which will happen in the future. The book discusses how, why and where hydraulic fracturing was developed, it impartially argues that opponents stand against fracking because it causes pollution, earthquakes, and health problem. Then it argues proponents stand behind fracking because it creates more jobs and revenues, low energy prices, reduction in greenhouse gases emission, and more important it can bring energy independence.

Prud'homme explains that how hydraulic fracturing creates many jobs, how it affects price of energy, and how it impacts the industry or transportation system and the global market. Due to the uncertainties of the global energy market or international circumstances, and ongoing technological advances the author does not take position if this technology is safe or unsafe. However some critical concerns exist regarding the environment and global warming. Prud'homme in one section of the book "what questions about hydraulic fracturing need to be asked and answered" raises such concerns and provides comprehensive answers from the aspects of politics, law, the environment and economy.

Drill, Baby, Drill Can Unconventional Fuels Usher in a New Era of Energy Abundance? (2013), which has been written by David J. Hughes, calls into question energy independence rhetoric and tries to lay out real energy circumstance in the United States and the world. The author argues that the energy consumption has grown more rapidly than the population in the United States and the world, for example U.S. energy consumption was 4.2 times more than the world average per capita in 2011.

The book has three main parts; the first part provides information on energy production and consumption (mostly oil and natural gas), it also offers a projection for future trends of production and consumption. In addition, this part presents a comprehensive introduction to the concept of conventional and unconventional reserves and supplies. At the end of the part, the author concludes that hydrocarbon resources are plentiful, but the costly energy which is required to be invested in order to extract hydrocarbon resources is equal or more than the output energy, in this case such resources seem more expensive and inaccessible.

The second part of the book introduces unconventional resources and their potentials to meet energy demand. It states that there are 30 shale gas plays. The author explains that three main plays account for 66% of the total production and gives an in-depth analysis of the production rate. He discusses that these plays are experiencing decline in production and need intensive drilling to preserve the current rate of production. On the subject of tight oil Hughes says there are 21 tight oil plays but the most rate of production is pertinent to two major plays which are accounting for 81% of the total production. He argues that intensive drilling may not be feasible because it increases the cost of production, likewise it provokes environmental and health concerns.

In the last part, the author refuses the issue that tight oil and shale gas would guarantee the endless and stable flow of energy. He explains that shale resources require high expenditures to offset the decline rate of production and this issue would influence the effective economic growth. He claims that instead of depending solely on shale resources the first step to manage energy scarcity would be conservation and efficiency. A brief viewpoint of the author on unconventional resources could be summarized in this sentence: "We have legions of scientists telling U.S. that continuing to rely on fossil fuels is suicidal for the climate, and yet greater legions of stockbrokers, politicians, and corporate leaders continue to herald a new bonanza of fossil fuels, based on unconventional resources. This bonanza is projected by government officials to propel U.S. to a blissful future of a continuously growing economy with low unemployment."

David Hughes has written another book namely *Drilling Deeper: A Reality Check on U.S. Government Forecasts for a Lasting Tight Oil & Shale Gas Boom* in 2014 in which he points to the high decline of shale production in major U.S. shale plays. He underlies the intensive drilling and high expenditure which is required for a cost-effective production. He attempts to bring in to focus an unstable and uncertain outlook for shale development. Hughes emphasizes the overestimation for shale production by the U.S. Energy Information Administration.

The Frackers the Outrageous Inside Story of the New Billionaire Wildcatters has been written by Gregory Zuckerman in 2013 in which he advocates the opportunities by hydraulic fracturing. The author who is a Wall Street journalist strongly believes horizontal drilling and hydraulic fracturing provide a huge amount of energy from shale resources. He mainly puts emphasis on several points: the profit by tight oil and shale gas productions, the reduction in energy prices, a guarantee for U.S. energy security, and the soaring supplies of oil and gas. Zuckerman makes interview with major players and outlines the geopolitical influences of fracking from a financial perspective.

The book starts with George Mitchell's effort of inventing a method to extract gas deposits from shale resources. In spite of all barriers and high cost, he pursued this policy because at that time Mitchell Energy Company was facing a decline in oil production and profit. There was no national energy policy at that time; in fact the only inducement for George Mitchell (father of hydraulic fracturing) to promote this technology was revival of his company's shares and profit. The first chapter focuses on Mitchell family's biography, their business and the way they financed it, and how George Mitchell made his way to gas discovery and drilling. The next chapter describes the actions were taken by pioneers in developing fracking technology; how they succeeded and how they failed. The book points to the historical background of hydraulic fracking and horizontal drilling. The author mainly emphasizes a high profit which has been gained by energy companies who have promoted this technology.

Another book on the subject of shale outlook is *Snake Oil How Fracking's False Promise of Plenty Imperils our Future* written by Richard Heinberg in 2013. The author claims that shale prospect has been exaggerated and motivated mostly by interest groups; he believes that the public have the right to know about the real shale potential and impact on the environment and health. Heinberg classifies energy analysts into two groups: the first one is called Cornucopians who are a well funded team involve IEA (the International Energy Agency), EIA (the U.S. Energy Information Administration) and bankers who stand at the back of this industry. The second group are called Peakists involve some geologists and energy analysts who have little funding at their disposal.

Cornucopians believe there are abundant sources of energy in contrast to that of Peakists' idea who believe the era of cheap oil has come to an end. The author provides readers with more information which is hardly available to the public. Heinberg argues that "the book is a story about Wall Street investment bankers", which "drive independent oil and gas companies to produce uneconomic resources just so bankers can collect fee", he claims official agencies overestimate shale oil production. The estimations presented in this book differ from the statistical information submitted by official agencies such as EIA or IEA. This book has been written mainly based on data from the book *Drill, Baby, Drill* and it confirms the viewpoint of the author in that book, and this can be considered a weakness of the book.

The author says oil and gas companies are required to convince investors that "fracking is the Next Big Thing", the book emphasizes on three standpoints:

I. A short-term success of shale production which has been discussed by Hughes in *Drill, Baby, Drill*.

II. The high and hidden cost of fracking which is required to capture oil from shale resources.

III. The overestimated significance of shale oil and gas.

Heinberg attempts to convince readers and policy-makers that it is wrong to believe in the abundance of fossil fuels, and in his view hydraulic fracturing is a dangerous technology for both the environment and human health.

The author also points out that two groups affect energy policy: the first one are the environmentalists who emphasize on negative effects of greenhouse gases emission, and the second one are economists who underlie energy scarcity in coming decades. Heinberg motto is "it's time to learn how to live well with less", it means he believes in energy efficiency more than the availability of abundant energy. At the same time he believes in the idea of energy scarcity and peak oil that prompts states to decrease oil dependency. Based on the current technology and sources the longest life span of shale rocks that Heinberg anticipates would be 10 or fewer years. Like Hughes, he claims that intensive drilling makes this technology more expensive and uneconomic. Heinberg remarks that "the Unites States would not achieve oil independence, but it would make substantial progress in that direction."

Heinberg notes hydrocarbon reserves are plentiful but the decline of EROEI (energy return on energy investment) would be the main obstacle in the way of stable shale production. He apparently attempts to convince the reader that "we must reduce our dependency on fossil fuels as quickly as possible. It is the only realistic answer both to climate change and our economic vulnerability to declining fossil fuel resource quality and EROEI."

Literature Review on U.S. Energy and National Security

The second part of the research reviews writings on possibility of U.S. energy self-sufficiency and its relationship with national security. It examines the geopolitical application of "shale statecraft" to U.S. national security.

Global Trends 2030: Alternative Worlds, is a report prepared by the U.S. Intelligence Council. The report discusses demographic patterns, scarcity of energy, food and water, diffusion of power that will influence trajectory of international relations in the future. The report focuses on the increasing conflict, regional instability, and emergence of new economic and political power which will lead to a gap in the global leadership. On the subject of energy the report anticipates a rising in global production by 2035, which mainly would be the result of unconventional resources:

> Much of this increased production—and recent optimism—derives from unconventional oil and gas being developed in North America. The scale-up of two technologies, horizontal drilling and hydraulic fracturing… is driving this new energy boom. (p. 34)

The Intelligence Council has declared that U.S. energy independence is not an unrealistic expectation, but it is possible to occur by means of shale resources. These resources can meet the domestic demand for decades to come. *Global Trends 2030* anticipates: “The US would import less or no crude oil from its current suppliers—Canada, Mexico, Saudi Arabia, Latin America and West Africa, forcing them to find alternative markets”, instead the U.S. will be a major energy exporter by 2020. (p. 35)

The Energy Policy and Conservation Act of 1975: Are We Positioning America for Success in an Era of Energy Abundance? is the title of a hearing session on energy which was held on December 11, 2014 by House of Representatives subcommittee on Energy and Power. In the session representative Barton pointed out that *Energy Policy and Conservation Act of 1975* which imposed a ban on export of crude oil from the United States. At that time the ban made sense, said Barton, but today “the United States is the number one oil producer on a daily basis in the world.” He explained that U.S. consumption has decreased and production has increased so if U.S. oil producers are allowed to export the surplus, the United States will be able to create more jobs and put pressure on producing agencies and countries like OPEC and Russia to manage oil price. In the same fashion, Adam Sieminski, the administrator in U.S. Energy Information Administration pointing to the decline in liquid fuel consumption stating that: “The U.S. went from being the world’s largest net importer to becoming a big net exporter of petroleum products.” In general, representatives and experts called to attention the rise of oil production in the United States as the result of unconventional resources and attempted to convince the committee to lift the ban because this upsurge could provide more GDP, and more effective foreign policy. On the contrary some representatives pointed to the environmental consequences and lack of reliable, consistent and detailed information on U.S. oil which should be available for policy-makers in order to make wise decisions. “The U.S. has the opportunity and responsibility to be a global leader in the energy sector. A balanced energy policy informed by oil transparency must guide energy decision-making in ways that satisfy

U.S. consumers, strengthen the American economy, protect the climate, and enhance national and global security.” said Deborah Gordon who aimed to highlight the impact of shale production on U.S. foreign policy.

Chapter Two: Unconventional Resources, Hydraulic Fracturing, and the Environmental Impacts

This chapter is mainly conducted based on literature review and quotations that presents the arguments about the advantages and disadvantages of hydraulic fracturing. Though it is not a technical thesis, given the nature of the technical issue at hand it is needed to advance through it.

Shale discoveries started from 1821 when operators in Devonian shale play which was located in Fredonia, New York produced the first commercial gas. According to the England Department of Energy and Climate Change the next shale development took place in 1859 when a commercial drilling of an oil well was developed. Significant progress have occurred since the 1860s to the 1920s as Appalachian and Illinois basins started to produce shale gas (Green).

Years later in the 1940s and the 1970s hydraulic fracturing and directional drilling were invented respectively. Although knowledge on unconventional resources and technology of hydraulic fracturing has originated from the United States since 1821, it did not become a priority of U.S. energy policy until the 1980s. U.S. Shale resources have recently created a bright prospect for global energy outlook and invalidated the idea of energy scarcity to the point that some energy agencies have estimated a hundred-year of gas supply. For example, the Task Force on Strategic Unconventional Fuels which was established under the Energy Policy Act of 2005 in a report to the Congress and the President has declared:

> The United States is endowed with solid and liquid fuel resources equivalent to approximately 9 trillion barrels of oil, or close to 1,000 years of consumption at current levels. This is in addition to U.S. Geological Survey (USGS) estimates of the world's recoverable conventional oil resources of more than 3 trillion barrels. (Crane et al., 2009, pp. 82-83)

Shale resources and technological improvements have called into question whether the United States will continue policy of oil imports or it will become self-sufficient in energy production. Basically the answer pertains to availability of resources and efficiency of technology. This chapter will examine the U.S. capacity of mass production in terms of the available resources and efficient technology. For this purpose the first part of this chapter reviews shale formations, scale of shale resources, a general classification of resources and reserves, and the volume of shale reserves in the United States. The second part introduces hydraulic fracturing, the history, the process, and the environmental consequences.

Unconventional Resources

Both conventional and unconventional resources are composed of hydrocarbons but types in each formation and the technology to extract them are different. Conventional resources consist of permeable rocks in which oil and gas are accumulated in an expanded area and flow easily toward the surface through drilling operation. In unconventional resources like sandstone or shale, oil and gas are trapped in low permeable or impermeable rocks that cannot easily flow to the surface without stimulation, indeed such resources are accessible by very costly technologies in comparison with conventional resources. It is important to note that by means of more capital and through ongoing technological improvements more unconventional resources stand to be viewed as conventional ("Energy Independence & Sustainability? The Example of Shale Gas in the United States," 2012, November p. 6).

Unconventional term can be applied to shale gas, tight gas, sour gas, shale (tight) oil, oil shale, tar sands, coal-bed methane, or coal gasification. Shale oil and tight oil maybe used interchangeably, but it should be noted that tight formations consist of sandstones, carbonates as well as shales. Indeed tight oil is a broad term that encompasses shale oil as well as other formations. The point is that many energy agencies mostly refer to tight oil, not solely shale oil, in their assessment of oil resources. In comparison with other types of unconventional resources, shale oil and shale gas are the most prominent types due to a large scale, the advanced technology, and potential for mass production (Alex Prud'homme, 2013, p. 60); thus this research focuses on U.S. shale and disregards other sources of energy in its analysis.

In 2007 the National Petroleum Council in the United States in an extensive study on global oil and gas has defined unconventional gas:

> Natural gas that cannot be produced at economic flow rates nor in economic volumes of natural gas unless the well is stimulated by a large hydraulic fracture treatment, a horizontal wellbore, or by using multilateral wellbores or some other technique to expose more of the reservoir to the wellbore. (Perry & Lee, 2007, p. 5)

This definition on unconventional gas can also be applied to unconventional oil. There is a lack of historical data on unconventional resources to the extent that estimating the exact size of technically recoverable resources seems uncertain and unreliable. However it is important to note that more experiences and technological advances would provide more accurate estimation over time. A long-term productivity of wells in most shale plays [a geographic area that contains economically accessible oil or gas, and it is target of operators for exploration and production] is still untested for two reasons: First, many shale plays are not old enough to be assessed properly, also they are too widespread in size that the precise estimation would be problematic. Second, due to different characteristics of shale formations in different regions the current rate of production cannot be a reliable indicator for future rate. Furthermore, oil and natural gas prices, technological advances, or environmental regulations can change estimation of the reserves (Susan, 2012, p. 37). It means in the case of law prices, more advancement in technology, and less tough regulations the estimation would increase.

Paul Stevens (2012), a Fellow for Energy at Chatham House and Emeritus Professor at Dundee University remarks that: "There has been considerable debate over the level of technically recoverable shale gas resources together with significant revisions to some estimates of those resources." (p. 1) He emphasizes that shale gas may not be a proper substitute for coal, but rather it can be a reasonable substitute for renewable energy.

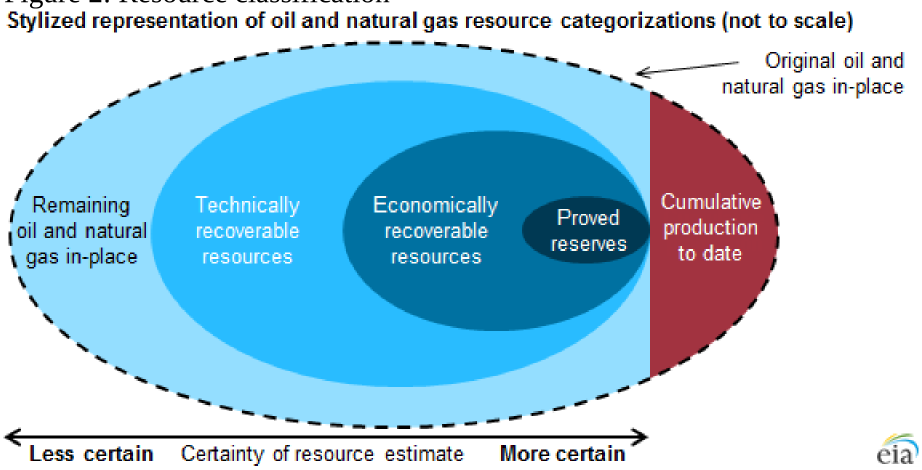
Differences between Resources and Reserves

For a number of reasons the exact estimation of resources remains uncertain: different characteristics of the resources, lack of enough knowledge on technology or geology, and diverse methods of assessment. Terms of *resource* and *reserve* may be used interchangeably but a closer look at data indicates a subtle difference between them. Commentators need a common framework that thoroughly defines and categorizes a *resource* and a *reserve* so that they can make a more precise estimation. In general, based on geographical regions and geological features of the formations, energy experts and some agencies have provided different definitions for a *resource* and a *reserve*. According to level of uncertainty, estimation of a resource can be classified into three types: low estimation, intermediate estimation, and high estimation. The rest of this part presents the most common classifications of a *resource* and a *reserve*.

It is worth noting that *resource* is a general and broad term, but in practice some part of a resource is inaccessible, some part is technically accessible and just a small part of it is economically accessible, this small part is called *reserve*. In order to have profitable production commercial actors pay more attention to economically accessible resources. In different reports or analysis when an expert aims to evaluate volume of reservoir he or she may refer to *resource* or refer to *reserve*. Richard Heinberg, a leading theorist of Peak Oil, states considerable quantity of resources exists but all of this quantity is not accessible or recoverable, while reserves are applied to small fraction of resources which are recoverable and commercial. Heinberg (2013) states:

> Some reserves are termed technical reserves: these are resources that theoretically could be extracted given current technology. A smaller but more important category consists economic reserves: these are resources that can profitably be extracted with current technology and at current prices. (p. 130)

Figure 2: Resource classification



Source: Energy Information Administration, July 2014

Figure 2 presents a general classification of a resource with four categories, it is based on the size and level of certainty (Budzik & Ford, 2014):

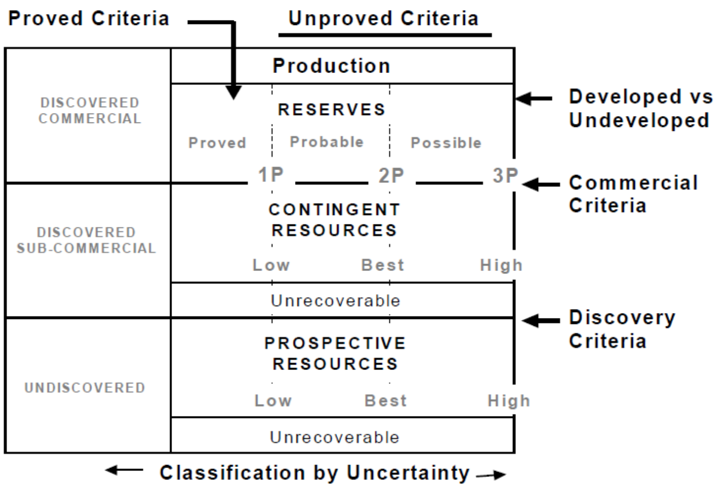
First, remaining oil and natural gas in-place: This category is applied to all quantities of oil and gas which are trapped in rock formations before the start of operation. This category is the largest but the most uncertain type of resources, which is consisted of discovered and undiscovered resources, and it may be recoverable or unrecoverable.

Second, technically recoverable resource: This category represents a resource that can produce oil and gas based on current technology and geologic knowledge, but it may not be profitable or even cost-effective at present.

Third, economically recoverable resource: It is applied to a technically recoverable resource which is profitable to be produced. Prices of oil and gas or operational expenditures influence the size of such resources.

Fourth, proved reserve: This category is the smallest but the most certain type of resources, based on current economic conditions and technology it yields profitable production.

Figure 3: Resource classification



Source: Comparison of Selected Reserves and Resource Classifications and Associated Definitions, by Society of Petroleum Engineers, 2005

Another classification has been proposed by the Oil and Gas Reserves Committee of Society of Petroleum Engineers (SPE) (see Figure 3). In 2005, it coupled with eight international agencies [U.S. Security and Exchange Commission (1978), UK Statement of Recommended Practices (2001), Canadian Security Administrators (2002), Russian Ministry of Natural Resources (2005), China Petroleum Reserves Office (2005), Norwegian Petroleum Directorate (2001), United States Geological Survey (1980), United Nations Framework Classification (2004)] conducted a study on a system to classify types of resources (Etherington, Pollen, & Zuccolo, 2005, pp. 25-27). The outcome of the study divided a resource into three types:

First, undiscovered resource: It implies that based on "discovery criteria" some resources remain undiscovered.

Second, discovered sub-commercial resource/contingent resource: It implies accessibility or inaccessibility of resources depend on economic conditions, environmental constraints or lack of infrastructures or technology. In other words all discovered resources are not commercially recoverable, but they may remain in contingent category. It should be reminded that based on "commercial criteria" such resources might turn into commercial ones.

Third, discovered commercial resource: It is a discovered resource which is profitable for mass production. This type is divided into proved reserve, probable reserve and possible reserve. Observers define "commercial criteria" and based on it they determine type of resources. They explain that *commercial* does not solely correspond to the economy but there are other factors for a project to be profitable as well. The Society of Petroleum Engineers (SPE) in a more detailed description defines *commercial*:

> … [a] demonstrated intent to bring to production status within a reasonable time frame. Intent may be demonstrated with firm funding/financial plans, declarations of commerciality, regulatory approvals and satisfaction of other conditions that would otherwise prevent the project from being developed and brought to production. (Etherington, Pollen, & Zuccolo, 2005, p. 27)

Discovered commercial resources are at the central attention because they bring cost-effective production, based on commercial criteria these resources are divided into three types: proved reserve which is low in estimation, probable reserve which is best in estimation and possible reserve which is high in estimation. In this classification the primary focus of the industry is proved reserves containing small quantity in comparison with contingent resources containing large quantity.

The Society of Petroleum Evaluation Engineers has provided a more precise classification. It brings into focus that original resources are consisted of undiscovered and discovered resources and that each of these can be recoverable or unrecoverable. According to this classification estimation of each type might be conservative, realistic or optimistic ("Characterization of Resource Assessments," n.d.; "Definition of Oil and Gas Resources and Reserves," 2007, December pp. 3-10).

The Society of Petroleum Evaluation Engineers has reported undiscovered resources are of two types:

A. Undiscovered unrecoverable resources, which are neither economically nor technically, recoverable.
B. Undiscovered recoverable resources or prospective resources, which are technically and economically recoverable in the future, but not at present.

The Society has categorized discovered resources into two categories, each one has two sub-divisions:

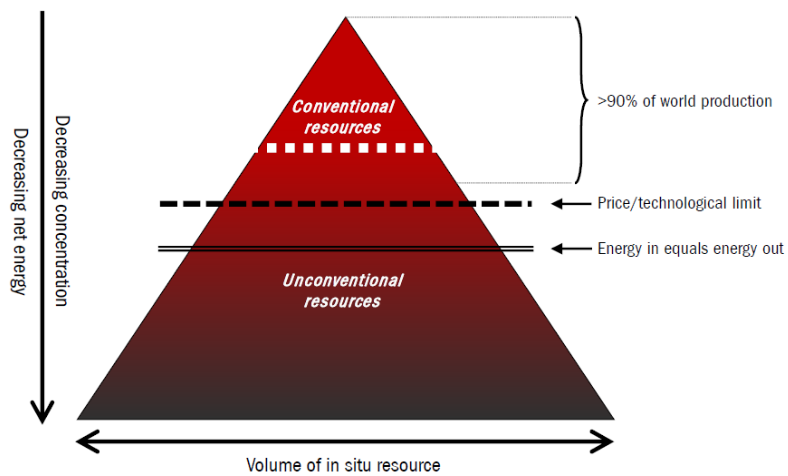
A. Discovered recoverable resources that are divided into two sub-divisions:
    a) Economic resources that lead to cost-effective production at present.
    b) Uneconomic resources that yield costly production at present.
B. Discovered unrecoverable resources that are divided into two sub-divisions:
    a) Contingent resources, which are technically, but not economically, recoverable.
    b) Unrecoverable resources that are neither technically nor economically recoverable.

So far the meaning of a resource and its type has been explained. As it was noticed there is difference between a *resource* and a *reserve*, in order to know the difference, term of *reserve* and its types is required to be explained as well. The Society of Petroleum Evaluation Engineers has defined *reserves* as “those quantities of oil and gas anticipated to be economically recoverable from discovered resources are classified as reserves." ("Definition of Oil and Gas Resources and Reserves," 2007, December p. 6) Reserves are of three types: proved reserves which are recoverable with high certainty, probable reserves which are recoverable with less certainty in comparison with proved reserves, and possible reserves which are recoverable with less certainty in comparison with probable reserves.

The research till now has shown the distinctions in definition of a *resource* and a *reserve* in order to indicate the distinction between conventional and unconventional resources; it has presented different terminology on this issue.

David Hughes, a geologist and energy expert, has applied the preceding concepts of resource classification to a pyramid and divided hydrocarbon resources into conventional and unconventional categories. (See Figure 4)

Figure 4: The pyramid of unconventional resources versus conventional resources; the volume and quality



Source: J. David Hughes, 2013

Hughes (2013) argues that top of the pyramid corresponds to recoverable resources which have the highest quality with the lowest cost; these resources are available in small volume. Toward bottom of the pyramid volume of the resources increases, but quality of them decreases, at the same time the required energy to extract such resources increases.

Indeed those resources with high quality that are easily accessible at the low cost are termed conventional, and those resources with lower quality that are plentiful but roughly inaccessible or accessible at higher cost are termed unconventional. It must be remembered that technological improvements might make these resources more accessible in the future.

The price/technology line means that in the case of higher prices and further technological innovations, the bottom resources become more accessible. The energy line means the energy that comes from the bottom resources is less than or equal to the energy that is required to be invested in order to extract hydrocarbons (Hughes, 2013).

In general, improvement in technology and knowledge or a shift in energy prices make a basic distinction between resource and reserve in a manner that in a good economic conditions volume of a reserve maybe increased because in a good economic condition more quantity of oil and gas is commercially recoverable. Thus energy experts and strategists are required to take this issue into consideration in order to have a more accurate assessment (Hughes, 2013).

Available Reserves or Resources in the United States

With regard to the above discussion volume of a reservoir could be estimated based on technically/economically recoverable resources, or based on proved reserves. This part reviews statistics and data by different agencies in order to indicate the apparent distinction between a resource and a reserve, and then it presents data on major shale plays that account for most production of shale gas and tight oil in the United States.

Estimation by the Energy Information Administration

In 2005, the Energy Information Administration estimated that 140 trillion cubic feet of technically recoverable shale gas was available. In 2010, the Advanced Resources

International raised the estimation to 1,000 Tcf in North America including Canada and the United States (Jafee, Medlock, & Soligo, 2011). Later in 2011, it revised the estimation to 1,930 trillion cubic feet (Medlock, Jaffe, & Hartley, 2011). In 2013, the EIA reported that the United States holds 58 billion barrels of technically recoverable shale oil and 665 trillion cubic feet of technically recoverable shale gas (U.S. Energy Information Administration"Technically Recoverable Shale Oil and Shale Gas Resources: An Assessment of 137 Shale Formations in 41 Countries Outside the United States," 2013, June).

Estimation by British Petroleum

In 2013, the British Petroleum announced that the United States holds 70 billion barrels of tight oil and 47 trillion cubic meters of shale gas, which are technically recoverable. It reported that “in 2012, 2.1 Mb/d (24%) of U.S. oil production was from tight oil and 24 Bcf/d (37%) of natural gas from shale.” ("BP Energy Outlook 2030," 2013, January p. 23)

The key point to bear in mind is the changing and uncertain pattern of estimation, that is to say estimation is changeable in terms of unit of energy or origin of resources. For example, shale gas could be estimated based on cubic feet or cubic meters, meanwhile the estimation could be based on North America's resources or just the United States’ resources. Moreover ongoing technological advances and unstable economic conditions could change estimation.

The Energy Information Administration has reported that there are five major tight oil plays in the United States including Eagle Ford, Bakken, Barnett, Marcellus, and Niobrara; and there are six major shale gas plays including Marcellus, Barnett, Haynesville, Eagle Ford, Woodford, and Fayetteville. According to a report by EIA, these plays contain more than 90% of the proved reserves and they are experiencing an increase both in oil production and proved reserves since 2011 ("U.S. Crude Oil and Natural Gas Proved Reserves, 2012," 2014, April).

Table1: Tight oil plays: oil production and proved reserves, 2011-12

Million barrels						
			2011	2011	2012	2012
Basin	Play	State(s)	Production	Reserves	Production	Reserves
Western Gulf	Eagle Ford	TX	71	1,251	209	3,372
Williston	Bakken	ND,MT,SD	123	1,998	213	3,166
Ft. Worth	Barnett	TX	8	118	10	66
Appalachian	Marcellus	PA,WV	-	-	4	72
Denver-Julesberg	Niobrara	CO,KS,NE,WY	2	8	3	14
Sub-total			204	3,375	439	6,690
Other tight oil			24	253	41	648
All US tight oil			228	3,628	480	7,338

Source: U.S. Crude Oil and Natural Gas Proved Reserves, 2012

Eagle Ford and Bakken are the leading shale plays that have a significant share in production and reserves. In 2011, the U.S. produced 228 million barrels of tight oil; it increased the production to 480 million barrels by 2012. This is while the U.S. proved reserves contained 3,628 million barrels of tight oil in 2011, this scale increased to 7,338 million barrels by 2012 (see Table 1). A sharp distinction between amount of production and scale of proved reserves indicates that a large volume of reserves do not necessarily lead to high production; but rather technological, economical or environmental factors can disrupt commercial production of these reserves.

On the subject of gas Table 2 presents statistical data on six major shale gas plays in the U.S. that hold most of the proved reserves, Marcellus remained at the top with 31.9

trillion cubic feet of gas by 2011, and 42.8 trillion cubic feet by 2012. Barnett and Haynesville were in the second and third positions.

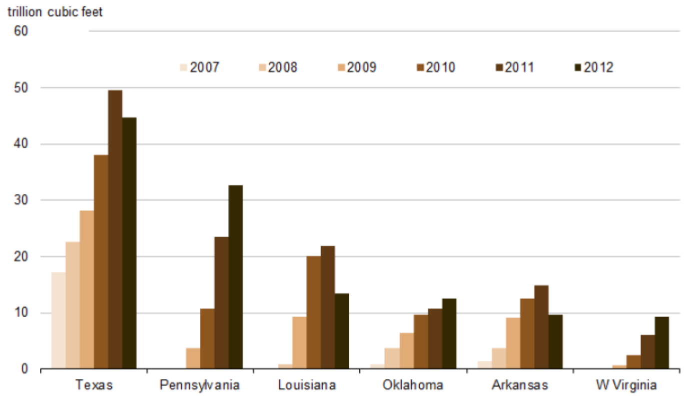
Table 2: Principal shale gas plays: natural gas production and proved reserves, 2011-12

Trillion cubic feet							Change 2012-2011	
			2011		2012			
Basin	Shale Play	State(s)	Production	Reserves	Production	Reserves	Production	Reserves
Appalachian	Marcellus	PA,WV,KY,TN,NY,OH	1.4	31.9	2.4	42.8	1.0	10.9
Fort Worth	Barnett	TX	2.0	32.6	2.0	23.7	0.0	-8.9
Texas-Louisiana Salt	Haynesville/Bossier	TX,LA	2.5	29.5	2.7	17.7	0.2	-11.8
Western Gulf	Eagle Ford	TX	0.4	8.4	0.9	16.2	0.5	7.8
Anadarko	Woodford	TX,OK	0.5	10.8	0.6	11.1	0.1	0.3
Arkoma	Fayetteville	AR	0.9	14.8	1.0	9.7	0.1	-5.1
Sub-total			**7.7**	**128.0**	**9.6**	**121.2**	**1.9**	**-6.8**
Other shale gas			0.3	3.6	0.8	8.2	0.5	4.6
All U.S. shale gas			**8.0**	**131.6**	**10.4**	**129.4**	**2.4**	**-2.2**

Source: U.S. Crude Oil and Natural Gas Proved Reserves, 2012

Despite the United States has recorded growth in shale gas production, the scale of proved reserves show a downtrend. As Table 3 indicates the U.S. contained 131.6 trillion cubic feet of shale gas reserves in 2011, but the volume decreased to 129.4 Tcf in 2012. The reduction occurred as the result of low gas price which made shale gas exploration and exploitation unprofitable. Three plays of Marcellus Eagle Ford, and Woodford showed rise in proved reserves, while Barnett, Haynesville, and Fayetteville experienced decline ("U.S. Crude Oil and Natural Gas Proved Reserves, 2012," 2014, April).

Table 3: Proved shale gas reserves of the top six U.S. shale gas states, 2007-12



Source: U.S. Crude Oil and Natural Gas Proved Reserves, 2012

Major Shale Plays in the United States

According to Prud'homme these are the major shale plays in the United States (2013, pp. 96-105):

Anadarko-Woodford: It is based in Oklahoma; it contains crude oil and natural gas at depths of 11,500 feet to 14,500 feet.

Bakken: It covers 200,000 square miles which is located under Montana, North Dakota, Saskatchewan, and Manitoba at depths of 3,000 feet to 11,000 feet. It contains 3.6 bb of oil and 1.85 Tcf of natural gas, and 148 Mb of natural gas liquids.

Barnett: It is the most productive shale gas play in the United States which covers 5,000 square miles in Fort Worth, Texas. The Barnett accounts for 6% of natural gas production containing 360 Tcf of natural gas.

Eagle Ford: It is located in Texas, at 4,000 to 14,500 feet deep. It holds oil and 150 Tcf of natural gas.

Fayetteville: It is based in Arkansas at depths of 1,450 feet to 6,700 feet and stretches 4,000 square miles. It is the second largest shale play which contains 20 Tcf of gas.

Granite Wash: It spreads to beneath north Texas and south Oklahoma, oil and gas are accumulated at depths of 11,000 feet to 15,000 feet.

Haynesville: It covers 9,000 square miles at 10,000 feet to 14,500 feet deep. Haynesville is located in east Texas and north Louisiana which is a productive shale play with an estimated 250 Tcf of gas.

Marcellus: It is based in Northeast mostly in Pennsylvania, at 6,200 feet deep. It contains both oil and gas.

Monterey Shale: It covers 1,750 square miles in California, and lies at 11,000 feet deep. According to EIA estimation it holds 15.4 Bb of oil.

Niobrara: It spreads to Colorado, Wyoming, Nebraska, and Kansas at depths of 6,200 feet.

Permian Basin: It is located in New Mexico and West Texas, which contains 500 Mb of oil and 5 Tcf of gas.

Utica Shale: It is one of the largest gas plays, at depths of 3,000 feet to 7,000 feet beneath Marcellus Shale; it spreads from Canada to New York, Pennsylvania, Ohio, and West Virginia, likewise to some part of Kentucky, Maryland, Tennessee, and Virginia. According to estimation it holds 1.3 to 5.5 bb of oil and 3.8 to 15.7 Tcf of gas. Utica Shale is called "a resource of the distant future."

Woodford: It is located under Oklahoma and started to produce oil and gas since the 1930s.

In short, it is undeniable that a substantial resources of shale gas and tight oil are available in the United States, however the exact estimation of shale reservoirs remain uncertain for some reasons: First, enormous volume of shale resources do not necessarily increase profitable or cost-effective production due to the changing technical or economic factors which are susceptible to increase or decrease production.

Second, U.S. shale plays are experiencing mass production just recently, so they cannot be assessed properly. Meanwhile these plays are too widespread in terms of characteristics of the formations insofar as the precise estimation of production would be problematic in all shale plays. Another point is that the current rate of production may not be a reliable indicator of future rate due to a number of factors: energy prices, technological advances, or environmental regulations. These issues will affect stable supply of energy in spite of the abundant available resources.

Hydraulic Fracturing Technology

Although this study is not a technical research, for a better understanding of the issue the use of technical terms is inevitable. In discussing hydraulic fracturing it is necessary to review the different aspects such as the meaning, the process and history of fracturing development, the environmental impacts, the opportunities and impediments.

Definition

I. Hydraulic fracturing, also known as hydrofracturing, hydrofracking or fracking, is a method to extract hydrocarbons which are trapped in geologic formation such as limestone or sandstone. In the 1940s, the method was only used in limestone and sandstone, but later in the 1970s, it was applied in shale formations as well. The technique involves vertical and horizontal drilling of low permeable rocks, pumping water, sand, and propants to the wellbore in order to create fractures in shale rocks and finally recovering natural gas or oil (Trembath et al., 2012).

II. Holloway and Rudd define hydraulic fracturing as:

> Fracking is the process of using fluid power to fracture rock to release gas (and sometimes crude oil). It is not drilling per se, although drilling must be done to establish a well in order to pump fluid that fractures rock to release product. (2013, p. xi)

Hydraulic fracturing accomplishes two objectives: It increases the rate of production, it also raises volume of the reserves which are economically recoverable (Hagemeier et al., 2011, September).

III. Spellman also defines it as:

> Hydraulic fracturing can be used to overcome natural barriers to the flow of fluids (gas or water) to the wellbore. Such barriers may include naturally low permeability common in shale formations or

> reduced permeability resulting from near-wellbore damage during drilling activities....Typical fracking treatments, or frack jobs, are relatively large operations compared to some drilling operations. The oilfield service company contracted for the work may take a week to stage the job, and a convoy of trucks will be necessary to deliver the equipment and materials needed. (2013, p. 110)

Process

Hydraulic fracturing is often misused with drilling operation, extraction or the process of shale production, while fracturing is part of the process of extraction and production. The process is consisted of pre-operation, main operation and post-operation. Pre-operation includes well pad construction, drilling, and casing. Main operation includes hydraulic fracturing and production. Post-operation includes reclamation (Clark et al., 2013, April ; "Shale Gas Exploration and Production: Key Issues and Responsible Business Practices, Guidance Note for Financiers," 2013, March).

Well Pad Construction

Construction of a pad is a phase before drilling operation. A well requires a level and stable area on the surface which is called a well pad, on which equipments such as drilling rig, storage tanks, trucks and retention ponds are located. The size of a pad is determined according to the depth of a well and number of wells (Clark et al., 2012, December pp. 1-4).

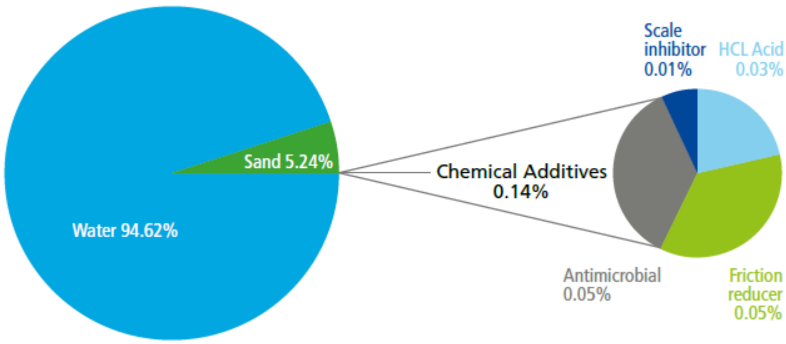
Drilling and Casing

Operators conduct drilling operation at depths of 1,450 feet to 15,000 feet underground to reach the shale formation, this operation takes weeks or months. There are three types of drilling: In vertical drilling, the drill bit reaches the shale deposits in a vertical direction, at this stage a 90-degree curve is created through directional drilling to make the wellbore horizontal. Horizontal drilling makes more shale formation available from a single pad. Later, a steel pipe which is called casing is inserted to the wellbore, cement is then injected into a space between casing and mineral formation which is called annulus. Casing and cementing is applied to prevent water from contamination or gas migration through shale formation, also to prevent wall of the well from collapsing (Clark et al., 2012, December pp. 1-4). Although both vertical and horizontal drillings are used in shale well, frackers mostly rely on horizontal drilling to recover resources and optimize economic profit because horizontal drilling makes more shale formation available than does vertical drilling. For example, in Marcellus shale of Pennsylvania vertical drilling makes 50 feet of shale rocks accessible, while horizontal drilling extend it to the length of 2000 to 6000 feet within the 50 to 300 feet thick formation (Spellman, 2013). According to a study by the U.S. National Petroleum Council in 2007, for the first 180 days horizontal drilling increases production to two or three times compared to vertical drilling (Perry & Lee, 2007, July).

Hydraulic Fracturing

In conventional reserves when drilling bit reaches the deposit, oil and gas flow easily to the surface without any stimulation. But in unconventional reserves a smooth flow of oil and gas among formations is done by hydraulic fracturing. In this process several gallons of a fluid -mainly consists of water, proppant, and chemical materials- are injected into the well at a high pressure in order to create a fracture in shale rocks so that oil and gas move toward the surface through the pathway. The fluid is mostly composed of 98-99.5% of water and sand, 0.5-2% of chemical materials (Figure 5). These chemical additives are used to improve gas flow, reduce friction, prevent growth of bacteria and corrosion, or preserve viscosity of the fluid. After injection the flow-back water comes to the surface, it is composed of chemical additives as well as chemicals that are naturally existed in a reservoir like hydrocarbons, salts, minerals, and naturally occurring radioactive materials (Clark et al., 2013, April).

Figure 5: Percentage of water consumption by hydraulic fracturing



Source: Energy Independence & Sustainability? The Example of Shale Gas in the United States

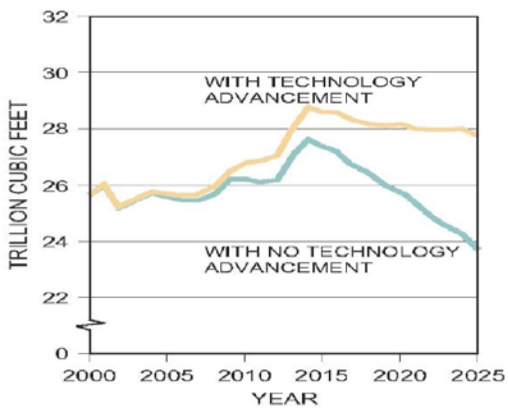
Production and Reclamation

At the end of fracturing, the fluids need to be pumped back so that oil and gas can flow in a created path. The returning fluid is called wastewater; it can be reused or recycled for the next operation. During the procedure the produced oil and gas are transmitted by pipeline or tankers. It is important to note that the unconventional resources experience a shorter lifetime of production compared to the conventional types. At this time operators remove the wellhead and fill the wellbore by cement in order to prevent gas emission to the air. In the next step they reclaim the surface and abandon the site to the landowner (Heinberg, 2013).

Technological improvements also play a crucial role; it influences the cost and rate of production (Figure 6). For example, advancements in drilling decrease the operating costs and increase the production. In 2007, the National Petroleum Council announced:

"Adding new North American natural gas supplies will require finding, developing, and producing more technologically challenging resources than ever before" (Perry & Lee, 2007, July p. 30). As it was noticed a decline in production in the early months of operation poses challenge to shale development, this is while technological advances can offset the decline and contribute to a cost-effective production.

Figure 6: Technological impacts on the U.S. and Canada Gas Production



Source: Unconventional Gas Reservoirs—Tight Gas, Coal Seams, and Shales, by U.S. National Petroleum Council, 2007

History of Shale Exploration and Hydraulic Fracturing Development

Two factors have contributed to development of shale resources and hydraulic fracturing: First, attempts by energy companies to extend the knowledge and improve the technology in order to obtain more commercial and profitable production, second, short-term or long-term policies by the U.S. government in order to enhance energy efficiency and energy security.

A comprehensive study on technical improvements of hydraulic fracturing is beyond the scope of this research, so it suffices to a brief history of the progress.

The stimulating idea of extracting oil and gas from fractured rocks can be traced back to 1866 by Edward A.L. Roberts. During the Civil War he noticed when mortar shells dropped down into a canal, jets of water spouted out. In the 1860s, the first fracturing operation occurred in Pennsylvania, New York, Kentucky, and West Virginia by the use of nitroglycerin (NG) in shale formation. Later in 1947, hydraulic fracturing was developed in Grant County, Kansas when the Stanolind Oil and Gas Corporation injected gelled gasoline and sand into limestone formation. Afterwards in 1953, fracturing fluids including crude oil, gasoline, and kerosene were replaced by water; this improvement increased consumption of water but decreased chemical challenge to the environment. In 1976, directional drilling was invented, this technology made more shale formation economically accessible. In the 1970s, the federal government started to stimulate fracturing treatment as the result of energy crisis of 1973. Indeed the era of 1970s is a turning point in energy policy of the United States. (Zuckerman, 2013, pp. 58-63) (Trembath et al., 2012, pp. 1-5) Prud'homme states that:

> In the 1970s the federal government initiated the Eastern Gas Shales Project and dozens of pilot hydraulic fracturing projects, and supported public-private research. These efforts were spurred by the energy crisis of 1973, when the Arab members of OPEC, the Organization of Petroleum Exporting Countries, imposed an oil embargo to punish the United States for its support of Israel during the Yom Kippur War. (2013, p. 75)

He adds:

> In response to the crisis, the Ford and Carter administrations prioritized the search for new energy supplies. Industry and federal researchers began to focus on techniques to access "unconventional" resources, such as …coal bed methane, "tight sands" natural gas, and shale gas. (2013, p. 75)

The next incentive for promotion of unconventional resources was offered by the U.S. Congress when it approved the Windfall Profits Tax Act of 1980 after the Islamic Revolution in Iran in 1979, because the Revolution caused "the second energy crisis". The act provided tax credit for unconventional production, it explained:

> Subject to various conditions, producers of certain alternative energy sources get a tax credit of $3 per barrel of oil equivalent, adjusted for inflation; the qualifying sources are oil from shale and tar sands, natural gas from certain nontraditional sources, synthetic fuels (other than alcohol) from coal, gas from biomass, steam from solid agricultural byproducts, and processed wood. (Gelb, 1981, December 17, p. 18)

Legislative drivers have basically spurred hydraulic fracturing since the 1940s. On the one side decision makers were required to pay attention to the public concerns, on the other side they had to notice the U.S. needs for energy. In 2011, the U.S. National Petroleum Council reported:

> Public concern and opposition to the technology and regulatory framework have become more prevalent over the last decade, and coupled with the industry response to public concerns, have been primary drivers in the progression of hydraulic fracturing technology and regulation as it stands today and into the future. (Hagemeier Paul D., 2011, September p. 11)

Hydraulic fracturing is regulated at the federal, state and local levels. Federal regulations are mostly proposed by the Environmental Protection Agency or the Department of the Interior. In 2012, at the state level 170 bills were submitted, but only 14 bills became law on this issue (Alex Prud'homme, 2013, pp. 211-212).

The National Petroleum Council in the United States has outlined those acts that have regulated hydraulic fracturing from 1974 to 2011. The most important ones include:

I. *The Safe Drinking Water Act* (SDWA): The act was introduced by the U.S. Environmental Protection Agency in 1974, it aimed to protect water supply from contamination.

II. *The Energy Policy Act*, section 322: The act was passed by U.S. House of Representative in 2005. It excluded the fluid which was used in underground injection. Indeed the Act restricted authority of the Environmental Protection Agency on hydraulic fracturing.

III. *The Frac Act Introduced*: The act was approved by the U.S. Congress in 2009, by which the operators were required to disclose chemical materials they use in hydraulic fracturing (Hagemeier et al., 2011, September, pp. 11-12). More details on fracturing regulations are available in appendix.

According to the American Petroleum Institute the acts that regulated hydraulic fracturing at the federal level include:

> Clean Water Act; Clean Air Act; Safe Drinking Water Act; National Environmental Policy Act; Resource Conservation and Recovery Act; Emergency Planning and Community Right to Know Act; Endangered Species Act and the Occupational Safety and Health Act. ("Hydraulic Fracturing :Unlocking America's Natural Gas Resources," 2014, July p. 10)

Put aside the acts that have played role in fracturing improvements, Paul Stevens mentions four other factors that contribute to shale development in the United States: geology, regulation, industry and research (2012, p. 9).

I. On the subject of geology he argues that large and shallow technically or economically recoverable resources are available, meanwhile operators easily access drill core data by which they can discover the "sweet spots", while these data are not easily accessible in other regions of the world (Stevens, 2012, p.9).

II. On the subject of regulation Stevens explains that energy policies and rules have spurred the industry to apply new technologies and new sources of energy so that the U.S. can meet the growing energy demands. For example, *the Energy Act of 1980* has created an incentive of fifty cent tax credit per million BTUS [unit of energy]. This act also includes *Intangible Drilling Cost Expensing Rule* by which it provides 70% expenditure for well development, this issue is important for those small firms that are not able to provide finance. Moreover, *the Energy Act of 2005* has removed hydraulic fracturing from the *Clean Energy Act*, this act has been proposed by the Environmental Protection Agency and it has restricted the use of hydraulic fracturing. Another factor that has facilitated shale development is the system of Property Rights, by this system shale play is regarded as a landowner's property that can bring more wealth for the owner, so the owner eagerly handovers his or her land to the operators (Stevens, 2012, p.9).

In contrast to European countries like France, Luxembourg, Bulgaria, Germany, Poland and United Kingdom which have imposed constraint on fracking, in the United States mineral rights have spurred it, because households gain thousands or even millions of dollar in addition to production royalties. Likewise in the United States Fracking is driven by risk-seeking capitalists such as Wall Street or independent companies, whereas in other countries the government runs it (Heinberg, 2013, pp. 142-144).

Access to pipeline route provides another inducement for energy firms; it means the existing pipeline is accessible for all gas producer companies. In this case those firms that do not construct or own any pipeline have the opportunity to use the constructed pipeline, so they are not required to spend time and money on designing and constructing new pipelines. It is true that the U.S. policy is a driving force for running of hydraulic fracturing in the United States compared to other countries, but still there is no unified regulatory system to organize this issue at the federal level, insofar as some states prohibit hydraulic fracturing and some states promote it (Stevens, 2012, p.9).

III. On the subject of industry Stevens states: "The system is used to license large areas for exploration with fairly vague work program commitments, which is what is needed when dealing with shale plays" (2012, p. 9), he adds that the United States has established the monopoly of the respective technology, thus a highly competitive firms perform the majority of the operations, while in Europe the service industry is mostly dominated by the U.S. oligopoly.

IV. Finally research as a pivotal factor has contributed to the development of shale production. For example the U.S. government in 1982 invested R&D for some projects namely “shale formation and low permeability hydrocarbon bearing formations”, while in Europe funding of research projects is left only to the market (Stevens, 2012, p.9).

Hydraulic Fracturing Impacts on Environment

Unconventional hydrocarbons have changed the global energy outlook to the point that strategists argue that it would significantly affect the global economy and energy market in a long-term. However an inconclusive debate has remained over the uncertain consequences of hydraulic fracturing on environment and human health. Anti hydraulic fracturing or environmentalists believe that the technology has negative impacts on environment. While, hydraulic fracturing proponents argue that there is an environmental track record on the process which indicates no serious warning is required. Given the impacts of this issue on the main question of the research the environmental impacts needs to be scrutinized.

Since 2010, hydraulic fracturing has caused serious concern about negative environmental impacts, therefore the official agencies like the Environmental Protection Agency, the Energy Information Administration, and other research centers have devoted efforts to inspect and examine these impacts (Paul, 2012, pp. 3-4). According to the International Energy Agency, the energy market in the United States and in the world cannot yet consider a certain and promising future for unconventional gas due to the numerous social and environmental hurdles. It is generally considered that unconventional resources expose more risks to the environment than conventional resources. Water withdrawal, water contamination, earthquake, air pollution and greenhouse-gas emission are among those crucial concerns that make shale outlook more uncertain and unreliable ("Golden Rules for a Golden Age of Gas World Energy Outlook Special Report on Unconventional Gas," 2012, November, p. 22).

Water Withdrawal and Water Contamination

A high consumption of water or contamination is regarded as the main challenge of hydraulic fracturing, so a quick review of the issue is called here.

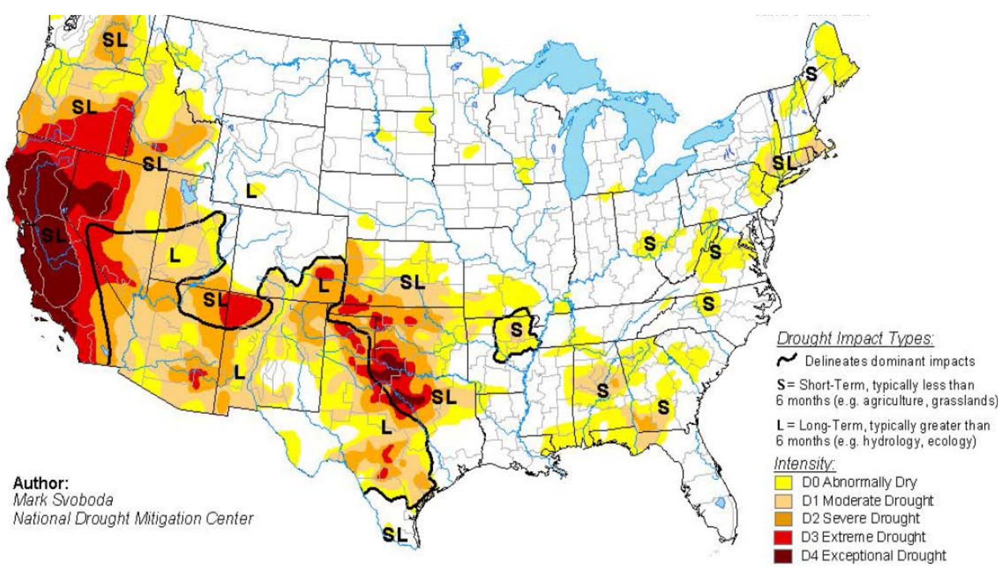
Environmentalists argue that hydraulic fracturing poses risk to the environment, though its extent is unknown. In their views, water consumption and water contamination is one of the main obstacle to this technology. The required water for drilling operation ranges from 65,000 gallons to 13 million gallons (Prud'homme, 2013, p. 59). In 2011, in order to produce 441 million barrels of oil 632 million barrels of water were consumed. It should be noted that mostly the water used for fracking is clean and just one-fifth of it being recycled (2013, p. 95). In addition to drilling operation each well uses 1,2 to 5 million gallons of water over its lifetime, Prud'homme argues that: "all of the shale wells drilled and completed in 2011 used 135 billion gallons of water, which was equivalent to 0,3% of total U.S. fresh water consumption" (2013, p. 85). He continues that compared to water consumption by other form of energy this is not that much, "natural gas uses about 60% less water than coal and 75% less water than nuclear power generation."(2013, p. 85)

Another report by Dexia Asset Management indicates in order to produce oil and gas, shale formation needs between 2 to 5 million gallons of water, however the required water depends on the characteristic and geological formation of each shale plays. For example, according to a report by Candriam Investors Group, Marcellus shale requires 50% more water in comparison with Barnett shale. The report points out:

> According to an assessment by Merrill Lynch Bank of America, approximately 50,000 wells are fractured each year across the U.S., leading to an annual water requirement ranging from 70 to 140 billion gallons. This amount could increase the competition between farmers and the oil and gas operators for access to scarce water. (p. 16)

The report compares level of water consumption by Chesapeake Energy, the second major energy company in the United States, with data of the International Energy Agency in 2012 and concludes: “the amount of water required for shale gas, calculated per unit of energy produced, is higher than for conventional gas but not so different from the amount used for the production of conventional oil.” ("Energy Independence & Sustainability? The Example of Shale Gas in the United States," 2012, November p. 16) It means both conventional and unconventional resources consume much water but in some cases unconventional resources need more water. Data by the Drought Monitor upholds the view that shale production would be at risk in the arid states of the United States in the long-term. Risky states are presented in Figure 7.

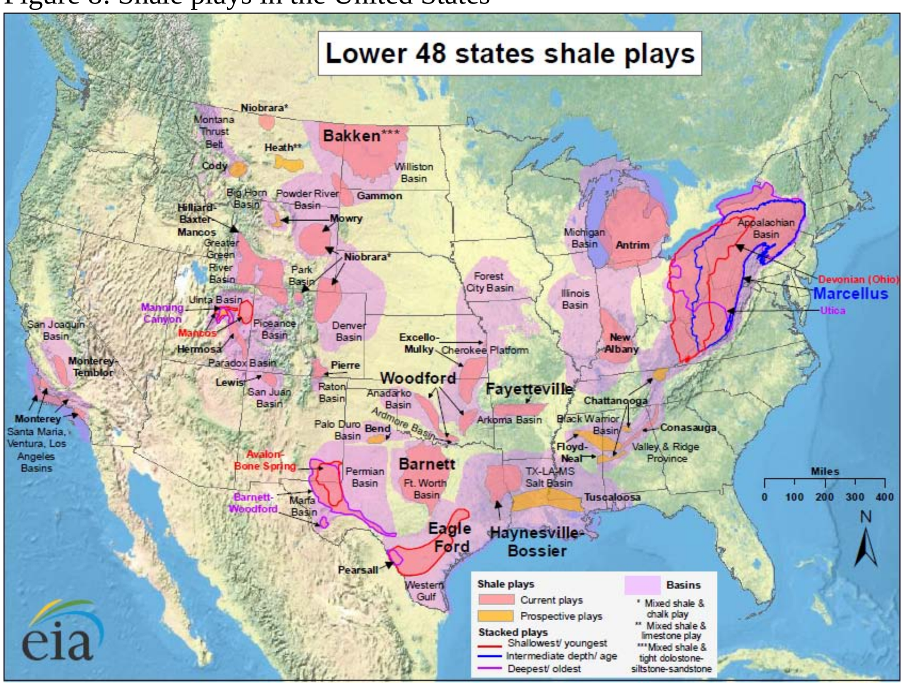
Figure 7: U.S. regional drought conditions



Source: U.S. Drought monitor, October 7, 2014 (http://droughtmonitor.unl.edu)

As Figure 8 shows some major shale plays like Barnett, Haynesville, Eagle Ford or Marcellus are located in the arid states of the South. In 2011, on the average 4,850,000 gallons of freshwater were consumed in Barnett play per well. The volume increased to 5,125,000 gallons of water in Eagle Ford, and 5,600,000 in Haynesville (See Table 4). As noted before the amount of water depends on characteristic of shale formations as well as quality or impurity of water. Likewise, drilling operation including making the drilling mud, cooling, and lubricating the drill bit is in need of water. It is important to note that water insufficiency may not halt production, but it would impede the smooth running of hydraulic fracturing.

Figure 8: Shale plays in the United States



Source: U.S. Energy Information Administration, May 9, 2011

Table 4: Water Usage by hydraulic fracturing

Average Freshwater Use per Well for Drilling and Hydraulic Fracturing		
	Average freshwater used (in gallons)	
Shale play	For drilling	For hydraulic fracturing
Barnett	250,000	4,600,000
Eagle Ford	125,000	5,000,000
Haynesville	600,000	5,000,000
Marcellus	85,000	5,600,000
Nobrara	300,000	3,000,000

Source: GAO analysis of data reported by George King. Apache Corporation (2011)

The point is that volume of consumed water is not substantial in comparison with agriculture or industry, but there would be constrain on supply of freshwater in the arid or semiarid states with regard to the growing population and expanding demand for water in these states. The Government Accountability Office in 2012 reported that total of the required water for fracturing treatment is uncertain because the scale of shale development is unknown, also operators do not submit any record to any appropriate agency so the assessment of a long-term effect of water withdrawal is uncertain as well ("Oil and Gas: Information on Shale Resources, Development, and Environmental and Public Health Risks," 2012, September pp. 37-39).

Every five years the U.S. Geological Survey publishes a comprehensive report on estimated use of water in the United States. In the latest one it has outlined 8 groups that consume water: public supply, domestic, irrigation, livestock, aquaculture, industrial, mining, thermoelectric-power generation. It has analyzed data based on a state, source of water, and group of use. According to the report thermoelectric-power generation is the first-largest group that causes water withdrawal nearly one-half of the total usage, 201,000 million gallons per day (Mgal/d). The report explains: “withdrawals for thermoelectric-power generation represented 41% of all freshwater, 61% of all surface water, and 95% of all saline-water withdrawals." According to the report irrigation is the second-largest group of water withdrawal nearly 128,000 Mgal/d. It says: "irrigation withdrawals represented 31% of all water withdrawals and 37% of all freshwater withdrawals." water withdrawal that caused by production of oil and gas is included in mining category. USGS has reported: "mining withdrawals were about 1% of total withdrawals". The evidence indicates water usage by hydraulic fracturing is not that much compared to the usage by industry or agriculture. The report notes: "total mining withdrawals in 2005 were 11% smaller than in 2000" (Kenny et al., 2009, pp. 4,35).

Water withdrawal puts the environment at risk because it strongly affects water sources including surface water and aquifers. According to a report by the Government Accountability Office in 2010, water withdrawal might increase temperature in the summer and decrease it in the winter, changing the temperature can seriously affect the aquatic life and riparian vegetation. Groundwater withdrawal also influences the connected rivers and the fluvial life.

Another problematic point is water contamination, which poses another threat to the environment. According to a research by the Asset Management Dexia in 2012, there are three possibilities by which the groundwater might be contaminated:

First, in the process of hydraulic fracturing some fractures have been created among rocks, this issue might spread methane and fracturing fluids to the target formation. In order to undermine this concern the proponents bring into focus the far distance between aquifers and impermeable layers of shale formation, they believe contamination of aquifers is unlikely to occur. However operators are strongly required to conduct an accurate fracturing treatment and use seismic technology in order to control the process of fracturing and length of created fractures so that they can prevent water from contamination.

Second, Drilling operation in both unconventional and conventional resources starts with vertical drilling in which the drill bit penetrates deeply into the ground and passes through groundwater. In the process of hydraulic fracturing well design and casing may be conducted improperly, in the case of bad casing and cementing chemical materials can flow among the rocks and contaminate the aquifer.

Third, at the end of operation wastewater is pumped back to the surface in order to simulate the smooth flow of oil and gas. Another issue that makes water contaminated can be leakage of wastewater from the surface storage or at the time of transportation. Operators may store or transport wastewater to prevent water from contamination. Regular monitoring or close observation minimize the likelihood of water contamination ("Energy Independence & Sustainability? The Example of Shale Gas in the United States," 2012, November pp. 19-23).

As it was noticed aquifers are susceptible to be contaminated as a result of imperfect casing and cementing or even as a result of created cracks in ineffective cement which have been caused by natural seismic. Natural fracture may be created in old or abandoned wells as well. It is necessary to point out that ineffective casing and the risk of underground contamination is not unique to shale resources because conventional resources are also exposed to inadequate cementing ("Oil and Gas: Information on Shale Resources, Development, and Environmental and Public Health Risks," 2012, September pp. 37-50).

On the subject of surface water it is important to note that toxic wastewater is also susceptible to contaminate fresh water. Wastewater comprises two constituents: First, “produced water”, which is the fluids returning back to the surface; second, “flow-back”, which is the fracturing fluids consisted of toxic chemical materials. Operators employ a number of methods to decrease the possibility of contamination. For example, wastewater is injected back to the storage well; the well can be a new drilled one or the old well which has become inactive or unproductive at present. Another method is transporting of wastewater to recycling system by means of pipeline or trucks (Prud'homme, 2013, p. 59). Operators can also hold wastewater in an evaporation pools, or send it to a municipal system of recycling in order to control water pollution. However all of these methods are problematic and cannot remove all concerns because in some cases wastewater may flow to the road or following the process of injecting and storing it may contaminate aquifers, even the evaporation pools are susceptible to poison wildlife through leaking or spilling of wastewater to the environment. Moreover, municipal system may not be equipped enough to recycle water perfectly, or maybe water is too radioactive to be recycled. One of the responses to the problem of water contamination is recycling system but this method just achieves 50% efficiency, while chloride, solid and other chemical additives affect seriously the environment to the degree that it decreases level of dissolved oxygen in rivers or increases water temperature (Heinberg, 2013, pp. 75-77).

At the end of a well lifetime operators plug the borehole with cement in order to prevent the flow of toxic fluids between layers. However cement may shrink as a result of seismic activity and it may lead to migration of gas. Concerning the risk of water contamination, Heinberg has presented some statistics: “even if just 1% of well casing fail, for the more than 65,000 current wells in fracking country that translate to 650 instances of likely contamination. If failure rates are 6%, it raises the number to 3,900” (2013, pp. 78-9). Heinberg argues that scientific studies should address level of water contamination but such analysis is withheld to be available on the public. Besides, a study of 68 wells by the Proceeding of the National Academy of Science indicates that methane concentrations near fracturing wells are 17 times higher than non-fracturing wells (2013, p. 78).

A research team of the Resources for the Future conducted a large-scale research for 11 years in which they observed more than 20,000 surface water samples of Marcellus shale in Pennsylvania with the purpose of investigating water quality. They found two pollutants of chloride and total suspended solid (TSS). Three key findings that were outlined are:

I. The upstream treatment and release of shale gas wastewater by treatment plants raises downstream chloride concentrations in surface water, but it does not raise TSS concentrations. An increase of one upstream waste treatment facility accepting shale gas waste raises downstream chloride concentrations in a watershed by about 7%.
II. The presence of well pads upstream raises the concentration of TSS but not chloride. An additional well pad upstream increases downstream TSS concentrations in a watershed by about 0.3%.
III. There is no systematic statistical evidence of spills or leaks of flow-back and produced water from shale gas well pads into waterways. (Krupnick, 2013, p. 7)

According to a report by the Government Accountability Office in 2012, some contaminants that are produced by drilling and hydraulic fracturing are consisted of:

I. Salts, which include chlorides, bromides, and sulfides of calcium, magnesium, and sodium.
II. Metals, which include barium, manganese, iron, and strontium, among others.
III. Oil, grease, and dissolved organics, which include benzene and toluene, among others.
IV. Naturally occurring radioactive materials (NORM).
V. Production chemicals, which may include friction reducers to help with water flow, biocides to prevent growth of microorganisms, and additives to prevent corrosion, among others.("Oil and Gas: Information on Shale Resources, Development, and Environmental and Public Health Risks," 2012, September pp. 41-42)

Chemical additives create negative impacts on environment and human health. For example, barium causes blood pressure, salt leads to disorder in crop growth, or biocide increases livestock mortality. Since 2001 to 2010, a number of fractures which were hydraulically created were monitored near the location of aquifers in Barnett, Eagle Ford, Marcellus, and Woodford in response to the concern for water contamination. The Government Accountability Office regarding this issue has reported:

> … the results of the monitoring shows that even the highest fracture point is several thousand feet below the depth of the deepest drinking water aquifer. For example, for over 200 fractures in the Woodford Shale, the typical distance between the drinking water aquifer and the top of the fracture was 7,500 feet, with the highest fracture recorded at 4,000 feet from the aquifer. In another example, for the 3,000 fractures performed in the Barnett Shale, the typical distance from the drinking water aquifer and the top of the fracture was 4,800 feet, and the fracture with the closest distance to the aquifer was still separated by 2,800 feet of rock. (2012, p. 47)

According to a study by the Center for Rural Pennsylvania in 2011 there are no significant pollutants in water sample before and after drilling in the area near fracturing sites ("Oil and Gas: Information on Shale Resources, Development, and Environmental and Public Health Risks," 2012, September).

The U.S. Government Accountability Office has published a report about water depth in shale formation of Barnett, Fayetteville, Haynesville, Marcellus, and Woodford and provided data about depth to shale rocks, depth to aquifers and the distance between them. As Table 5 indicates the maximum distance has been recorded in Haynesville between 10,100 to 13,100 feet and the minimum distance has been recorded in Fayetteville between 500 to 6,500 feet. The data seem to support the view that water contamination infrequently occurs in impermeable shale layers due to the far distance between shale formations and aquifers.

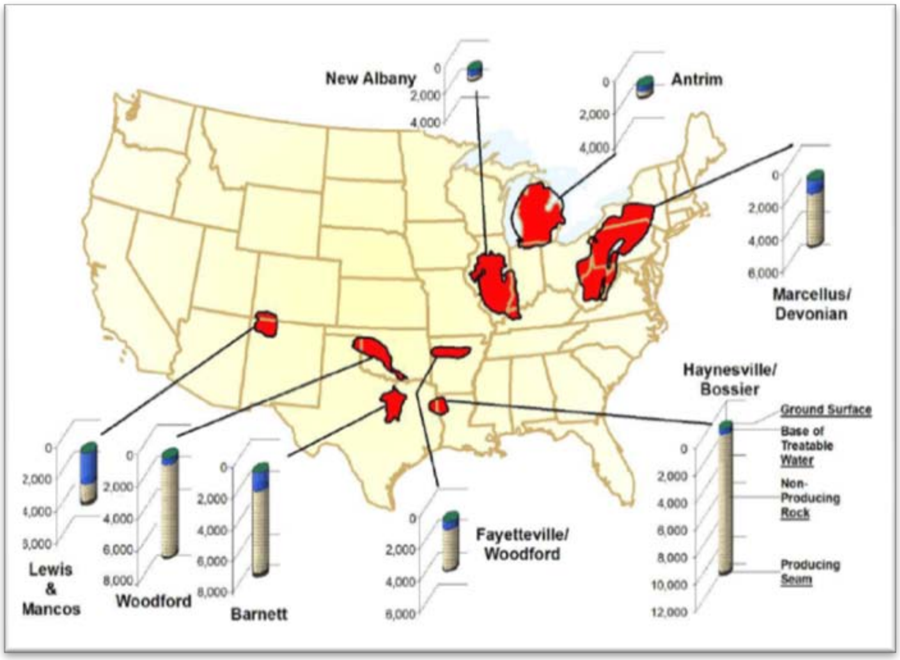
Table 5: Distance between shale formation and groundwater

Shale Formation and Treatable Water Depth			
Distance in feet			
Shale play	Depth to shale	Depth to base of Treatable water	Distance between shale and base of treatable water
Barnett	6,500- 8,500	1,200	5,300- 7,300
Fayetteville	1,000- 7,000	500	500- 6,500
Haynesville	10,500- 13,500	400	10,100- 13,100
Marcellus	4,000- 8,500	850	2,125- 7,650
Woodford	6,000- 11,000	400	5,600- 10,600

Source: Oil and Gas: Information on Shale Resources, Development, and Environmental and Public Health Risks

This viewpoint has been confirmed by the Groundwater Protection Council as well. The Council has reported: "with the notable exceptions of the shallow Antrim and New Albany Shales, many thousands of feet of rock separate most major gas-bearing shale formations in the United States from the base of aquifers that contain drinkable water." For example, in Marcellus shale there is 4,000 to 8,500 feet of distance between shale layers and groundwater (Zoback, Kitasei, & Copithorne 2010, p. 7) (see Figure 9). By the way the key aspect of the argument is that still there is no consensus on fracturing impact on sources of water.

Figure 9: Comparison of Target Shale Depth and Base of Treatable Groundwater



Source: GWPC (cited from Bipartisan Policy Center)

Air Pollution and Climate Warming

Methane is the main constituent of natural gas which is colorless, odorless and non-toxic, it is supposed that methane is a contributing factor in air pollution. It is said that drilling and fracturing directly causes air pollution, the issue occurs as the result of diesel smog or methane emission from flaring, evaporation pools, storage tanks, pig launcher/receiver, and compressors.

Air pollution occurs when wastewater evaporates from evaporation pools or when trucks and generators produce smog at the well sites. Heinberg mentions some illnesses that have occurred near shale sites, “skin rashes, open sores, nosebleeds, stomach cramps, loss of smell, swollen and itching eyes, despondency and depression” (2013, p.79). Volatile organic compounds (VOC) which are emitted from shale gas are key factors in the increase of air pollution. In 2013, Michael D. Holloway, and Oliver Rudd outlined these compounds: “propane, BTEX (benzene, toluene, ethylene, and xylene) constituents, and the six principal criteria pollutants classified by the EPA, nitrogen dioxide (NO_2), ozone (O_3), sulfur dioxide (SO_2**)**, particulate matter (PM), carbon monoxide (CO), and lead (Pb)” (2013, p. 90).

Another factor that cause**s** air pollution is burning of methane on the site because there are no adequate infrastructures to capture it. This burning is called flaring. A study conducted based on data from the National Oceanic and Atmospheric Administration (NOAA) indicates oil and gas activity increase 55% ozone pollution in Wattenberg field (Heinberg, 2013, p. 80). In comparison with CO_2, methane is decomposed rapidly and contributes to global warming. It is warned that if methane emission by industry cannot be controlled, the policy of gas substitution for coal would be ineffective ("Shale Gas Exploration and Production: Key Issues and Responsible Business Practices, Guidance Note for Financiers," 2013, March).

Heinberg has raised doubt over natural gas cleanness based on recent research which has done by Robert Howarth. He states that:

> As much as 1.9% of the gas in a typical well escapes to the atmosphere during fracking, compared with 0.01% in a conventional gas well. This turns out to make an enormous difference: over short time frames, methane is 20 to 100 times as powerful a greenhouse gas as carbon dioxide. If Howarth’s figures are accurate, this means that life-cycle greenhouse gas emission from shale gas is 20% to 100% higher than those from coal on a 20-year time frame basis (2013, p. 84).

Although critics have accused Howarth of overestimation, a study by the National Oceanic and Atmospheric Administration has declared that in the Wattenberg field 4% of methane leaks to the atmosphere. Also a research by ExxonMobil confirmed that 1% of methane emits to the air (Heinberg, 2013, p. 85).

It is important to point out that a significant discrepancy occurs over the scale of methane emission and the approach to measure it. Two optimistic and pessimistic views on climate change have been represented accordingly by the International Energy Agency and Cornell University:

IEA has suggested an optimistic view based on two cases: First, the best case in which gas is flared; second, the worst case in which gas is vented. It has reported:

> Total emissions from shale gas from production through to use (well-to-burner) are only 3.5% higher than when using conventional gas in the best case and around 12% higher in the worst case. This means that the emissions from unconventional gas, even in the worst-case scenario, are well below the amount of emissions from coal. (Heinberg, 2013, p. 32)

The pessimistic view is a study that has been conducted by Robert Howard. It explains methane emission from unconventional gas is 30% more than conventional gas, it is emitted from flow-back water to the air, Methane emission also occurs during storing and transportation of flow-back water ("Energy Independence & Sustainability? The Example of Shale Gas in the United States," 2012, November pp. 31-32).

IEA in *Golden Rules for a Golden Age of Gas* has reported that more greenhouse-gas is emitted through shale production compared to the conventional sources for two reasons: First, in hydraulic fracturing operators need to do more drilling in order to maintain the current rate of production, they use diesel motors and trucks to provide more energy, thus redoing the operation causes more CO_2 emission. Second, during well completion, flow-back water results in more venting and flaring (2012).

Both methane and CO_2 affect global warming, however controversy exists in evaluating the effect of methane and CO_2. Unlike CO_2, methane is a stronger greenhouse-gas with a shorter lifetime. IEA has reported:

> Averaged over 20 years, the GWP [global warming potential], estimated by the IPCC [Intergovernmental Panel on Climate Change], is 72. This figure can be argued to be more relevant to the evaluation of the significance of methane emissions in the next two or three decades, which will be the most critical to determine whether the world can still reach the objective of limiting the long-term increase in average surface temperatures to 2 degrees Celsius (°C). ("Golden Rules for a Golden Age of Gas World Energy Outlook Special Report on Unconventional Gas," 2012, November, p. 39)

Earthquake and Soil Contamination

Environmentalists argue that increasing earthquakes occur as the result of some micro seismic vibrations which are accomplished by fracturing treatment in order to optimize the efficiency. Prud'homme explains:

> As the number of wastewater injection wells has risen since 2001, the number of earthquakes measuring 3.0 or higher on the Richter scale in midcontinent regions that are usually seismically quiet has surged—from 50 in 2009 to 87 in 2010 and 134 in 2011, representing a six fold increase over last century. (2013, p. 110)

On the contrary the American Petroleum Institute in a report opposes the view that earthquake is triggered by hydraulic fracturing, it has announced: "A review of published research shows no cases of injuries or damage as a result of the very low level of seismicity related to this well-completion technique, which has been used in more than one million applications." Then it has concluded:

> As shown by the research, this well-understood phenomenon represents minimal risk to humans, animals, structures or the environment. Nonetheless, the industry has made safety a top priority and invests heavily in modeling and mapping the earth’s subsurface to constantly improve its understanding of fault lines and other geological structures. ("Hydraulic Fracturing :Unlocking America’s Natural Gas Resources," 2014, July p. 16)

By the way it seems fracturing activity has triggered weak earthquakes in Arkansas, Texas, Ohio, and Colorado. More important the number of quakes is on the rise, as the U.S. Geological Survey (USGS) has reported:

> In the last four years the number of quakes in the middle of the United States jumped eleven fold from the previous three decades. The largest yet measured, in central Oklahoma in November 6, 2011, was a magnitude 5.7 temblor tied to the injection of fracking wastewater. It was the biggest quake ever recorded in Oklahoma, destroying 14 homes, buckling a highway, and leaving two people injured. (Heinberg, 2013, p. 82)

Furthermore, fracturing threatens the environment by contaminating the soil which is near shale plays. For example, Heinberg argues that: “Heavy metals such as lead, mercury, cadmium, chromium, barium, and arsenic have been found in soils near natural gas drilling sites. And when fracking leads to increased ground-level ozone, plants are damaged by inhibited photosynthesis and root development.” (2013, p. 81)

Wastewater also contaminates the soil and affects livestock or wildlife; it causes neurological, reproductive and gastrointestinal disabilities. Toxic chemical penetrates into water and affects waterfowl and fish populations, it also creates problem for animals in mating or laying egg. Industrial activity including well pad or road construction requires lands to be fragmented, this fragmentation negatively affects farmlands and streams, it therefore threatens population of deer and elks (Heinberg, 2013, pp.82-83).

In response to the problem of soil contamination by hydraulic fracturing the proponents argue that people use chemicals like vinegar, dish soap, bleach or gasoline every day; the difference is that these chemicals with higher volume are used in workplace so it may pose threat to the environment or individuals. In order to remove the problem they suggest workers are required to be informed which chemicals are safe and which one needs to be handled safely. Hazard Communication standard was released in 1983 and it was revised in 2012 by OSHA's [Occupational Safety and Health Administration, the US agency under the Department of labor]. It provided information on how employers and employees can safely employ chemical materials. Michael D. Holloway and Oliver Rudd have set forth:

> The general public would be pretty surprised at how little chemical and products are stored on site during construction, drilling, and frack operations. For the most part, oilfield operations have become such a streamlined and efficient operation that operators will know how much of a given chemical product will be necessary and, for the most part, make all attempts to have the chemicals arrive on location as close to when needed as possible to avoid storage (2013, pp. 102-103).

Uncertainty over Shale Outlook

An ongoing argument has been developed in favor of or against hydraulic fracturing, yet for some reasons it seems implausible to come to a definite conclusion about its actual impacts:

First, because it is at the initial stages of progress insofar as there is serious doubt on it. Kalicki and Goldwyn point to public skepticism over shale development:

> The recent, yet rapid, impact of combining the old technologies of horizontal drilling and hydraulic fracturing accounts for some of the public skepticism. Many find it hard to believe that this new resource endowment is real or sustainable. Some resistance is born of fear. (2013, p. 3)

Second, there are different resources of hydrocarbons with distinct methods of assessment and extraction, while sufficient information on these issues is not available. Deborah Gordon, a director at Carnegie Endowment for International Peace, in a hearing session which was held in December 2014 on energy issue, said necessary information and more transparency are required to be generated so that policy-makers can come to a wise decision. He noted: “The truth is we know precious little about these new resources. The nation needs reliable, consistent, detailed, open-source data about composition and operational elements of U.S. oil. Significant information gaps have accompanied the Nation’s oil.”

Gordon said despite the fact that there are abundant hydrocarbon resources at home, oil is being traded in an interdependence market; so policy-makers need precise data to gain maximum benefit, but such data are unavailable. He remarked: “Ironically, there is more detailed open-source data about OPEC crudes than the oils in the Bakken, Permian, and Eagle Ford.” Gordon explained the lack of knowledge would pertain to a set of reasons: First, light tight oil is a new phenomenon. Second, the quality and features of shale formation in each plays are quite different so there are distinct oil assays which are unique to a particular play and are not comparable to each other. Third, the Energy Department cannot freely gather data because the industry sector provides such data, therefore the Department of Energy accesses the information that the industry reports out. He emphasized that oil data are mostly inaccessible because they are owned by big companies: “There is data that is owned by these big oil consultancies, and after negotiating for a matter about a year and hundreds of thousands of dollars, they were told that the data was not for sale because it is competitive. They do not want the academic sector to compete with the consulting sector."

Third, abundant shale resources are available in the United States; however in practice production from shale gas is more productive and beneficial than shale oil, because shale gas emits less carbon and provides more heat. This is while shale gas also encounters some obstacles that slow down the process of production. Kalicki and Goldwyn explain:

> Natural gas can only be transported by pipeline, or if it is liquefied for transport and regasified upon delivery. The world is awash in natural gas, but much of it is stranded far from the infrastructure needed to transport it. The political challenges that plague oil suppliers also plague suppliers of natural gas, and the risks of dependency on foreign gas are real, but for now [2005] less threatening. The United States' reserves of natural gas are dwindling or inaccessible for environmental reasons, and its demand will soon outstrip domestic supply. (2013, p. 10)

In short, distinct statistics and substantial discrepancy and evidences suggest that hydraulic fracturing negatively affects the environment, but the scale is uncertain. Also the scale of shale development is uncertain at present due to technological, economic and environmental changes.

Key point: Although environmental impacts call into question shale development, energy security is much more important than environmental impacts for policy-makers. Therefore in the pursuit of national interests, shale development may move ahead despite the destructive consequences. It maybe plausible to say that:

> The world has witnessed several major human and environmental disasters since 2007, each born of negligent energy operations and inadequate regulatory supervision and controls. The Macondo oil spill of 2010, the Fukushima nuclear meltdown of 2011, and reports of water contamination and methane emissions coinciding with shale gas development in Pennsylvania have made many wary of the energy boom." (Kalicki & Goldwyn, 2013, p. 3)

Chapter Three: Trend of Oil and Gas Production and Consumption in the United States

John Deutch, a professor at Massachusetts Institute of Technology and chair of shale studies in the U.S. Department of Energy, has stated that shale industry creates job and leads to more economic growth, “More jobs are being created in Pennsylvania and Ohio by shale gas production than anything else that I’m aware of”. Henry Jacob, the William F. Pounds Professor of Management, Emeritus in the MIT Sloan School of Management also has a positive view on shale development and the impacts it has on U.S. energy policy, “People speak of [natural] gas as a bridge to the future, but there had better be something at the other end of the bridge.” (Ekstrom, 2012, January) In 2012, Jacob along with O'Sullivan and Paltsev made a report the Influence of Shale Gas on U.S. Energy and Environmental Policy, which was published in Journal Economics of Energy and Environmental Policy. In the report they paid attention to the opportunities by shale development and noted: “We found much of what we already knew — which is a good thing — that shale makes a big difference. It helps lower gas prices, it stimulates the economy and it provides greater flexibility to ease the cutting of emissions. But it also suppresses renewable” (Ekstrom, 2012, January).

Bob Dudley, a chief executive of BP, give a speech at the World Affairs Council of America on energy crisis and energy security in 2013. He pointed to increasing trend of energy consumption in the world between 2011 and 2030 which would be about 36%, he said at that time oil would be the prominent fuel in transportation sector, Dudley remarked:

> We expect that 90% of our cars and trucks in 2030 will still run on gasoline or diesel. And we expect demand for oil to grow at about 0.8% a year. That may not sound a lot but it translates into an extra 16 million barrels a day worldwide - more than the current daily production of Russia or Saudi Arabia.

He explained that the idea of “peak oil” has already peaked because historically increasing demand for energy brings increasing innovation in energy sector. Dudley with the hope of a bright energy outlook expressed:

> With the right policies and incentives, we see no reason why the U.S. energy revival cannot go on well into the future. …I am confident that the energy sector can meet the challenge of fueling the future generations of the globe. And the reason I am confident is because we have already done it.

Hitherto, the preceding chapter has focused on shale potential for mass production of oil and gas. It has reviewed the size of available resources and technology which can turn potential of shale resources into actual production. Now the research continues to delve into level of energy supply and demand in order to examine contingency of energy self-sufficiency by means of shale resources. For more accuracy it has collected and compared data from distinct official agencies such as the British Petroleum (BP), the Organization of the Petroleum Exporting Countries (OPEC), and the Energy Information Administration (EIA). It is worth noting that this part does not intend to present an economic analysis, but it just aims to review level of energy production and consumption in order to come to a common point on this issue.

British Petroleum: Energy Supply and Demand in the World and the United States

In 2014, the British Petroleum published *BP Statistical Review of World Energy* in which the data illustrate despite stagnant economic growth in 2013, global energy consumption increased by 2.3%, of which 32.9% was dependent on oil. This is translated into a continuing demand for energy with oil as the prominent fuel in the future.

Meanwhile energy consumption of oil and gas in OECD [Organization for Economic Co-operation and Development] countries increased by 1.2%, this is while the United States (with 2.9% growth) accounted for all net increase in energy consumption of OECD and the European Union.

On the subject of oil consumption the report indicates it increased to 1.4 million barrels per day, 51% of consumption occurred in countries outside OECD. Although OECD countries have experienced the seventh decrease in consumption over the past eight years, the U.S. has recorded the largest increase in world oil consumption which was about 400,000 barrels per day. (Table 6) ("BP Statistical Review of World Energy," *2014*, *pp.* 2-28)

Table 6: Oil Consumption (Thousand barrels per day)

	2005	2006	2007	2008	2009	2010	2011	2012	2013	Change 2013 over 2012
United States	20,802	20,687	20,680	19,490	18,771	19,180	18,882	18,490	18,887	2.0%
OECD	50,078	49,888	49,690	48,085	46,057	46,509	46,040	45,545	45,558	- 0.4%
Total World	84,389	85,325	86,754	86,147	85,111	87,801	88,934	89,931	91,331	1.4%

Source: BP Statistical Review of World Energy, 2014

The data suggests that there is imbalance between growth of oil production and consumption in the world. In 2013, total oil production experienced %6 growth, which was about 550,000 barrels increase in production per day. The key point is that the U.S. had 1.1 million barrels per day increase in production which is regarded the largest growth in the world and in the country's history. BP reported: "the U.S. accounted for nearly all (97%) of the non-OPEC output increase of 1.1 million b/d (the strongest since 2002) to reach a record 49.9 million b/d." ("BP Statistical Review of World Energy," 2014, p. 3) While according to statistics, Canada had 210,000 b/d; Russia 150,000 b/d; and UAE 250,000 b/d growth in supply. (Table 7)

Table 7: Oil Production (Thousand barrels per day)

	2005	2006	2007	2008	2009	2010	2011	2012	2013	Change 2013 over 2012
United States	6,903	6,828	6,862	6,783	7,263	7,552	7,868	8,892	10,003	13.5%
OECD	19,902	19,465	19,151	18,440	18,445	18,547	18,601	19,492	20,523	5.6%
OPEC	35,170	35,489	35,161	36,279	33,978	35,088	35,911	37,427	36,829	- 1.8%
Total World	82,107	82,593	82,383	82,955	81,262	83,296	84,049	86,204	86,754	0.6%

Note: production included crude oil, tight oil, oil sands and NGLs

Source: BP Statistical Review of World Energy, 2014

On the subject of natural gas consumption, data illustrate that there was 1.4% increase in global consumption in 2013, yet it is below the historical average of 2.6 %. It is noticeable that China with 10.8% and the U.S. with 2.4% growth recorded the largest increase in consumption of natural gas, that is to say both countries accounted for 81% of growth in demand. (Table 8)

Table 8: Natural Gas Consumption (Billion cubic meters)

	2005	2006	2007	2008	2009	2010	2011	2012	2013	Change 2013 over 2012
United States	623.4	614.4	654.2	659.1	648.7	682.1	693.1	723.0	737.2	2.4%
OECD	1430.0	1430.9	1478.5	1501.2	1459.9	1551.8	1539.9	1573.9	1596.5	1.8%
Total World	2764.3	2839.6	2954.4	3027.7	2957.4	3180.8	3233.0	3310.8	3347.6	1.4%

Source: BP Statistical Review of World Energy, 2014

On the subject of natural gas production, data illustrate 1.1% growth, yet it is below the historical average of 2.5%. The U.S. has remained the leading producer in the world with 1.3% growth of production, while Russia with 2.4% increase and China with 9.5 % increase have recorded the larger growth in production. (Table 9)

Table 9: Natural Gas Production (Billion cubic meters)

	2005	2006	2007	2008	2009	2010	2011	2012	2013	Change 2013 over 2012
United States	511.1	524.0	545.6	570.8	584.0	603.6	648.5	681.2	687.6	1.3%
OECD	1084.3	1097.4	1101.2	1131.0	1128.7	1151.9	1170.0	1199.3	1200.0	0.4%
Total World	2778.6	2881.8	2962.7	3068.5	2981.0	3190.8	3287.7	3343.3	3369.9	1.1%

Source: BP Statistical Review of World Energy, 2014

According to BP statistics, the United States has consumed 18,887 thousand barrels of oil per day and has produced 10,003 thousand barrels (including crude oil, tight oil, oil sands and NGLs). Concerning natural gas, it has consumed 737.2 billion cubic meters of natural gas and has produced 687.6 billion cubic meters. With no doubt the United States has recorded growth both in production and consumption of oil and natural gas, but based on evidence it still requires import of crude oil in order to manage its energy demand. BP has reported the U.S. imported 7,719 thousand barrels of crude oil per day, and exported 112 thousand barrels of it per day in 2013.

OPEC: Energy Supply and Demand in the World and the United States

The Organization of the Petroleum Exporting Countries (OPEC) has provided a detailed statistical data about global supply and demand of energy. Although OPEC has reported 0.9% increase to global oil demand, OECD countries and the United States have experienced 1.1% and 1.8% decline in demand. Despite the fact that the U.S. demand for oil has decreased overtime, it seems self-sufficiency in energy still is not on the horizon. In 2012, the U.S. required 18,907 thousand barrels of oil per day (Table 10), trend of U.S. oil imports showed 4.7% decline this is while it managed its demand by import of 8,492 thousand barrels of oil per day. ("OPEC Annual Statistical Bulletin," 2013, pp. 20-60)

Table 10: World and the U.S. Oil Demand (Thousand barrels per day)

	2008	2009	2010	2011	2012	%change
United States	19,789.6	19,065.3	19,476.5	19,248.2	18,907.6	–1.8
OPEC	7,426.0	7,703.2	8,101.2	8,328.3	8,656.5	3.9
OECD	48,337.2	46,333.1	46,930.9	46,491.8	45,980.4	–1.1
Total world	86,067.8	84,780.4	87,187.2	88,103.8	88,868.5	0.9

Source: OPEC Annual Statistical Bulletin, 2013

Table 11: World Crude Oil Imports (Thousand barrels per day)

	2008	2009	2010	2011	2012	%change
United States	10,522.9	9,630.9	9,733.8	8,914.4	8,492.3	–4.7
OECD	30,808.7	28,255.5	28,516.7	28,778.0	27,632.0	–4.0
Total world	46,554.4	44,774.8	45,588.2	44,695.7	45,265.8	1.3

Source: OPEC Annual Statistical Bulletin, 2013

This is while contrary to decline in U.S. oil imports data illustrate it has experienced the most growth in its exports. It exported 60,000 barrels of oil per day in 2012 which represented 27.0% increase (Table 12). The increase in export could be the result of more production of tight oil, but it is important to know that tight oil produces light oil, while U.S. refineries are set up for heavy oil so United States needs to export light oil and instead continues to import heavy oil.

Table 12: World Crude Oil Exports (Thousand barrels per day)

	2008	2009	2010	2011	2012	%change
United States	39	44	44	47	60	27.0
OPEC	24,031.7	22,312.7	23,112.1	23,457.4	25,281.4	7.8
OECD	5,048	5,013	4,772	5,662	5,798	2.4
Total world	39,602	38,093	38,158	38,854	40,452	4.1

Source: OPEC Annual Statistical Bulletin, 2013

On the subject of natural gas, the world has followed a downtrend in volume of exports (0.3% decline), while the United States has followed an uptrend in volume of exports (7.4% growth), it exported 45,850 million cubic meters of natural gas in 2012. This upsurge occurred because hydraulic fracturing enhanced the efficiency of shale formation for commercial production. (Table 13) Subsequently the U.S. imports of natural gas experienced 8.7% decline and decreased to 88,360 million cubic meters. (Table 14)

Table 13: World natural gas exports (Million standard cubic meters)

	2008	2009	2010	2011	2012	%change
United States	27,280	30,370	32,195	42,681	45,850	7.4
OPEC	166,410	162,955	222,955	220,059	242,559	10.2
OECD	336,350	329,150	349,530	341,780	348,616	2.0
Total world	971,260	926,185	1,023,699	1,029,959	1,027,371	−0.3

Source: OPEC Annual Statistical Bulletin, 2013

Table 14: World natural gas imports (Million standard cubic meters)

	2008	2009	2010	2011	2012	%change
United States	114,350	105,000	105,925	96,830	88,360	−8.7
OPEC	33,570	33,940	35,284	42,419	37,486	−11.6
OECD	713,435.0	687,877.0	748,164.0	751,723.0	742,426.0	−1.2
Total world	974,355	904,068	989,580	1,026,620	1,020,939	−0.6

Source: OPEC Annual Statistical Bulletin, 2013

U.S. Energy Information Administration (EIA): Energy Supply and Demand

A closer look at data in Table 15 indicates a gradual uptrend in energy production and export, and downtrend in energy consumption and import since 2005. The trend may convince policy-makers that U.S. energy independence is on the horizon.

Table 15: Energy supply and demand in the United States (Quadrillion Btu)

	Production [a]	Consumption [b]	Imports		Exports	
			Natural Gas	Crude Oil	Natural Gas	Crude Oil
2000	57.366	84.731	3.869	19.783	.245	.106
2001	58.541	82.902	4.068	20.348	.377	.043
2002	56.834	83.699	4.104	19.920	.520	.019
2003	56.033	84.014	4.042	21.060	.686	.026
2004	55.942	85.819	4.365	22.082	.862	.057
2005	55.044	85.794	4.450	22.091	.735	.067
2006	55.938	84.702	4.291	22.085	.730	.052
2007	56.436	86.211	4.723	21.914	.830	.058
2008	57.587	83.551	4.084	21.448	.972	.061
2009	56.662	78.487	3.845	19.699	1.082	.093
2010	58.230	81.412	3.834	20.140	1.147	.088
2011	60.548	79.991	3.555	19.595	1.519	.100
2012	62.349	77.994	3.216	19.239	1.633	.143
2013	64.230	79.891	2.955	16.957	1.587	.284
2014 7-month	39.271	47.303	1.625	9.366	.915	.367
2013 7-month	36.927	46.319	1.733	9.843	.975	.148
2012 7-month	35.951	45.365	1.906	11.517	.910	.083

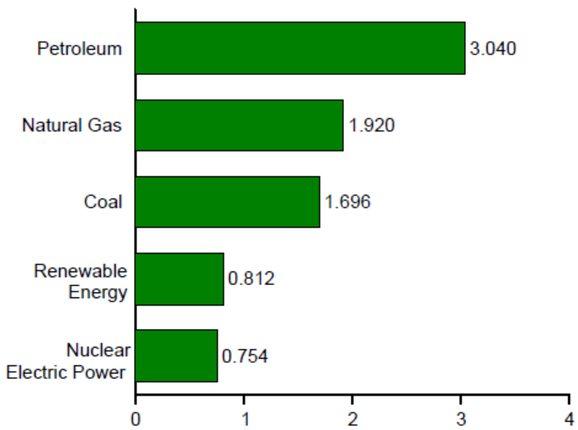
a : Coal, natural gas, crude oil, natural gas plant liquids
b: Coal, natural gas, petroleum

Source: Monthly Energy Review, October 2014 / 40th Anniversary Issue

Overall, energy is target of four main sectors: residential, commercial, industrial, and transportation. Transportation sector is mostly driven by oil because it has been adjusted to this type of energy, and it is easy to be stored and transported at a lower cost. On the one side oil-dependent transportation turns oil into a worthy commodity in the U.S. economy, on the other side oil is a crucial commodity for transportation because currently there are no proper substitutes for oil that can be used in a large scale (Figure 10, 11) ("Monthly Energy Review," 2014, pp. 21-75) (Crane et al., 2009, May, pp. 5-6).

Figure 10: U.S. Energy Consumption by Source, July 2014

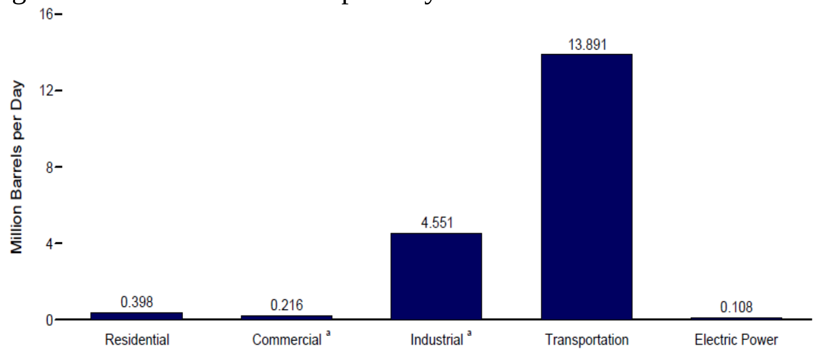
(Quadrillion Btu)



Source: Monthly Energy Review, October 2014 / 40th Anniversary Issue

In 2006, the U.S. Council on Foreign Relations announced that: "… liquid fuels are essential to the nation's transportation system. Barring draconian measures, the United States will depend on imported oil for a significant fraction of its transportation fuel needs for at least several decades." (Deutch, Schlesinger, & Victor, 2006, November, p. 14)

Figure 11: Petroleum Consumption by Sector



Source: Monthly Energy Review, October 2014 / 40th Anniversary Issue

Some energy experts state that global energy market will tie with oil and gas as the main source of energy:

> Despite an increase in the development of renewable energy technologies, oil and gas will remain the primary source for energy in the twenty-first century. …for at least the next twenty years, oil will be the dominant transportation fuel, and gas and coal will compete to be the fuel of choice for power generation. (Kalicki & Goldwyn, 2005, p. 17)

Table 16 displays a great dependence on oil particularly in industrial and transportation sectors. Although consumption has followed an unsteady downtrend, demand for energy is still substantial. It is important to note that part of this downtrend may be the result of policy of energy efficiency, and the other part may be the impact of economic recession which has been started since 2008.

Table 16: U.S. Energy Consumption by Source, July 2014 (Trillion Btu)

	Residential		Commercial		Industrial		Transportation	
	Natural Gas	Petroleum	Natural Gas	Petroleum	Natural Gas	Petroleum	Natural Gas	Petroleum
2005	4,946	1,451	3,073	761	7,907	9,633	624	27,309
2006	4,476	1,224	2,902	663	7,861	9,770	625	27,651
2007	4,835	1,254	3,085	649	8,074	9,451	663	27,763
2008	5,010	1,330	3,228	664	8,083	8,588	692	26,230
2009	4,883	1,161	3,187	663	7,609	7,814	715	25,375
2010	4,878	1,125	3,165	651	8,278	8,171	719	25,683
2011	4,805	1,052	3,216	641	8,481	8,108	734	25,264
2012	4,242	896	2,960	571	8,816	8,140	777	24,751
2013	5,053	939	3,368	586	9,078	8,386	795	25,022
2014 7-month	3,454	500	2,226	311	5,473	4,819	484	14,494
2013 7-month	3,180	587	2,032	376	5,241	4,723	466	14,418
2012 7-month	2,590	538	1,747	347	5,118	4,663	459	14,435

Source: Monthly Energy Review, October 2014 / 40th Anniversary Issue

The key aspect of the argument is that direct and indirect imports of crude oil and natural gas are two parts of one issue. Anthony H. Cordesman, a strategic analyst, argues statistical data only indicate direct imports which have been decreased and disregard indirect imports of energy. He believes transportation sector will remain dependent on liquid fuel imports as the result of indirect imports. In *American Strategy and US "Energy Independence"* Cordesman says:

> The U.S. imported some $2.3 trillion dollars worth of goods and services in 2012 – equivalent to some 17.5% of the U.S. GDP. They represented an immense volume of indirect imports of energy and well over one-third consisted of goods came from Asian and European states heavily dependent in gas and oil imports. None of the estimates of US import dependence – past, current- or future – take these indirect imports into consideration.…It is equally important to point out that the Energy Information Agency (EIA) of the Department of Energy does not estimate that the U.S. will ever achieve independence in the import of the liquid fuels the U.S. must have for its transportation sector in its reference case - which makes estimates to 2040. Regardless of what various other sources estimate, the U.S. government does

not project energy independence in this critical area even in terms of crude oil and other liquids in its most probable scenario. (2013, October p. 1)

Table 17: The Average U.S. Petroleum and Natural Gas Exports and Imports

	Petroleum (Thousand Barrels per Day)			Natural Gas (Billion Cubic Feet)	
	Imports		Exports [c]	Imports [d]	Exports [e]
	OPEC [a]	Non-OPEC [b]			
2005	5,587	8,127	1,165	4,341	729
2006	5,517	8,190	1,317	4,186	724
2007	5,980	7,489	1,433	4,608	822
2008	5,954	6,961	1,802	3,984	963
2009	4,776	6,915	2,024	3,751	1,072
2010	4,906	6,887	2,353	3,741	1,137
2011	4,555	6,881	2,986	3,469	1,506
2012	4,271	6,327	3,205	3,138	1,619
2013	3,720	6,138	3,621	2,883	1,572
2014 7-month	3,417	5,858	3,981	1,585	907
2013 7-month	3,753	6,174	3,421	1,691	966
2012 7-month	4,377	6,475	3,129	1,859	901

a: Algeria, Angola, Ecuador, Iraq, Kuwait, Libya, Nigeria, Saudi Arabia, Venezuela, other
b: Brazil, Canada, Colombia, Mexico, Netherlands, Norway, Russia, United Kingdom, U.S. Virgin Islands, other
c: Crude oil and petroleum products
d: Algeria, Canada, Egypt, Mexico, Nigeria, Qatar, Trinidad and Tobago, other
e: Canada, Japan, Mexico, other

Source: Monthly Energy Review, October 2014 / 40th Anniversary Issue

Increase in exports and decrease in imports of natural gas may provide support for U.S. self-sufficiency in this field, but it should be noted that oil has more significant role in U.S. economy than does natural gas particularly in industry and transportation sectors. (Table 16) At the same time energy analysts should not disregard the environmental, technical and financial factors that can pose shale development at risk in the long-term. (Table 17) All these factors imply in spite of shale development and upsurge in production of oil and gas the United States is still required to import oil.

As it has been noticed there are some uncertainties in downtrend of shale production, environmental consequences, and access to capital insofar as there cannot be a certain prospect for shale outlook (Rosenberg, 2014, February pp. 22-25). In the foregoing discussion, geology, technology, and environmental consequences came under scrutiny. The rest of this section deals with technical and financial factors that contribute to shale improvement.

Technical Factors: Downtrend of Production and Upgrading Refineries

The first technical factor that creates difficulty and uncertainty over shale development is a rapid decline in rate of production. Lou Pugliaresi, president of Energy Policy Research Foundation, in the House hearing session held on December 11, 2014 compared downtrend of production in conventional and unconventional resources:

> Traditionally, conventional oil had a very modest decline rate, maybe 5 percent, and a pretty high recovery factor, as much as 50 percent. …Even though we have this very high decline rate in these unconventional resources we have now, but we have to keep drilling, our recovery factor is quite small. Small improvements in this recovery factor are going to make a big difference.

Lou Pugliaresi pointed to high cost and less returns of hydraulic fracturing in the process of shale production, “If you look at a traditional hydraulic fracturing job, across the U.S., 40% of the frack jobs are very uneconomic in some ways. Or 40% of the preparation on a horizontal pipe is not working.”

It is projected that U.S. tight oil production will rise to 4.8 million barrels per day since 2018 to 2021 and then decline to 3.2 Mb/d in 2040, concerning shale gas production it is projected that it will rise from 9.7 (40% of total natural gas production) trillion cubic feet in 2012 to 19.8 (53% of total natural gas production) Tcf in 2040 ("Annual Energy Outlook 2014, with Projections to 2040 ", 2014, April, pp. 108-113).

David Hughes, geologist and an expert on energy resources of Canada for forty years, has conducted a comprehensive report called *Drilling Deeper: A Reality Check on U.S. Government Forecasts for a Lasting Tight Oil and Shale Gas Boom* in which he made detailed comments on government forecast over shale production. He believes U.S. shale production is unsustainable and projection by the EIA is optimistic, Hughes says:

> What this means is that the country's current energy policy—which is largely based on the expectation of domestic oil and natural gas abundance far into the future—is badly misguided and is setting the country up for a painful, costly, and unexpected shock when the boom ends. (2014, p. 4)

Hughes' report which has been released by the Post Carbon Institute is an in-depth assessment of well production through early- to mid- 2014 in major U.S. shale plays which are accounted for more than 80% of tight oil and shale gas production. It has examined the estimation by the Energy Information Administration and accused it of overestimation. For example, in 2011 the EIA revised the estimation of technically recoverable shale gas in the Marcellus play by 80%, and in 2014 it cut the estimation of tight oil in Monterey Formation in California by 96% (Hughes, 2014, p. 5).

The current production of tight oil is 3.7 million barrels per day of which two major plays-Bakken and Eagle Ford-account for 62% of the whole production. The EIA has estimated 8.8 and 10.8 billion barrels of tight oil will be produced in Bakken and Eagle

Ford by 2040, while the Post Carbon Institute projection is 6.8 and 7.8 billion barrels. Concerning this discrepancy Hughes (2014) notes:

> These projections are optimistic in that they assume the capital will be available for the drilling “treadmill” that must be maintained (roughly $188 and 210 billion is needed to drill more than 23,500 and 26,200 wells, exclusive of leasing and ancillary costs). This is not a sure thing as drilling in the poorer-quality parts of the play will require much higher oil prices to be economic. Failure to maintain drilling rates will result in a steeper drop-off in production. (p. 62)

The Energy Information Administration has projected there will be 19.2 billion barrels of tight oil between 2012 and 2040 from Bakken and Eagle Ford, while the Post Carbon Institute has projected the volume will decline to 13.9 billion barrels (Hughes, 2014, p. 144). David Hughes says:

> The consequences of getting it wrong on future tight oil production are immense. The EIA projects that the U.S. will be a significant oil importer in 2040. Although the flush of tight oil production is likely to peak before 2020 and decline thereafter at much more rapid rates than projected by the EIA, there is increasing pressure by industry to allow crude oil exports. The longer term geopolitical complications certain to arise given increased competition for available oil exports in a shrinking export market should be obvious. Rather than viewing tight oil as an unlimited bounty, it should be viewed for what it is—a short term reprieve from the inexorable decline in U.S. oil production. A sensible energy policy would be based on this prospect. (2014, p. 149)

Hughes has analyzed data on drilling and well production in seven tight oil plays including Bakken, Eagle Ford, Spraberry, Wolfcamp, Bone Spring, Austin Chalk, and Niobrara; these plays produce 89% of tight oil in the United States. On the subject of natural gas, he has taken into consideration the rate of production in seven shale gas plays including Barnett, Haynesville, Fayetteville, Woodford, Marcellus, Bakken, and Eagle Ford which account for 88% of shale gas production. He has concluded: “over the short term, U.S. production of both shale gas and tight oil is projected to be robust—but a thorough review of the production data indicates that this will be unsustainable in the longer term."(2014, p. 6)

According to the EIA the current production in U.S. tight oil plays is 3.7 million barrels per day, but the decline rate in major plays indicates production would not be remained at the level projected by the EIA later than 2020. (Table 18) It has been estimated Bakken and Eagle Ford which are accounting for 62% of current production would peak by 2017. The report by Hughes explains the decline rate of wells in 3-year average ranges from 60% to 91%, he has emphasized 98% of the EIA projection for tight oil has a "high" or "very high" optimism bias.

Table 18: Well decline rate in tight oil plays

Play	Average 3-Year Well Decline Rate	Optimism Bias Rating of EIA's Forecast
Bakken	85%	High
Eagle Ford	79%	High
Spraberry	60%	Very High
Wolfcamp	81%	High
Bone Spring	91%	Low
Austin Chalk	85%	Very High
Niobrara	90%	High

Source: Drilling Deeper: A Reality Check on U.S. Government Forecasts for a Lasting Tight Oil and Shale Gas Boom

The report has estimated that Bakken and Eagle Ford will produce 73,000 barrels of tight oil per day by 2040, while the EIA has estimated production will be over 1 million B/d.

On the subject of natural gas, the EIA has projected gas production will increase to 38 trillion cubic feet per year by 2040, however the report by Hughes has demonstrated the enduring production at the forecasted rate by the EIA would be problematic in the medium term, because most of the major shale gas plays are experiencing decline, barring

Marcellus, Eagle Ford, and Bakken. According to the report the decline rate of wells in 3-year average ranges from 74% to 82%. (Table 19)

Table 19: Well decline rate in shale gas plays

Play	Average 3-Year Well Decline Rate	Optimism Bias Rating of EIA's Forecast
Barnett	75%	Very High
Haynesville	88%	Very High
Fayetteville	79%	Very High
Woodford	74%	High
Marcellus	74-82%	Reasonable
Eagle Ford	80%	Very high
Bakken	81%	Conservative

Source: Drilling Deeper: A Reality Check on U.S. Government Forecasts for a Lasting Tight Oil and Shale Gas Boom

The EIA has reported that the current shale gas production in U.S. shale plays is 37 billion cubic feet per day in which Barnett and Marcellus account for 48% of production. It has estimated production will peak in 2016 with 377 trillion cubic feet of shale gas in the period of 2014 to 2040. On the contrary, the Post Carbon Institute has decreased the projection to 230 trillion cubic feet. Hughes argues that $6 billion investment per year is required for drilling in order to offset rate of production in Marcellus. This level of investment does not include leasing, infrastructure, and operating expenditures. In the case of Barnett, it requires $4 billion investment per year.

Hughes explains that the optimistic estimation of shale production has created false promises such as recovering domestic manufacturing, providing many jobs, lifting the oil export ban as the result of abundant domestic production, shifting the geopolitical policy of the U.S., and limiting carbon dioxide emissions. (2014, pp. 17-151)

As it has been discussed oil and gas extraction from shale rocks need intensive and costly drilling because 36 months after operation each well falls into 80% to 95% decline. Based on per-well production in significant shale plays, Arthur E. Berman, petroleum geologist, notes that shale production would not be viable commercially because of the decline rate of production and high expenditure. In an interview with James Stafford on March 5, 2014, he has argued:

> The idea that Texas shales will produce one-third of global oil supply is preposterous…. production growth in U.S. shale gas plays excluding the Marcellus is approaching zero; growth in the Bakken and Eagle Ford has fallen from 33% in mid-2011 to 7% in late 2013. (Heinberg, 2013, p. 58)

In 2000 there were 341,678 wells in the United States; this number was increased to 514,637 in 2011. This is while the EIA has estimated 410,722 more wells are needed to be drilled; the large number of wells means high cost and less return of capital. The key point is that $42 trillion capital is required to be invested per year in order to promote shale production or even keep it flat, this is while shale gas yielded only $33 billion revenues in 2012. Heinberg has translated this process into a "treadmill to hell", he underlines the uneconomical status of shale plays for mass production (2013, pp. 63-4).

Rafael Sandrea, IPC Petroleum consultant, has emphasized decline rate is considered a serious obstacle in the way of shale production. He says the recoverable estimation of gas is nearly 240 tcf, which will meet gas needs for less than 10 years. Robert Smith, a geologist, has hinted at high cost of shale drilling and says: "Horizontal drilling is suspended because operators reach a point where they are just burning cash." (as cited in Heinberg, 2013, pp. 65-66)

Heinberg does not agree with the forecast submitted by some agencies, he states: "Compared to actual 2011 production, these projections invariably overestimated world oil production levels. In projection of 2002, for example shale production had been overestimated by 13%, or 11 million barrels per day in 2011."(2013, p. 70) He has accused agencies of over-optimism which politically provide estimation in line with economic growth, Heinberg says:

> The International Energy Agency set up in 1970 to warn the world's industrialized nations about future oil shocks, evidently bows to pressure from the United States. Meanwhile, the U.S. Department of Energy's Energy Information Administration appears to make its forecasts of future oil production conform to politically comfortable assumption about economic growth. (2013, p. 71)

Raymond Pierrehumbert, professor of the University of Chicago has recounted this claim: "oil production technology is giving U.S. ever more expensive oil with ever-diminishing returns for the ever-increasing effort that needs to be invested."(2013, p. 72)

In November 2014, Adam Vaughan, editor of *Environment Guardian*, raised doubt over shale development especially in the United Kingdom. He stated: "Fracking's potential has been 'overhyped' by politicians and shale gas will not reduce energy prices or reliance on gas imports." Vaughan quoted from Jim Watson, professor of energy policy at the University of Sussex:

> Looking at the evidence base, it's very hard to support some of the statements made both by industry and some politicians that it's going to bring down prices, strengthen energy security or create jobs through cheaper energy any time soon. It may have an impact. But a lot depends on how fast shale develops. (as cited in the Guardian by Vaughan, 2014, November 11)

Another technical factor that makes shale outlook more uncertain is high expenditure of upgrading refining capacity, because most U.S. refineries are adjusted for heavy oil, while shale rocks produce light oil so these refineries are incapable of refining light oil inasmuch as small refineries around the U.S. are on the threshold of shutdown. Representative Green in the House hearing session on the issue of energy explained in the 1990s the United States mainly imported heavy crude oil from the Middle East so it had to set up its refineries for heavy crude oil, he said at that time $2.5 billion was required so that one refinery being adjusted to heavy crude oil, and now much more investment again is needed in order to upgrade these refineries for light oil.

In December 2014 in the same hearing session Sieminski, administrator at U.S. Energy Information Administration, hinted at high investment on upgrading refineries:

> Over the last decade, billions of dollars were invested in upgrading refineries in Texas, Louisiana, and elsewhere on the Gulf Coast to process heavy crude oil, and now we have a surplus of light crudes [from shale plays] and so it has created problems.

Sieminski explained the United States is in need of oil imports and the level will not necessarily go to zero because some refineries are adjusted to heavy crude oil, so they need to import crude oil, refine it and put the product on the market.

Financial Factors: Economic Profits and Energy return on investment (EROI)

Economic Profits

In 2014, Bloomberg reported that the U.S. shale development has posed at risk 30 million jobs in Europe because petrochemical or fertilizer companies are moving to the United States to take the advantages of investment in shale industry. Fatih Birol, chief economist of the International Energy Agency said: “Many petrochemicals companies in central Europe are moving out….thirty million jobs are in danger.” According to Bloomberg some foreign companies are going to invest about $72 billion in the U.S. shale industry (Sharma & Nguyen, 2014, July para. 3). Bloomberg declared foreign investors have reinforced development of U.S. shale, For example, $5.5 billion have been invested by Chinese companies not only for profit but also for the sake of learning the technology. Aloulou Fawzi, an energy economist at the Energy Information Administration said: “They want to learn the technology and have a partner that may help them later to develop their own [domestic] shale resources." (Larson, 2013, April, para. 2)

Bloomberg in more details reported that since 2008 to 2012, U.S. shale has attracted $133.7 billion investment, 20% of it was made by foreign companies. In 2013, Christina Larson reported at Bloomberg about the level of foreign investment in U.S. shale: "From Asia, Japanese companies have invested $5.3 billion; Indian companies $3.55 billion; and Korean companies $1.55 billion. From Europe, U.K. companies have invested $3.95 billion; French companies $4.55 billion; and Norwegian companies $3.38 billion."(Larson, 2013, April, para. 3)

Mineral rights, few financial hurdles, and some federal exemptions from tax, or environmental statutes convince multinational corporations to invest in U.S. shale industry. Economic profits have propelled decision-makers toward more development, exploration and exportation; for example, in 2011 Cheniere Energy Company was authorized by the U.S. Department of Energy in order to export shale gas. Later in November 2012, 18 other corporations were permitted to do the same (Rogers, 2013, February, p. 5). As of this writing, the U.S. government has planned to review 43 applications for LNG export licenses, and as a matter of fact 6 applications were authorized to export LNG to non-free trade agreement countries and three other applications including the Freeport LNG Development project, Cameron LNG, and Cove Point LNG have been granted permission for construction. In order to speed up the approval process, the U.S. Department of Energy has removed the necessity of environmental approval before submitting the request for export license (Bradshaw et al., 2014, November, p. 22).

The structure of U.S. market accelerates shale development; the market manages high risk and makes shale development more profitable by sharing the risk through joint venture. For example, private companies construct pipeline to transfer natural gas and make contract based on end-user terms, this type of contract reduces the risk of transforming natural gas to the market. The other market opportunity is a long-term lease for exploration and production of shale gas, which provides producers with more time to more drilling and operation (Forbes, 2013, September, p. 6).

According to a report by the U.K. Energy Research Center, although small operators and free market system were the driving force of shale development in the United States, the principle and primary driver was the role of U.S. government in the 1970s and 1980s, when it conducted scientific researches and tax incentive. (Jacoby, O'Sullivan, & Paltsev, 2011)

Deborah Rogers, former financial consultant in Wall Street, holds a pessimistic view she put aside shale opportunities and points to its challenges:

> It is interesting to note that while once the oil and gas industry exploited other regions of the globe to affect energy security for the U.S., it is now exploiting the U.S. to provide energy security to other regions, primarily Asia. These economies will pay the highest price and thereby offer the most profitability to the individual corporations. (2013, February, p. 5)

Rogers explains energy companies are not seeking environmental protection, economic prosperity of families, or producing chemical and fertilizer production, but they try to extract oil and gas as cheaply and efficiently as possible and sell it at high prices. She also claims there is a superficial growth in reserve because it is mostly based on financial trade not drilling operation, “In fact, approximately one quarter of their reserve growth has come from acquisitions rather than the drill bit, such as ExxonMobil’s acquisition of XTO Energy. This constitutes consolidation rather than organic growth.” (2013, p. 5)

Connection between financial market and energy companies has improved economic growth of these companies; otherwise they would remain small at the local level. Indeed oil and gas companies run two types of economics: a field economics that manages operation in the field, and Wall Street or "Street" economics that makes connection with investment bankers to move up share price. Deborah Rogers believes Wall Street analysts are the main supporters of U.S. shale, she says: "street economics has more to do with the frenzy we have seen in shales than does actual well performance in the field." (2013, February, p. 6) she has explained "Street" economics and "field" economics; here her explanation is quoted from *Snake Oil*:

> In order for a publicly traded oil and gas company to grow extensively, it must manage not only its core business but also the relationship it enjoys with its investment bankers. Thus, publicly traded oil and gas companies have essentially two sets of economics. There is what may be called field economics, which addresses the basic day-to-day operations of the company and what is actually occurring out in the field with regard to well costs, production history, etc.; the other set is Wall Street or "Street" economics. This entails keeping a company attractive to financial analysts and investors so that the share price moves up and access to the capital markets is assured.
>
> It was "street economics" rather than "field economics" that drove the gas glut and price rout, according to Rogers, who notes that the price decline "opened the door for significant transactional deals worth billions of dollars and thereby secured further large fees for the investment banks involved. In fact, shales became one of the largest profit centers within these banks in their energy M&A portfolios since 2010." She concludes that the glut was engineered in large measure "in order to meet financial analysts' production targets and to provide cash flow to support operators' imprudent leverage positions." When natural gas prices tanked, Wall Street began executing deals to spin assets of troubled shale companies off to larger players in the industry. Such deals deteriorated only months later, resulting in massive write-downs in shale assets. (Heinberg, 2013, pp. 211-213)

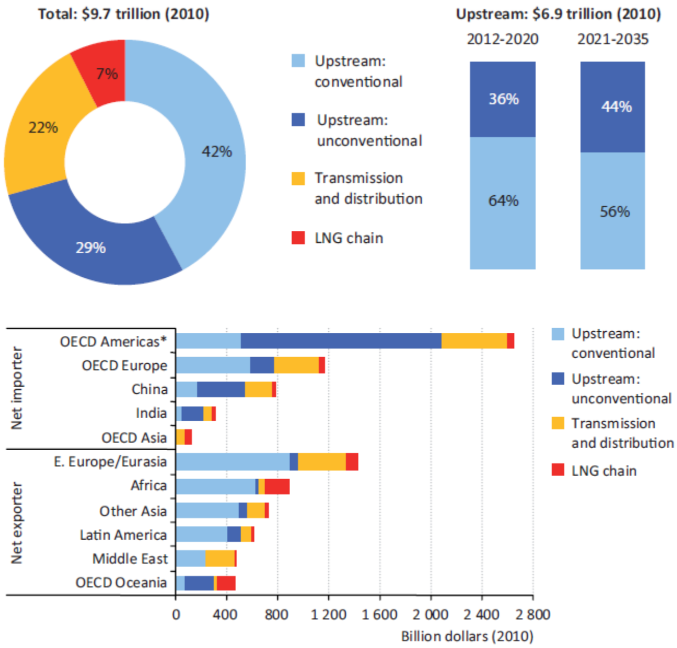
A relationship between shale investment and oil price is another challenge to shale development. Fatih Birol, chief economist in the International Energy Agency, says if oil price continues to decline or remain low, there will be 10% decline in the U.S. shale investment in 2015. Low investment consequently leads to decline in production (Rava & Hume, 2014, November).

The International Energy Agency conducted a report in which it proposed two scenarios for shale outlook. First, the Golden Rules Case which means "sees gas supply from a more diverse mix of sources of gas in most markets, suggesting growing confidence in the adequacy, reliability and affordability of natural gas"; second, the Low Unconventional Case which means "primarily because of a lack of public acceptance – only a small share of the unconventional gas resource base is accessible for development." The IEA estimated at the global level $9.7 trillion investment in both conventional and unconventional gas-supply infrastructure is required between 2012 and 2035 based on the Golden Rules Case. (Figure 12) It declared:

> Spending on gas exploration and development, to find new fields and bring them into production and to maintain output from existing ones, amounts to nearly $6.9 trillion, bolstered by the large number of new wells required.…Unconventional resources attract an increasing share of this upstream investment, about 36% before 2020 and 44% in the subsequent period to 2035.…Spending on exploration and development for unconventional gas in the United States alone is more than double total upstream spending in any other country or region. ("Golden Rules for a Golden Age of Gas World Energy Outlook Special Report on Unconventional Gas," 2012, November, pp. 88-90)

Investment in unconventional gas in the Low Unconventional Case would be $1.4 trillion, the United States contributes to 60% of the investment ("Golden Rules for a Golden Age of Gas World Energy Outlook Special Report on Unconventional Gas," 2012, November, pp. 88-98).

Figure 12: Cumulative investment in natural gas-supply infrastructure by major region and type in the Golden Rules Case, 2012-2035



Source: Golden Rules for a Golden Age of Gas, World Energy Outlook Special Report on Unconventional Gas, 2012

Energy return on investment (EROI)

The last factor that makes shale outlook more uncertain is the issue of energy price and energy return. In real economy any process of producing goods and services require energy. There is a relation between growth of GDP and oil price, it means in the case of low prices industry can consume more energy or specifically more oil and bring about more economic growth (Hall, Lambert, & Balogh, 2014, p. 142).

Regarding the available resources of energy there are two viewpoints: One group believes there are limited energy resources which will reach the peak soon or has already reached the point. Other group believes there are plentiful energy resources which are accessible by technological advances. The point is that both groups agree that cheap and easy to extract resources are no longer remained (Gagnon, Hall, & Brinker, 2009, p. 491). If the easier-to-explore resources are diminishing, it will be inevitable to turn to more expensive and hard-available resources which need more energy and money to be extracted. Nathan Gagnon at College of Environmental Science and Forestry, State University of New York notes the critical point is the amount of net energy, but not gross energy, and the role of technology that is believed can offset reserve depletion.

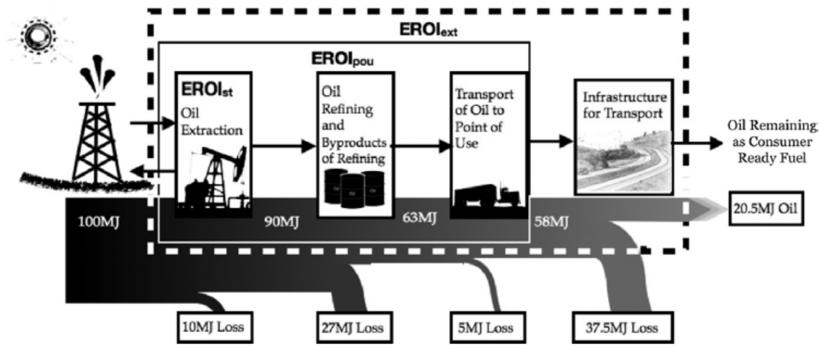
In order to study the profitability of resources observers need to assess energy return on investment (EROI). A low EROI indicates most of the produced energy should be used in process of production, but a high EROI indicates a small quantity of the produced energy is required to be used in circle of production so the majority proportion of energy can run the economy and increase productivity (Guilford et al., 2011; Gagnon, Hall, & Brinker, 2009 Gagnon Nathan, 2009). Energy return on investment is a technique to evaluate energy system, which means “the ratio of how much energy is gained from an energy production process compared to how much of that energy is required to extract, grow, etc., a new unit of the energy in question.” It is also called “the assessment of energy surplus., energy balance, or net energy analysis.” (Murphy & Hall, 2010, p. 102)

EROI is a broad concept in definition and methods of determining or application. It has different types:

I. Societal EROI: It focuses on total energy gains and total energy costs.
II. EROI at the mine-mouth: It focuses on the amount of energy which is required for discovering and producing fuel.
III. EROI at the point of use: It focuses on the amount energy which is required for discovering, producing, and delivering to the point of use.
IV. Extended EROI: It focuses on the amount of energy which is required not only for discovering, producing, delivering energy, but also for using energy, it means it assesses the amount of energy used by vehicles and other infrastructures, it also

focuses on the amount of energy which is used in order to construct highways or preserve the infrastructure. (Figure 13) (Hall, Lambert, & Balogh, 2014, p. 142).

Figure 13: Types of EROI



Source: EROI of different fuels and the implications for society

EROI examines direct energy (i.e., the required energy to rotate drilling bit) and indirect energy (i.e., the required energy to construct the drilling bit), both direct and indirect energy are required to supply a unit of energy. Indeed EROI is a method of quantifying the size of produced energy and its costs (Cleveland & O'Connor, 2011, p. 2309). The ratio would fall in the case of energy scarcity or difficult situation to extract oil and gas ("Energy Return On Investment - EROI," n.d.).

Charles A. S. Hall, system ecologist and professor at State University of New York in College of Environmental Science & Forestry says: "It [EROI] indicates whether a fuel is a net energy gainer or loser (and to what extent). EROI studies for most energy resources show a decline, indicating that depletion has been more important than technological improvements over time."(2012, p. 1) Hall points to flaws in EROI assessment, "different studies give different answers to what appears to be the same question, that the boundaries of the analysis are controversial, that market solutions are always superior to "contrived" scientific studies, and that EROI too often is dependent upon monetary data for its results." (2012, p. 4)

Nathan Gagnon, Charles A.S. Hall, and Lysle Brinker participated in a research to estimate global EROI for oil and gas production. They intended to evaluate the amount of produced energy in comparison with the amount of money used to gain this amount of energy. They believe:

> If the energy return on that invested by the industry is increasing over time, then we would have evidence that new technologies are currently outpacing depletion, and the converse. The rate of change of EROI may also give U.S. some indication of how close we are to the point at which it takes as much energy to extract the resource as we gain through its production. (2009, p. 492)

The article argues that EROI for global oil and gas production was 26:1 in 1992; it increased to 35:1 in 1999, and then declined to 18:1 in 2006. The researchers argue if EROI continues to decline, it will put the economic growth at risk (Gagnon, Hall, & Brinker, 2009, p. 490). They provide reasons for EROI decline and conclude:

> It appears that depletion is a somewhat more powerful force than technological improvement. A second, possibly equally important effect is that of drilling intensity. Previous studies have shown that exploitation efficiency in the petroleum industry declines when exploitation intensity increases. Exploitation intensity increased substantially from 1999 to 2008 in response to price increase. (Gagnon, Hall, & Brinker, 2009, p. 502)

U.S. EROI for oil was valued 100:1 at the beginning of oil industry, but later it declined to 20:1 (Rogers, 2013, February, p. 6). Megan C. Guilford, Charles A.S. Hall, Pete O' Connor, and Cutler J. Cleveland in another extensive research in 2011 acquired data on total energy gains and total direct and indirect energy cost in order to estimate EROI for both exploring and producing oil and gas at five-year intervals from 1919 to 2007. The research indicates decline in EROI, though it is not particular to shale resources:

> EROI for discoveries declined sharply from over 1200 to 1 for 1919 to 5:1 in 2007. EROI for production of the oil and gas industry(with no quality corrections) were about 20:1 from 1919 to 1972, declined to about 8:1 in 1982, when peak drilling occurred, recovered to about 17:1 during low drilling years 1986–2002 and declined sharply to about 11:1 in the mid-late 2000s. There is an inverse relation between the energy return on investment and the drilling rates so that after 1957 EROI tends to be higher when the drilling rate is lower. (Guilford et al., 2011, p. 1873)

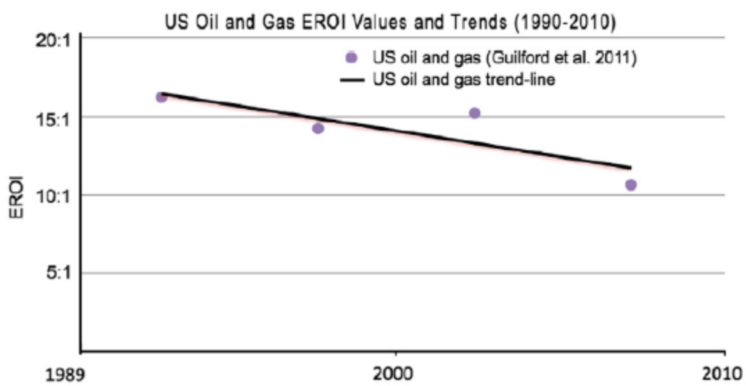
They discuss that since 1970, peak production of oil and gas with the maximum production of 9 million barrels per day has been decreasing. Since then, the highest production (with substantial contribution of natural gas) was 5 million barrels per day. Overall, U.S. EROI indicates a negative trend over time due to decrease in exploration and production of oil, and increase in energy cost. It is necessary to point that gas production has stayed flat as a result of substitution of unconventional resources for conventional resources. The researchers note the U.S. has experienced a decline in EROI which means depletion is more important than technology, if EROI follows a downtrend it will cause difficulty for society. They conclude:

> There are sources of energy that may delay the beginning of the end of cheap oil. Unconventional sources of oil such as tar sands, natural gas extraction through hydraulic fracturing and off shore drilling may add to our supply of energy but will probably be expensive once.…Technology has not alleviated the problem of decreasing EROI and may not be able to do that in the future as depletion of highest quality resources continues. Thus society probably faces a continuing decline in the EROI of both conventional oil and gas. The EROI of most alternatives to conventional hydrocarbons is also low, so that the EROI of the future seems unlikely to be high enough to support society as a whole in the format we are familiar with. (Guilford et al., 2011, pp. 1880-1881)

In 2013, Charles A.S. Hall, Jessica G. Lambert, and Stephen B. Balogh at College of Environmental Science and Forestry, State University of New York in an article pointed to downtrend of EROI. They explain from the 1970s to 1980s and late the 2000s extensive explorations increased oil price, meanwhile more exploration required more energy therefore EROI declined. (Figure 14) The researchers remark that in recent years high investments have been made on oil and gas development but EROI decreased in spite of increase in production. They add unconventional resources of tar sand and oil shale have also experienced a lower EROI of 4:1 and 7:1, they conclude:

> The decline in EROI among major fossil fuels suggests that in the race between technological advances and depletion, depletion is winning. Past attempts to rectify falling oil production i.e. the rapid increase of drilling after the 1970 peak in oil production and subsequent oil crises in the U.S. only exacerbated the problem by lowering the net energy delivered from U.S. oil production. (Hall, Lambert, & Balogh, 2014, p. 151)

Figure 14: The U.S. oil and gas EROI



Source: EROI of different fuels and the implications for society

In all articles the researchers, who are mostly environmentalists, put emphasis on low EROI and recommend fossil fuels need to be replaced with renewable energies because a decline in EROI makes investments on renewable technologies more feasible and profitable. Meanwhile they emphasize that the environmental consequences and health publics are not included in EROI assessment.

Access to capital is one of the challenges to shale outlook. On the subject of investment Kalicki and Goldwyn note: “the danger today [2005] is that there will not be enough oil to meet global demand at stable prices-not because America and the world are running out of oil, but because they are running behind on investment.” (2005, p. 2)

Although statistical data indicate U.S. shale has reduced imported oil and it has brought more energy security, a long-term impact on energy security is still uncertain due to the environmental consequences, necessity of investment in infrastructures, downtrend of production, and high expenditure to offset the decline. Meanwhile it must be remembered that energy interaction is carried out in an interdependence market that is influenced by many other geopolitical factors as well.

Chapter Four: Energy self-Sufficiency: the Application of Energy Statecraft and the Consequences on U.S. National Security

The Twenty First Century might be viewed as a transition era which has experienced rapid changes in international relations, politics, economy, and technology. Today, energy is considered not only a driving factor behind the industry but a strategic commodity that policy-makers use to pursue their political objectives. It is obvious that producer countries are able to tap energy as a powerful leverage, while consumer countries remain potentially vulnerable to disruption of energy. This section is an attempt to investigate the relation between energy and national security in the United States. For this purpose it first explains the concept of energy security, national security and then studies the relation between them. The research focuses on shale gas and tight oil in the United States and proposes term of “shale statecraft” in order to examine the consequences of U.S. shale development on its national security.

Concept of National Security and Energy Security

Security seems an ambiguous concept to define; it can be applied to a cultural, economic, psychological or military realm at the individual, national or international level.

National security was almost equivalent to military security by the early 1990s, because at the time of vulnerability and military threats all countries would provide their security through military measures. After the Cold War and geopolitical changes this definition was required to encompass some other factors other than military. Since then economic developments started to be the main part of the definition. And finally in the new era of the Twenty First Century military security appeared to be replaced with economic security. (Kadkhodazadeh et al., 2013, pp. 4-13) Indeed economic security and military security are some elements of national security. It is influenced by numerous national or international factors. In 2010, the White House released *National Security Strategy*, in which it listed some key factors that influence U.S. national security such as military supremacy, engaging in global leadership through international cooperation, establishing a strong foundation at home, decreasing oil dependence, intelligence and diplomacy. The report explains:

> Our national security depends upon America's ability to leverage our unique national attributes, just as global security depends upon strong and responsible American leadership. That includes our military might, economic competitiveness, moral leadership, global engagement, and efforts to shape an international system that serves the mutual interests of nations and peoples. ("National Security Strategy," 2010, p. 7)

In order to have a powerful national security some experts believe that U.S. policy-makers need a shift in their attitudes toward the structure of foreign policy. Kalicki & Goldwyn recommend:

> [policy-makers] must evolve from a more traditional foreign policy view, preoccupied with military security issues and relatively disconnected from the world of resources and economic forces, to a more modern view that addresses economic and political factors and recognizes that world events are determined far more by the flow of resources-human and material-than by the flow of officials and diplomats, or even soldiers. (2005, p. 14)

Energy security in political lexicon is defined as "a political technology and tool of governance", however it is susceptible to be "another colonial form of resource management" (Bridge, 2014, p. 9). Henry Kissinger notes: "aside from military defense, there is no project of more central importance to national security and indeed independence as a sovereign nation than energy security." (as cited in Stulberg, 2008, p. 3) According to Kalicki and Goldwyn energy security is:

> Assurance of the ability to access the energy resources required for the continued development of national power. In more specific terms, it is the provision of affordable, reliable, diverse, and ample supplied of oil and gas (and their future equivalents)-to the United States, its allies, and its partners-and adequate infrastructure to deliver these supplies to market. (2005, p. 9)

By affordable they mean “the ability to buy supply at relatively stable as well as reasonable prices”, by reliable they mean “predictable supplies that are less and less vulnerable to disruption”, by diverse and ample supplies they mean “ensuring that a large number of nations with hydrocarbon reserves produce them for the global market” (2005, pp. 9-10).

On April 24, 2013, Tom Donilon, former National Security Advisor to the President, gave a speech at Columbia University’s Center on Global Energy Policy, New York City. He emphasized that energy is the foundation of any economy, development and governance which can affect national interests, stability, security and relation between nations. Donilon stated: “Energy matters profoundly to U.S. national security and foreign policy. It matters because the availability of reliable, affordable energy is essential to our economic strength at home, which is the foundation for our leadership in the world.” Donilon outlined strategic impacts of U.S. shale on energy security and national security: strengthening of U.S. economy, strengthening of U.S. geopolitical power in international relations, supplying of energy to its allies, keeping engagement in the Middle East and the world in spite of less energy imports to the U.S.("The Comprehensive Transformation of the World's Energy Economy," 2013, p. 182).

According to Leon Fuerth the main threat to U.S. energy security is political instability in energy producing countries, but not inaccessibility and unavailability of energy resources. Fuerth explains that some oil-producer countries are dependent on force and monopoly of power this issue can expose at risk the political stability of these countries and cause disruption to a stable flow of oil supply (Kalicki & Goldwyn, 2005, p. 415).

Daniel Yergin explains that energy security is reinforced by some basic principles that are listed as: First, widening and diversification of energy resources, which mitigate negative impacts of any disruption. Second, policy makers have to keep in mind that there is a global oil market in which the United State is a part, but not independent of it, in this case the stability of the market, but not U.S. energy independency, is a key point to ensure U.S. energy security. Third, a “security margin” is required as a guarantee of security; it means in the case of any disruption extra supply is available. Fourth, oil market is a flexible market in which intervention or controls could be counterproductive, it means in the case of any political pressure policy makers needs to avoid micromanaging the market. Fifth, a cooperative relationship is required among energy producers and energy consumers based on common interests; this mutual interdependence ensures “security of demand” as well as “security of supply”. Sixth, the industry needs ongoing innovation and diversification in technology so that oil and gas resources are open to more exploration and production. Seventh, energy security requires commitment to extensive research and development with a considerable investment. (Kalicki & Goldwyn, 2005, pp. 55-58)

Relationship between Energy Security and National Security in the Context of History

Energy security has had a distinct meaning and implication overtime in the United States. In the 1950s, policy-makers protected energy security by stimulating domestic production of oil, indeed they aimed to ensure adequate supply of energy during the World War. In the 1970s, U.S. oil embargo by Arab countries convinced policy-makers that a decline in oil imports would strengthen U.S. energy security. In the 1980s and 1990s, energy security was provided by enhancing the economy of states against shocks of oil prices. Energy security has turned into an essential part of U.S. national security since the attack of September 11. The United States intends to preside over oil market so as to control dollar market in oil producer countries those who have conflicting interests against U.S. national interest. (Kadkhodazadeh et al., 2013, pp. 4-13)

William F. Martin and Evan M. Harrje delineate a relation between energy security and national security:

> The United States should lead this effort to modernize the IEA's mission because improving global energy security will dramatically enhance America's own national security. Energy can be a path to bring Russia and china closer to the United States, enabling America to avoid destructive competition and better manage issues of weapons proliferation and regional security. Bringing Brazil and India into the IEA's fold will help advance free trade in energy and improve regional stability in Latin America and South Asia. Enhancing the consumer-producer dialogue will enable the United States and other IEA members to constructively engage with the energy-exporting countries of the Middle East as they undertake potentially destabilizing but essential political and economic reforms. (as cited in Kalicki & Goldwyn, 2005, pp. 115-116)

Kalicki and Goldwin emphasize that there is an inevitable relation between energy and foreign policy:

> We also see energy as a powerful tool of U.S. foreign policy. Alleviating energy poverty can promote economic development and provide political motivation for better governance. Collective energy security in the twenty-first century, like collective military security in the twentieth century, can transform competitors into partners and allies." (2005, p. 11)

They make connection between energy security and national security and put:

> It should follow from this link between energy and security, and the world's increasingly risky sources of energy supply that the foreign and national security policies of the United States, its allies, and its partners would be closely integrated with their energy security needs. (2005, p. 5)

Consequences of Energy Dependence on U.S. National Security

Oil as a strategic commodity profoundly influences U.S. national security to the point that being dependent on or independent from oil affects U.S. strategic approach of foreign policy. Both oil exporting and importing countries have been using energy as a weapon to put pressure on opposing foreign states so that they change their policy. For example, the United States restrained purchase of oil from Iran; this measure posed domestic economy of Iran at risk. Embargo is one of the prevalent evidence of energy weapon which seriously affects economic interactions of a target state. Although discussing the effectiveness of oil embargo is beyond this study, it only points to some instances in the history in order to illustrate the strategic role of energy in international relations.

The history of oil embargo goes back to prior to World War II. During Italy invasion of Abyssinia (Ethiopia), the League of Nations restrained the export of oil to Italy. In 1941, the United States banned the export of oil to Japan with the aim that Japan withdrew from China. In 1956, Saudi Arabia imposed an oil embargo against France and England in response to their military operation in which they tried to take control of the Suez Canal. In 1967, an oil embargo by Arab countries occurred against the United States, England, and Germany because they supported Israel. In 1973 and 1974, OPEC members constrained the export of oil to the United States, the Netherland, Portugal and South Africa because they supported the Arab-Israeli War of 1973. Although oil embargo as an energy weapon has not been so successful in some cases, it created disruption to a stable flow of energy in target countries, and consequently undermined economic power and national security of those countries. (Crane et al., 2009, May, pp. 25-28)

Statecraft: A "Strategic Manipulation"

In the Twenty First Century energy has turned from an industrial commodity to a strategic commodity that influences both the economy and politics of states. Klaus Guimarães Dalgaard says: "Having access to energy supplies is crucial for the survival of a state both in security and in economic terms, and has been 'fundamental to any position of power in the world' since the Industrial Revolution," by quoting Michael Klare he brings into focus the importance of energy supply:

> But the wheels of industry are not the only ones to slow down without an abundant supply of energy; military forces are equally dependent on a copious infusion of critical fuels. For major powers like United States that rely on airpower and mechanized ground forces to prevail in conflict, the need for petroleum products multiplies with each new advance in weapons technology. (2012, p. 61)

According to Adam N. Stulberg statecraft is "the ability of one state to get another to do something that it would not do otherwise. Success rests on a state's ability ex ante to threaten credibly to punish, reverse, or reward a target state's behavior ex post", he argues that "a state can influence a target's policy choices by altering its decision-making situation.…states can manipulate a target indirectly by altering the opportunity costs and risks of compliance without precipitating a crisis." Moreover he notes " the key to strategic manipulation rests with a state's power to set the decision-making agenda for targets." (2008, p. 6)

There are some techniques of statecraft that policy-makers apply to influence a target state. These techniques include propaganda that is based on manipulating verbal symbols, diplomacy that is based on negotiation, economic statecraft, military statecraft (Kemburi, 2011, p. 158), and energy statecraft as a subset of economic statecraft. Economic statecraft brings into focus the intersection of economy and security, at the same time energy statecraft brings into focus the intersection of energy and security.

Economic statecraft might be used for either defensive (positive) or offensive (negative) goals; meanwhile it can be implemented bilaterally or systematically. A defensive economic statecraft is used as a shield by a given state in order to protect the status quo or domestic economic and political autonomy. An offensive economic statecraft is used as a sword by a given state in order to alter the international status quo or coerce smaller powers. In a bilateral form of economic statecraft "State A seeks to influence or defend against choices of State B", and in a systemic form "State A aims to influence or defend against world markets or global governance regimes"(Armijo & Katada, 2014, pp. 47-48). Negative energy statecraft aims to affect coercively the political or economic behavior of a given state through some measures like sanction, embargo, licensing denial, etc. Positive energy statecraft aims to commensurate the goals of foreign policy between an origin state and a target state through subsidies and incentives (Dalgaard, 2012, pp. 71-72). Stulberg conceptualizes energy statecraft:

> Similarly, energy statecraft involves increasing or decreasing access to a resource, as well as to related property rights, pipelines, investment capital, price and tariffs that are extended to deter, contain, or coerce a target. These tools of statecraft contrast with the value of military and diplomatic techniques that are generally stipulated in terms of violence, symbols, or negotiation. (2008, p. 17)

Stulberg also clarifies the strategic role of energy statecraft: "Notwithstanding obvious market concerns, energy security is fundamentally 'politicized,' as states allow foreign ambitions to alter their behavior in energy markets; employ political instrument to advance their position in energy markets; and exploit this standing to influence the strategic behavior of target states." (2008, p. 3)

Energy statecraft is distinct from energy security and energy diplomacy. As discussed earlier energy security implies an affordable, sustainable, reliable and diverse sources of energy, while energy diplomacy is used "by net energy importers to reach the objective of securing their energy needs" (Dalgaard, 2012, p. 66). Beyond these two consepts, according to Dalgaard energy statecraft means:

> *The use of a sender state's domestic energy resources as a means to get one or more other international actors to do what they would otherwise not do, in order to achieve the political goals of the sender state's foreign policy.* This is achieved by

> manipulating or exploiting another actor's fundamental need for energy security, without which energy statecraft is likely to be ineffective, if not an outright exercise in futility. (2012, p. 67)

Criteria of an Effective Statecraft: the Case of Shale Gas and Tight Oil

In order to examine the relation between energy and security and how states apply energy as a tool to achieve their strategic objectives the research has focused on conditionalist approach of statecraft. This approach calls to attention when and under what condition energy statecraft is expected to be effective. The effectiveness of statecraft not only pertains to the degree of state control over commercial actors but also to other factors that are required to be observed by a state. These factors are listed as:

I. The first factor is a commensurability between ends and means, in the case of shale gas and tight oil it means there should be an accessibility and availability of shale resources, technology and regulatory system because these issues can ease mass production of energy. Nevertheless there is a lack of commensurability between the means and ends of "shale statecraft" in the United States, Kalicki and Goldwyn call to attention this issue: "In the United States, the structural federal policy-making undermines the government ability's to understand market shifts and formulate and deploy energy policy to serve US interests."(2013, p. 1) Energy producer countries like Russia and Middle Eastern countries have integrated their energy policy with foreign policy while the United States appeared unsuccessful to do so, they explain:

> The failure of the United States to integrate energy and foreign policy is a failure of political will and leadership, not a failure of vision. Indeed, the national energy strategies of President Bill Clinton and President George W. Bush are remarkably similar. Both focus on conservation, efficiency, diversity of supply, and increased domestic production, although there are important difference over the value of drilling in environmentally sensitive areas. But

> they-and their predecessors-have been unable to make the necessary transition from energy vision to energy security. (Kalicki & Goldwyn, 2005, p. 6)

Moreover, some energy experts point to the situations that acknowledge there is no commensurability between the ends and means such as: inefficient U.S. regulatory system, excessive U.S. energy consumption, high cost of energy production and high Americans' expectation for cheap energy. They explain: "The disconnect between what Americans pay for energy and what it really costs them, have led to political deadlock." (Kalicki & Goldwyn, 2005, pp.6-7)

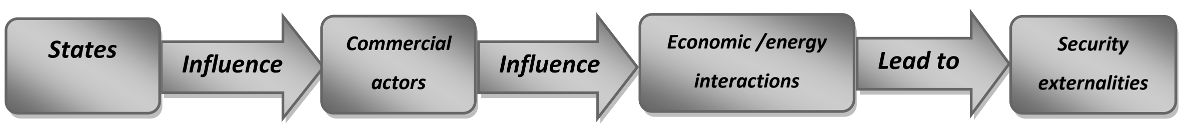
II. The second factor is the extent of state economic interaction and the extent of its dependence on this interaction. For example, a country whose trade presents 80% of its GDP would be at risk of disruptions of that trade in comparison with a country for whom trade has minimum influence on its economy.

III. "Strategic goods" and inelasticity of supply or demand for economic interaction are the third factor. For instance, if a state is dependent on light and sweet crude oil while there is lack of this commodity and no quick substitute for it, demand will be inelastic. In the case of inelastic demand economic statecraft would be more effective and successful against a target state (Norris, 2010, pp. 65-67). "Strategic goods" means "some goods have more strategic value than others. That is, for any given strategy, some things have more utility than others." According to Baldwin strategic value of a commodity is not intrinsic to that commodity itself but it depends on the function of a situation.

IV. The other factor of an effective energy statecraft is the ability of a given state to manage its economic interaction and control of the commercial agents (Norris, 2010, pp. 65-67). In the case of shale gas and tight oil in the United States, the government attempts to conduct the outcome by means of regulatory system and investment on research and innovation.

V. Finally, in order to have a successful energy statecraft it is necessary to understand the context in which it happens, “the utility of a technique of statecraft is a function of the situation and not a quality intrinsic to the particular technique.”(Baldwin, 1985, p. 123) Indeed a situational context in which the issue of providing energy security is taken place is translated into a determining factor for and effective energy statecraft.

Economic statecraft means there is a relation between economic interactions and security. This model can be also applied to energy statecraft or what this research terms “shale statecraft”, energy statecraft means there is a relation between energy and security externalities. These externalities might exert positive or negative effects on national security. A linear diagram of economic/energy statecraft is presented to indicate the relation between economy/energy and national security.



Negative Externalities’ Impacts on National Security

I. The first negative externality of “shale statecraft” for the United States would be a macroeconomic externality in a long-term. Sarah Ladislaw and her colleagues hold a bright prospect for shale production in a short-term, though they have doubt over viability of these resources and rate of production in a long-term. They declare: “Caution about the future is warranted: it is risky business to extrapolate long-term conclusion from a resources with such a short production history.”(Ladislaw, Leed, & Walton, 2014, p. 9) Besides, Heinberg points to the economic disadvantages of U.S. shale:

> Low prices have in turn been cited as economic benefits of shale development. Yet aside from having gained a PR talking point, the industry itself has actually been hurt by low prices. Chesapeake Energy has not only reduced drilling, but sold off hundreds of millions of dollars' worth of assets to cover unsustainable debt loads. BP has been forced to write off nearly two billion dollars in assets. Rex Tillerson, the CEO of ExxonMobil, told the Council on Foreign Relations in New York City in June 2012, "We're losing our shirts [on shale gas production]. We're making no money. It's all in the red." (2013, p. 210)

II. The second negative externality of "shale statecraft" would be public health and environmental externalities which have been discussed in Chapter 2.

Positive Externalities' Impacts on National Security

Job creation and revival of U.S. economy are among positive externalities of "shale statecraft". According to Kalicki and Goldwyn oil and gas production has been revived in the United States due to "…technological advances in energy production and consumption, increased private investment, and some wise government policies" (2013, p. 2). They state that energy revival has boosted U.S. economy:

> In 2012, reduced imports will have improved the US balance of trade by about $471 billion (in 2005 dollars). Oil and gas production and the construction of the infrastructure to carry that supply to market have been the third-largest source of employment growth since 2000. And October 2012 analysis indicates that unconventional oil and gas drilling will have led to creation of 1.7 million US jobs in 2012 and predicts that this number could increase to 3 million by 2020. It also finds that growing unconventional exploration and production will have added $62 billion to federal and states revenues in 2012. (Kalicki & Goldwyn, 2013, p. 2)

The point is that U.S. "shale statecraft" has internal and external functions: In internal function "shale statecraft" would be effective because it brings energy security by producing more energy, however in external function it may not be that much effective because a cheaper and more accessible conventional resources of energy are still available in the global market insofar as U.S. policy-makers cannot use “shale statecraft” to change behavior of the opposing states.

“Shale Statecraft” and Geopolitical Impacts

Political Consequences

The first political consequence of “shale statecraft” is the enhancement of U.S. energy security and weakening of the economy in countries with oil-dependent economy that have opposing interests against the U.S. Oil provides revenue for those countries that have resources of oil and gas, this revenue gives them chances to achieve international consensus over their political or economic objectives or threaten U.S. energy security (Crane et al., 2009, May, p. 3). This is while by means of shale production the United States can decrease dependence on imported oil from unstable region of the Middle East and increase its energy security.

Corrosion and Bolstering are two types of security externalities explained by William Norris. In the case of corrosion, an origin state weakens the domestic economy of a target state through economic interaction. For example, shale production would decrease U.S. oil imports; this reduction would decrease oil revenues in countries with oil-dependent economy and leave them incapable of defending their strategic interests. Instead, “shale statecraft” would enhance the domestic economy of U.S. allies by providing them with a more stable supply of energy and eliminate their dependency on unstable regions.

The second political consequence of “shale statecraft” is political realignment between producers and consumers of oil and gas. For example, China as a major energy consumer enters into alliance with producer countries in the Middle East or Africa. Also European countries like Germany or France desire to develop a closer relationship with Iran and Russia. The new realignments might wane U.S. leverage in the Middle East or Central

Asia (Deutch, Schlesinge, & Victor, 2006, November, pp. 26-27). This is while if there is a stable shale production, the realignment may shift from the East to the West in favor of America's interests. It could create new realignments between the United States and some European countries who try to replace U.S. shale gas with Russian gas.

The third political consequence is a less international tension over demand for energy. Oil scarcity leads to more competition or tension among importing countries, this is while abundant shale resources can assure a stable supply of energy and reduce the international tension (Crane et al., 2009, May, p. 3).

Economic Consequences

The first economic consequence of "shale statecraft" is growth of economy and foreign investment in the United States. Disruption to oil supply affects U.S. economic activity; for example, a high price of oil increases payments by consumers and subsequently reduces economic output or causes economic recession. (Crane et al., 2009, May, p. 5) There may be a perception that shale production will remove all these threats but it should be noted that oil is a global commodity that is influenced by the global market, thus any oil disruption even in the global market will affect U.S. domestic market.

The second economic consequence is a low price of energy. A High price and limited supply of oil and gas may cause a concern that the current market system is incapable of ensuring energy security, this concern may cause a high investment be transferred from the market to the producer countries. For instance, China has invested in infrastructure projects in Africa or in Saudi Arabia, such financial agreements may lead to political agreements with U.S. enemies or competitors. In 2006, the Council on Foreign Relations recommended that the U.S. authorities have to eliminate the concern over scarcity of oil supply:

> Opening a dialogue with rapidly growing consumers, notably China and India can help those consumers gain confidence that will lead to a greater willingness to allow markets to operate. The United States and other consuming countries have a tremendous interest in maintaining the present open market oil commodity trading rules. (Deutch, Schlesinger, & Victor, 2006, November, p. 28)

It seems the concern over scarcity of oil can be eliminated by means of more shale production. Proponents of U.S. shale assert that it will attract foreign investment to the United States; this issue can bring about multilateral economic and political agreements that strengthen U.S. national security.

The third economic consequence is a low defense budget; this viewpoint is supported by some strategists. The evidence suggests there is a direct relation between the U.S. defense budget and oil dependency especially on the Persian Gulf. Some strategists believe that if the United States and its allies reduce their dependency on imported oil therefore defense budget would be reduced. There is a perception that shale production will reduce oil dependency and therefore reduce defense budget, however in the view of some other experts, oil independence from the region would unlikely occur so soon because the U.S. refineries are mostly suited for heavy oil from the Middle East, while domestic shale resources produce light oil which is not compatible with the current refineries (Rosenberg, 2014, February). This is while setting up the refineries for light oil needs times and a considerable investment. In 2006, John Deutch, James R. Schlesinger, and David G. Victor in a report emphasize this issue:

> U.S. strategic interests in reliable oil supplies from the Persian Gulf are not proportional with the percent of oil consumption that is imported by the United States from the region. Until very low levels of dependence are reached, the United States and all other consumers of oil will depend on the Persian Gulf. Such low levels will certainly not be reached during the twenty-year time frame of this study .(2006, November, p. 29)

On December 11, 2014, Representative Barton in the House hearing session pointed to a type of crude oil [mostly unconventional production] which is produced in the United States, but cannot be refined or consumed there, so they have to export the surplus in order to take the opportunities:

> If we allow our producers to export the crude oil that cannot be consumed here in the united States or refined here in the United States, we put pressure on OPEC, we put pressure on Russia, we create jobs here at home, and we make sure that world price which sets the crude oil price is based on real supply and demand, and that is a good thing for everybody.

Also in the case of a rise in gas production by shale gas the United States can replace coal with natural gas and export coal surplus to countries that are in need of it. The shift from coal to natural gas will change flow of U.S. trade. It is expected that U.S. shale attracts profitable investment from the expensive or risky regions to the United States (Ladislaw, Leed, & Walton, 2014).

Some analysts believe that U.S. shale not only have influenced the domestic production, but also have enhanced its supremacy in global leadership. On the contrary some other experts downplay the geopolitical impacts of shale development:

> The United States has been involved diplomatically and sometimes militarily, but in general, neither the United States' strengthened economic position, nor its increased production of shale gas and tight oil, has afforded much discernible additional influence to the United States and its ability to influence the actions of other nations in these instances. (Ladislaw, Leed, & Walton, 2014, p. 25)

In another description about the geopolitical impacts of U.S. shale the Center for a New American Security has announced: "The U.S. unconventional energy boom is the source of an important new global oil supply and has the potential to test OPEC's tolerance for maintaining a smaller market share or sustained lower price."(Rosenberg, 2014, February p. 19)

Amy Myers Jaffe and Kenneth Medlock made a speech at Rice University in 2012 about the geopolitical impacts of shale gas that has changed energy perception only in 10 years. The experts proposed that unconventional resources are going to change the global energy perspective and shift back center of energy market to America. They addressed the impacts of shale gas that are listed as:

I. It eliminates U.S. LNG imports, it also decelerates LNG project in countries like Venezuela which has influence on LNG importing countries of Europe and Western Hemisphere.
II. It reduces Russian power in energy market, it also reduces share of Russia, Iran and Venezuela in gas supply.
III. It reduces Europe dependence on Russian supply of natural gas, thus reduces Russian power to interfere in European foreign policy.
IV. It reduces global demand for energy from volatile regions of the Middle East and North Africa.
V. It reduces competition between the U.S. and china over energy supply.
VI. It limits power of energy producing countries to tap energy as a diplomacy tool.

There are some perceptions and realities about U.S. shale. Some analysts pay no attention to reality of shale development, but to perceptions. They perceive that the increase in shale production would lead to decrease of energy transition through the sea; therefore the prominent role of the United States in sea protection would diminish. Also due to upsurge in shale production the U.S. would become less interested in oil and gas from the Middle East or North Africa, therefore it would become less involved in preserving the stability of the region, thus abandon the responsibility to China or Russia as major powers in the region (Ladislaw, Leed, & Walton, 2014, pp. 12-27).

Charles L. Glaser, Professor of Political Science and International Affairs, believes that shale production plays no crucial roles in strengthening of the U.S. energy security because oil trade occurs in a global market so any disruption to supply or price would negatively affect U.S. energy security as well, either the United States imports large or small quantity of oil. Instead he points to the threat of a high consumption that put stability of U.S. economy at serious risk:

> Even if the United States achieves oil independence, its economy would remain sensitive to disruptions in the global supply of oil and, in turn, to global prices. … The standard policy prescriptions include reducing U.S. oil consumption—most importantly, by increasing the efficiency of the transportation sector and taxing gasoline—and cushioning the U.S. economy from disruptions. (Glaser, 2013, pp. 115,143)

According to a report by the Baker Institute shale gas development will strengthen U.S. economy just in the case of commercial, full and timely development of shale resources, this is while the essential requirements for shale development are investment and regulatory system which are encountering a high degree of uncertainty at the present time (Medlcok Kenneth B. , 2011).

Chapter five: Conclusion

U.S policy-makers believe that the U.S. shale has brought a bright prospect for the energy market insofar as it has created an expectation that the United States will soon become a net energy exporter. While this viewpoint is mostly supported by the government and commercial actors, environmentalists, geologists, or some energy experts take an opposite viewpoint. They believe there is an overestimation on shale prospect.

This research acknowledged there is no consensus on shale outlook in the United States because there are many uncertainties over the effects of shale production on the area of economy, politics, environment, and technology. These uncertainties make findings of the research too tentative as well.

In order to investigate U.S. shale potential of energy self-sufficiency in a long term the research just took technical factors into consideration. It concluded that the U.S. self-sufficiency in energy is unlikely to occur due to the environmental and economic impediments that are listed as:

I. The availability or accessibility of resources is a main point in the way of shale development. The research brought into focus the distinction between a resource and a reserve which makes difference in estimation of a reservoir. It means estimation of a resource differs with that of a reserve. Profitability of a reserve pertains to technological advances, energy prices and economic conditions. By economic conditions it means under stagnant economy shale production cannot be cost-effective. In general, this part concluded that although substantial resources of shale gas and tight oil are available in the United States, the vast size of resources may not necessarily lead to profitable production. Besides a precise assessment for future production would be problematic and uncertain because U.S. shale plays are widespread in formations and characteristics, therefore features and rate of production in one play cannot be attributed to the other plays. Meanwhile these plays are just recently experiencing mass production insofar as a precise estimation would n ot be possible. In other words, the current rate of production may not be a reliable indicator of future rate because energy prices, technological advances, or environmental consequences would affect a stable supply of energy despite the fact that there are abundant available resources.

II. The environmental consequences are important impediments in the way of shale development. An inconclusive debate has still remained over uncertain consequences of hydraulic fracturing on the environment and human health. Opponents of hydraulic fracturing or environmentalists believe that there are negative impacts while proponents argue that there is an environmental track record on the process which indicates no serious warning. Water contamination and consumption, air pollution, climate warming and earthquake are among those serious consequences that have raised public concerns since 2010, therefore the respective agencies called for an extensive effort to inspect and examine these impacts. For example, the U.S. Environmental Protection Agency seeks for strict regulations on hydraulic fracturing in order to decrease the environmental consequences.

III. The trend of U.S. energy production and consumption affects conclusion of the research as well. As it was discussed in Chapter 3, the U.S. industry and transportation system are highly dependent on oil rather than gas, while the data suggest the U.S. has recorded upsurge in production of shale gas more than tight oil. Increase in exports and decrease in imports of natural gas may provide support for U.S. self-sufficiency in energy, but it should be noted that oil has more significant role in U.S. economy than does natural gas, particularly in industry and transportation sectors, which cannot be easily and completely replaced in a short-term. Kalicki and Goldwyn explain that maybe the U.S. could reduce its dependency on oil and gas by a long-term policy of "advanced automotive technologies, alternative fuels, the promotion of hybrid vehicles, and the accelerated development of hydrogen technology", but this aim is hardly achievable because "dependence on gasoline is its greatest unchecked vulnerability, and it cannot reduce this dependency unless it addresses transportation." (2005, p. 566) The authors discuss that "natural gas offers a future bridge from excessive oil dependence to the hydrogen-based economy, but the future is not yet here….Yet the day when natural gas can serve commercially as a fuel or feedstock for transportation fuel is visible but not upon us." (p. 565)

IV. Downtrend of shale production is the last important point that makes difficulty in the way of shale development. To offset the decline shale resources require intensive drilling and much more expenditure.

In November 2014, Adam Vaughan, editor of *Environment Guardian,* said: "Fracking's potential has been 'overhyped' by politicians and shale gas will not reduce energy prices or reliance on gas imports." Vaughan quoted Jim Watson, professor of energy policy at the University of Sussex:

> Looking at the evidence base, it's very hard to support some of the statements made both by industry and some politicians that it's going to bring down prices, strengthen energy security or create jobs through cheaper energy any time soon. It may have an impact. But a lot depends on how fast shale develops. (as cited in Guardian by Vaughan, 2014, November 11)

In short, U.S. shale resource is unlikely to bring self-sufficiency in energy by itself. America is in need of other policies to become energy self-sufficient, these policies can be resource diversification, energy efficiency and conservation in order.

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Appendix

Glossary[1]

Annulus:The space between the casing and the wellbore or surrounding rock.

Aquifer*:* A body of rock that is sufficiently permeable to conduct groundwater and to yield economically significant quantities of water to wells and springs.

Basin: A closed geologic structure in which the beds dip toward a center location; the youngest rocks are at the center of a basin and are partly or completely ringed by progressively older rocks.

Casing: Steel piping positioned in a wellbore and cemented in place to prevent the soil or rock from caving in. It also serves to isolate fluids, such as water, gas, and oil, from the surrounding geologic formations.

Coal bed methane (CBM)/coal bed methane gas (CBMG): A clean-burning natural gas found deep inside and around coal seams. The gas has an affinity to coal and is held in place by pressure from groundwater. CBMG is produced by drilling a wellbore into the coal seams, pumping out large volumes of groundwater to reduce the hydrostatic pressure, and allowing the gas to dissociate from the coal and flow to the surface.

Directional drilling: The technique of drilling at an angle from a surface location to reach a target formation not located directly underneath the well pad.

Flow-back water:The water that returns to the surface from the wellbore within the first few weeks after hydraulic fracturing. It is composed of fracturing fluids, sand, and water from the formation, which may contain hydrocarbons, salts, minerals, naturally occurring radioactive materials.

Fracturing fluids: A mixture of water and additives used to hydraulically induce cracks in the target formation.

[1] . Source: Cited from *Hydraulic Fracturing and Shale Gas Production: Technology, Impacts, and Regulations* by C. Clark, A. Burnham, C. Harto, and R. Horner. Also cited from *Environmental Impacts of Hydraulic Fracturing* by Frank R. Spellman

Horizontal drilling: A drilling procedure in which the wellbore is drilled vertically to a kick-off depth above the target formation and then angled through a wide 90-degree arc such that the producing portion of the well extends horizontally through the target formation.

Hydraulic fracturing (fracking or fracing):A stimulation technique performed on low-permeability reservoirs such as shale to increase oil and/or gas flow from the formation and improve productivity. Fluids and proppant are injected at high pressure and flow rate into a reservoir to create fractures perpendicular to the wellbore according to the natural stresses of the formation and maintain those openings during production.

NORM: Naturally occurring radioactive materials; includes naturally occurring uranium-235 and daughter products such as radium and radon.

Play:A geologic area where hydrocarbon accumulations occur. For shale gas, examples include the Barnett and Marcellus plays.

Produced water:The water is brought to the surface during the production of oil and gas. It typically consists of water already existing in the formation, but may be mixed with fracturing fluid if hydraulic fracturing was used to stimulate the well.

Propping agents/proppant: Silica sand or other particles pumped into a formation during a hydraulic fracturing operation to keep fractures open and maintain permeability.

Proved reserves: That portion of recoverable resources that is demonstrated by actual production or conclU.S.ive formation tests to be technically, economically, and legally producible under existing economic and operating conditions.

Quadrillion Btu: 1 Btu = 251.9958 cal; "BTU stands for British Thermal Unit, a measure of energy. One BTU is not much: it's equal to 0.25 food calories. Because a single BTU is so small, energy is usually measured in thousands or millions of BTU. For entire economies, energy is measured in quadrillion BTU, or "quads" for short. A quadrillion is equal to 1015.”

Reclamation: Rehabilitation of a disturbed area to make it acceptable for designated U.S.es. This normally involves regarding, replacement of topsoil, re-vegetation, and other work necessary to restore the area.

Shale gas*:* Natural gas produced from low-permeability shale formations.

Slick water: Water-based fracturing fluid mixed with a friction reducing agent, commonly potassium chloride.

Stimulation: Any of several processes used to enhance near-wellbore permeability and reservoir permeability.

Sulfur dioxide (SO2): A colorless gas formed when sulfur oxidizes, often as a result of burning trace amounts of sulfur in fossil fuels.

Technically recoverable resources*:* The total amount of resources, discovered and undiscovered, thought to be recoverable with available technology, regardless of economics.

Total dissolved solids (TDS): The dry weight of dissolved material, organic and inorganic, contained in water and usually expressed in parts per million.

Tight gas: Natural gas trapped in a hard rock, sandstone, or limestone formation that is relatively impermeable.

Tight sand: A very low or no permeability sandstone or carbonate.

Wellbore*:*Also referred to as borehole. This includes the inside diameter of the drilled hole bounded by the rock face.

Wellhead:The structure on the well at ground level that provides a means for installing and hanging casing, production tubing, flow control equipment, and other equipment for production.

Bcf: Billion cubic feet, a gas measurement equal to 1,000,000,000 cubic feet.

Btu: British thermal unit, the amount of energy required to heat 1pound of water by 1°F.

Tcf: A natural gas measurement unit for one trillion cubic feet.

Mcf: A natural gas measurement unit for 1000 cubic feet.

MMcf: A natural gas measurement unit for 1,000,000 cubic feet.

History of Hydraulic Fracturing Regulations

Year	Action	Entity	Comments
1940s to present	Adoption of state natural gas and oil regulatory programs	All natural gas and oil producing states, including OK, TX, LA, CO, WY, PA, etc.	States have adopted their own comprehensive laws and regulations to protect drinking water supplies including the regulation of hydraulic fracturing. These states' programs have been refined over the years, as necessary, to address industry changes.
1974	Safe Drinking Water Act (SDWA)	Safe Drinking Water Act (SDWA)	Act drafted to protect health by regulating nation's public drinking water supply.
1996	Legal Environmental Assistance Foundation, Inc. (LEAF) vs. EPA U.S.	US EPA	Alabama regulation of hydraulic fracturing in CBNG stimulations under the Underground Injection Control (UIC) program.
2003	Memorandum of Understanding (MOU) between US EPA and service companies	US EPA	Major service companies agree to refrain from using diesel fuel in hydraulic fracturing fluids in stimulations involving underground sources of drinking water (USDWs) associated with CBM wells.
2004	Evaluation of Impacts to USDWs by Hydraulic Fracturing of CBM Reservoirs Final Report	US EPA	Study evaluated potential threat to USDWs from injection of hydraulic fracturing fluids into CBM wells. Concluded that injection of hydraulic fracturing fluids into CBM wells poses minimal

			threat to USDWs.
2005	Energy Policy Act	US House	Clarified that hydraulic fracturing (exception for diesel fuel) was not underground injection as defined in SDWA
2009	Frac Act Introduced	US Congress	Act would require chemical disclosure of hydraulic fracture fluid additives.
2010	Wyoming natural gas and oil Regulations	State of Wyoming	Full chemical disclosure of fracturing fluids regulations put into place.
2010	State Regulations	Various	Multiple State regulatory bodies and legislators studying or enacting regulations on disclosure of hydraulic fracturing fluids.
2010	Hydraulic Fracturing Study	US EPA	EPA announces commencement of a new study investigating the possible relationships between hydraulic fracturing and drinking water.
2011	Establishment of SEAB (Secretary of Energy Advisory Board) Natural Gas Subcommittee	U.S. DOE	The frack panel was established to provide recommendations to the SEAB on how to improve the safety and environmental performance of natural gas hydraulic fracturing from shale formations.
2011	EPA Regulation Review	US EPA	EPA initiates process to develop guidance for diesel use in UIC operations.

Source: cited from *Safe Drinking Water Act (SDWA)* by Hagemeier Paul D., Harvey Stephen J., Fowler William M., Hummel Leslie A., Morris Douglas W., Guy, IV John H.