

Beyond the Boom:

Developing Policy to Advance US Leadership in Shale Oil and Hydraulic Fracturing



TASK FORCE 2014

UNIVERSITY OF WASHINGTON

HENRY M. JACKSON SCHOOL
OF INTERNATIONAL STUDIES



Cover Photographs

Left: J. H. Fair. Environmental Health Perspectives. "*A lined impoundment receives waste at a fracking site in Dimock, Pennsylvania.*" Digital Image, 2014. Available from:
<http://ehp.niehs.nih.gov/122-a50/>

Top Right: United States Geological Survey. Untitled media. Digital image, 2004.
<http://pubs.usgs.gov/fs/2002/fs049-02/>.

Bottom Right: United States Department of Labor. "*Well pad with hydraulic fracturing equipment.*" Digital Image. Available from:
https://www.osha.gov/SLTC/etools/oilandgas/well_completion/well_completion.html.

All trademarks mentioned in this report remain the property of their owners. Their inclusion in this report should no way be taken as an endorsement of this report or its conclusions by the trademarks owners.

Printed at the University of Washington in Seattle, Washington

THE HENRY M. JACKSON SCHOOL OF INTERNATIONAL STUDIES
UNIVERSITY OF WASHINGTON, SEATTLE
Task Force Report 2014

Beyond the Boom:

Developing Policy to Advance US Leadership in Shale Oil and Hydraulic Fracturing

Faculty Advisor:

Scott L. Montgomery
*Affiliate Faculty, Jackson School of International Studies
University of Washington, Seattle*

Evaluator:

Julia Nesheiwat
*Deputy Assistant Secretary of State for Implementation
Bureau of Energy Resources
US Department of State*

Task Force:

Sarah Coney (*Coordinator*)
Nikolina Stoykova (*Editor*)
Kailyn Swarthout (*Editor*)
Allison Ashmore
Zoe Barker-Aderem
Kelly Gould
Davita Gurian
Syailendra Kamdani
Khiem Nguyen
Mengqin Ouyang
Monica Reeder
Rebecca Snyder
Stephanie Tam
Emily Vyhnanek
Chieh-Hsi Wang
Ola Wietecha

Table of Contents

Acknowledgements.....	iv
Acronyms.....	v
Introduction.....	1
Part I: Why Shale Oil and Why Now?: How Unconventional Drilling has Transformed the Oil Industry	
1. History of Shale Oil and Fracking.....	4
2. Federal, State, and Local Regulations.....	17
3. Global Perspective: World Oil Reserves.....	32
Part II: Status of the Shale Oil “Revolution”: US and Beyond	
4. Current Development of Shale Oil in the US.....	45
5. The Global Dimension: Resources, Development, and Regulations.....	68
Part III: Environmental Concerns and Responses	
6. Air and Water Pollution.....	91
7. Transportation of Shale Oil.....	108
8. Opposition to Fracking and Responses.....	121
9. Science Controversies.....	138
Part IV: Security and Energy Diplomacy	
10. Energy Security Issues.....	148
11. Impacts on the Global Position of the US.....	168
Part V: Future Outlook	
12. Trends in Innovation.....	185
13. Future Vehicle Transport and Implications for Oil Demand.....	200
Conclusion.....	215
Policy Recommendations.....	219
Bibliography.....	223

Acknowledgements

The Task Force would like to express its deepest gratitude to Scott Montgomery. This report would not have been possible without his expertise and knowledge on the subject of shale oil and fracking. We would like to extend our deepest appreciation for his dedication and determination to help every task force member, no matter how small or large an issue was.

We would also like to extend our gratitude to the University of Washington libraries for hosting a research workshop, which provided our task force with valuable sources for information and unparalleled research assistance.

Acronyms

AAR	Association of American Railroads
AEO	Annual Energy Outlook
AEV	Alternative Energy Vehicle
AMD	Abandoned Mine Drainage
ANGA	American Natural Gas Association
ARB	Air Resource Board
APTA	American Public Transportation Association
ARPA-E	Advanced Research Projects Agency - Energy
bbls	barrels of oil
boe	barrels of oil equivalent
BLM	Bureau of Land Management
CAEATFA	California Alternative Energy and Advanced Transportation Financing Authority
CAFE	Corporate Average Fuel Economy
CFIUS	Committee on Foreign Investment in the United States
CVRP	Clean Vehicle Rebate Project
CWA	Clean Water Act
DECC	Department of Energy and Climate Change (United Kingdom)
DGS	Department of General Services
DOE	Department of Energy
DOI	Department of the Interior
DOT	Department of Transportation
E&P	Exploration and Production
EERE	Office of Energy Efficiency and Renewable Energy
EIA	Energy Information Administration
EPA	Environmental Protection Agency
EPCRA	Emergency Planning and Community Right to Know Act
ERAP	Emergency Response Assistance Plan
ERR	Economically Recoverable Reserves
EV	Electric Vehicles
FERC	Federal Energy Regulatory Committee
FY	Fiscal Year
GCC	Gulf Cooperation Council
GDP	Gross Domestic Product

GE	General Electric
HEV	Hybrid Electric Vehicle
hhp	Hydraulic Horse Power
HOT	High Occupancy Toll
HOV	High Occupancy Vehicle
HTUA	High Threat Urban Area
IEA	International Energy Agency
IPAA	Independent Petroleum Association of America
KNOC	Korea National Oil Company
lbm	Pound-mass
LDV	Light Duty Vehicle
LPG	Liquefied Petroleum Gas
mb/d	million barrels per day
MEP	Ministry of Environmental Protection (China)
MLR	Ministry of Land and Resources (China)
MMTC_{02e}	Million Metric Tons of Carbon Dioxide Equivalent
MOF	Ministry of Finance (China)
MOST	Ministry of Science and Technology
MRL	Minimum Risk Level
NDRC	National Development and Reform Commission (China)
NEB	National Energy Board (Canada)
NESHAP	National Emission Standards for Hazardous Air Pollutants
NGL	Natural Gas Liquid
NIMBY	“Not in my backyard”
NIOSH	National Institute for Occupational Safety and Health
NOKE	National Operator of Energy Minerals (Poland)
NORM	Naturally Occurring Radioactive Material
NSPS	New Source Performance Standards
NSTB	National Transportation Safety Board
OAPEC	Organization of Arab Petroleum Exporting Countries
ODNR	Ohio Department of Natural Resources
OGJ	Oil and Gas Journal
OPEC	Organization of the Petroleum Exporting Countries
OPPPW	Polish Exploration and Production Industry Organization
OTC	Offshore Technology Conference
PHMSA	Pipeline and Hazardous Materials Safety Administration
PNR	Pioneer Natural Resources

PWC	Pricewaterhouse Coopers
R&D	Research and Development
RCRA	Resource Conservation and Recovery Act
RDD&D	Research, Development, Demonstration and Deployment
S&ED	Strategic and Economic Dialogue (US and China)
SAT	State Administration of Taxation
SDWA	Safe Drinking Water Act
SEAB	Secretary of Energy Advisory Board
STEO	Short Term Energy Outlook
Tcf	Trillion cubic feet
TMS	Tuscaloosa Marine Shale
TOC	Total Organic Carbon
TSB	Transportation Board of Canada
UGTEP	Unconventional Gas Technical Engagement Program
ULWP	Ultra Lightweight Proppant
UPI	United Post International
USDW	Underground Sources of Drinking Water
USGS	United States Geological Survey
VOC	Volatile Organic Compound
WTI	West Texas Intermediate

Introduction

The shale oil revolution of the early twenty-first century has placed the United States at one of its most pivotal points in recent history with regards to energy policy. The production boom in 2008 led to an increase of nearly three million barrels per day within five years, accounting for over 90% of new crude oil growth. Such growth has transformed the U.S. from the world's largest importer to a growing exporter of petroleum products, reducing its dependence on OPEC by more than half, rendering it a major competitor to Russia in refined product exports, and promising energy self-sufficiency for North America in coming decades.

In short, the shale revolution has altered the geopolitical map of global energy. Projections estimate that within the next twenty years, tight oil production in the US will increase by another four to six million barrels per day, changing the map even further. As the outlook of tight oil development has serious implications for many US interests, laying a sound framework for long-term development is integral to both US domestic and foreign policy.

The revolution in tight oil production has occurred because of innovation in hydraulic fracturing technologies, coupled with long-reach horizontal drilling, that opened up the potential of vast reserves of previously unproductive, organic-rich shale formations across the United States. Different from conventional forms of drilling, “fracking” in shale involves the use of many individual stages, or horizontal intervals, for stimulation. As many as 30-45 such intervals along a horizontal borehole 5,000 – 8,000 feet in length are individually fracked, opening up much larger portions of a reservoir to production than has been previously possible. Fracking is used to penetrate source rock with low-permeability, most commonly shale, that in the past has been difficult to access with conventional drilling techniques. Perforating guns are used to pierce through the well casing to create fractures within the shale, which are then widened by the pumping of fluids into the well at high enough pressures to stimulate oil flow.

Though fracking technology opens access to both oil and gas reserves, shale oil has higher influence on US interests for several reasons. First, oil represents a global market, thus one in which large increases in US production can affect many nations, including allies around the world. Second, oil has no known alternative, whereas gas competes with other energy sources such as nuclear, coal, and, increasingly, renewables like wind and solar. Oil remains indispensable to modern transport in every nation. This factor plus the concentration of petroleum resources and export capacity in just a few countries, above all OPEC and Russia—who have long employed petroleum as a tool of foreign policy—make oil a highly politicized commodity, even more than gas. The rise in U.S. production has the likely potential to greatly alter the geopolitical landscape of energy, providing advantages for the US both economically and geopolitically.

Additionally, shale oil has greater environmental consequences relative to gas. While much of the initial public controversy surrounding fracking came in response to the extraction of natural gas, shale oil has the potential to cause considerably more severe and long-term environmental impacts. The scale of these impacts is not yet fully understood. Yet, it is critical to address environmental health in US policy to ensure sustainable growth and long-term development options.

It is no exaggeration to say that the global energy landscape is in the midst of a massive transformation. New discoveries and development of shale oil basins have the potential to steer the U.S and other nations, including those in Europe, toward more energy self-sufficiency and therefore a more energy-secure future. Demand for oil is growing rapidly in developing and transition economies such as China and India. OPEC's clout is diminishing as other oil-producing countries are looking to meet those demands. Developments in renewable energy, meanwhile, are creating viable alternatives to oil-dependent technologies, especially in the transportation sector. Amidst these shifts, the policies and regulations implemented by the United States will have a significant affect on how shale oil production impacts economic, environmental and geopolitical interests around the world.

PART I

Why Shale Oil and Why Now? How Unconventional Drilling Has Transformed the Oil Industry

Part I focuses on contextualizing the topic of shale oil and fracking by providing background information necessary to understand the current shale oil phenomenon. Chapter One discusses the early history of fracking technology and the subsequent progress towards modern day fracking. It analyzes the role of government in spurring innovation and incentivizing development in the industry, such as horizontal drilling and the use of proppants, practices that have aided in materializing current shale oil revolution. Chapter Two provides a detailed analysis of current legislation and regulations in place regarding geographical restrictions, water and air regulations, on-site violations and inspections and the current taxation system. The discrepancies between federal, state, and local legislation undermine efforts aimed at creating a unified regulatory framework. Chapter Three discusses the overall global perspective of oil by examining current and predicted world oil reserves, global demand and consumption, and future outlook. Chapter Three highlights the growing demand and consumption of oil from non-OECD countries in order to better illustrate world oil trends, uncertainties, challenges and opportunities for the global oil industry. The chapter also illustrates the expected oil production outlook for OPEC and non-OPEC countries, an important consideration when taking into account the recent US shale oil production boom, which could potentially place the US as a major oil exporter in the near future.

Chapter One

HISTORY OF SHALE OIL AND FRACKING

Khiem Duy Nguyen

Abstract

This chapter provides the necessary context and background needed to understand the recent shale oil boom by examining the historical development of the shale oil industry and the progress of fracking technology. Through the examination of the historical process, this chapter analyzes and points to how the developments within the shale oil and fracking industry have provided the opportunity to witness the interaction between various economic and sociopolitical dynamics. The chapter starts by providing an overview of the early history and then moves onto discuss the road to modern fracking. Next, the chapter examines the development of shale oil and fracking technology, including the use of fluids and proppants, pumping and blending equipment and fracture-treatment design. The chapter concludes by looking at the future of shale and the role of government.

Introduction

Alongside the modern boom in US petroleum production, there has been a significant surge in the level of consideration given to new methods of gaining access to natural gas and oil reserves previously deemed inaccessible. Since 2003, shale oil and the fracking method behind its extraction have become popular topics of discussion. With what is popularly known as the ‘New Golden Age of Fracking’ kicking in, in parallel with the boom in petroleum production, fracking is now done on a large scale with new technologies that put once-inaccessible oil and gas within reach. Indeed, new approaches that mostly revolve around the application of high-pressure fracking, as well as horizontal well drilling, are increasing the possibility for producers to tap into vast new sources of oil and natural gas that are trapped in tight sand and shale formations. Some estimates put today’s producing wells to be as high as 90% due to innovation in fracking technology.¹

The large-scale production of crude oil from shale rock represents a true revolution in the US energy industry, and like all revolutions has a revealing history behind it. This history holds several key lessons regarding the nature of shale oil development, as well as its probable future and its potential spread to other parts of the world. Such lessons are an essential starting point to understanding the shale oil phenomenon. These lessons include the pattern of innovation, importance of geoscience, power of price, entrepreneurship, and, last but not least, the positive

¹ Michael MacRae, "Fracking A Look Back.", (ASME, 2012).

role of government. All of these elements played an important role and were needed for the shale oil revolution to occur.

As a major new domain of production, shale oil production began in the late 2000s, growing directly out of the success of shale gas. This success has been based on the technologies of long-reach horizontal drilling and multi-stage hydraulic fracturing, both of which emerged from progressive innovations over the past 30 to 40 years. Shale gas, in fact, has a long history of its own, reaching back to the early 19th century. Its modern evolution began in the 1970s, in large part due to the US Department of Energy's Eastern Gas Shales Program, which ran from 1976 to 1995 and was responsible for generating a considerable amount of geoscientific and engineering knowledge that later proved essential to development of shale oil reservoirs. Subsequent merging of this knowledge with innovations in horizontal drilling and fracking, combined with rising natural gas prices after 2000, set the stage for the explosion in shale gas drilling. Massive increases in gas supply lowered prices, which urged many companies to shift focus and target petroleum liquids, whose prices remained high. Such a shift, responsible for the current shale oil boom, was possible primarily because of the advanced state of fracking technology. It is therefore important to focus, in particular, on the history of this technology.

Section I: Early History

US Civil War veteran Colonel Edward Roberts is largely credited as being the original inventor of fracking as a technology that was applicable for the purpose of extracting natural gas and oil. His invention, "Exploding Torpedo" received the US Patent No. 59, 936 and accordingly introduced the US petroleum industry to a new method that helped companies significantly boost their production rate and subsequently paved a smooth path towards the modern-day shale gas and oil fracking industry. At a time when conventional natural gas and oil wells ceased to produce an adequate supply due to a lack of innovative, reliable, and cost-effective technology, leading to levels of falling production, Roberts's invention emerged as an important solution.

This newly discovered technique proved to be greatly successful, with production from certain wells increasing by a resounding 1,200% within a week.² In the next decade, fracking thrived both legally and illegally. By 1868, a new development in the fracking industry emerged, with gunpowder being quickly replaced by a highly dangerous and powerful chemical, nitroglycerin. The introduction of nitroglycerin brought about a vivid surge in well production. The safety disadvantages that came along with it were, however, large enough to cause instances of explosions that occurred up until 1989, when the last of the nitroglycerin supplier's plant exploded in Moosic, Pennsylvania.³

² MacRae, "Fracking A Look Back".

³ AOGHS, "Shooters – A "Fracking" History.", (American Oil and Gas Historical Society, 2013).

As early as the 1930s, non-explosive alternatives to the dangerous reliance on nitroglycerin were already being discussed. A series of experiments throughout the next two decades paved the way for the implementation of the first industrial-scale commercial application of hydraulic-based fracking. In 1947, the first experimental hydraulic fracturing was successfully executed at the Hugoton gas field, located in Grant County, Kansas. The technology was patented by the Stanolind Company (which later become known as Pan American Oil Company), and exclusively licensed by Halliburton and Company at the time. In turn, subsequent experiments of the technology began to prove that there was undoubtedly a possibility for considerable increases in productivity. Throughout the first year after hydraulic-based fracturing came to be recognized as the next revolution in the industry, up to 332 natural gas and oil wells were fracked with a remarkable 75% increase in production. By the mid 1950s, fracking reached an impressive pace of about 3000 wells a month.⁴

Section II: Horizontal Drilling and the Road to Modern Fracking

Despite the impressive boost in production that fracking brought to this unconventional gas and oil industry, this surge in quantity could still not make up for the decline in conventional gas production that began in the early 1970s. When members of the Organization of Arab Petroleum Exporting Countries (OPEC) proclaimed an oil embargo in 1973, in response to the military support provided by US to Israel during its war against Egypt and Syria, the US encountered the first oil crisis and consequentially saw the immediate need for an innovation push within the fracking field. Shale gas received more attention during this period when fracking began to become a popular and commercial feature within the industry.

The US experience with shale gas production shows that fracking has always played a crucial role in the industry. Important advances in technology, which include the application of horizontal drilling and improvement in the completion phase of the fracking process, had given fracking the substantial level of development that it took during the last three decades of the 20th century. Although horizontal drilling was first experimented with in 1929, it wasn't until the 1980s – having been originally developed by the Energy Research and Development Administration (later known as the Department of Energy), the Bureau of Mines, and the Morgantown Energy Research Center (later the National Energy Technology Laboratory)⁵ that the technology became economically viable. A pilot study by Devon Energy shows that fracking in horizontal wells resulted in production increases two to three times higher than that of vertical

⁴ MacRae, “Fracking A Look Back”.

⁵ Alex Trembath, Jesse Jenkins, Ted Nordhaus, and Michael Shellenberger, “*Where The Shale Gas Revolution Came From: Government's Role In The Development Of Hydraulic Fracturing In Shale.*”, (Breakthrough Institute Energy & Climate Program, 2012).

wells during the first 180 days.⁶ Between 1984 and 1989, horizontal drilling proved to be especially effective in significantly recovering new amounts of oil and gas at Prudhoe Bay, the Austin Chalk, the Bakken Shale, and the Niobrara, all of which are proven to hold vast reserves of shale oil. The Bakken Shale, in particular, is claimed to hold the largest oil accumulation in the Contiguous US by the US Geological Survey.⁷ It was relatively difficult to case the horizontal portion of a well within these formations all the way to total depth, but the continuous improvements in horizontal technology during the 1990s made it so that this was no longer an issue. By the late 1990s and early 2000s, it was possible to drill, case, and hydraulically fracture long-reach horizontals over numerous plays – leading to an ultimate improvement in the oil production level.

George Mitchell and his company, Mitchell Energy, is often credited as being the individual who unleashed an ocean of shale gas, previously inaccessible, by applying large-volume water-based fracture stimulation to the Barnett Shale in the Fort Worth Basin of north-central Texas. Having benefited from the US government's public subsidy and cost-sharing program, which was initiated during this period to provide more incentives for fracking development,⁸ many consider the success of this approach the key breakthrough for the industry. Shale gas became an attractive target for oil companies and every shale formation in the US was open for evaluation and business. The key innovation pioneered by Mitchell Energy was the use of very large amounts of water (> 1 million barrels) and similarly massive quantities of proppant (>250,000 pounds) to force open more of the natural fracture system and induce new fractures as well. Mitchell realized that shale needed to be stimulated on a larger scale than had ever been previously done. The ensuing result was phenomenal and the Barnett Shale quickly became an enormous natural gas reserve. By 1995, Mitchell had firmly established commercial production from the Barnett and accordingly delineated a sizeable field area – the Newark East Field – which went on to become the largest gas field in Texas in 2000, as well as the second largest in the US by production.⁹ Quantities of natural gas are measured in cubic feet, and five trillion cubic feet (Tcf) of natural is sufficient to fulfill the energy consumption needs of five million US households for 15 years.¹⁰ In this regard, estimated proven reserves at the Newark East Field were 2.7 Tcf in 2003. Given the full advent of multi-state fracking in long horizontals, estimates

⁶ Kent Perry and John Lee, *"Unconventional Gas Reservoirs: Tight Gas, Coal Seams, and Shales."* (National Petroleum Council, Global Oil and Gas Study, 2007), 20.

⁷ David Michael Cohen, "USGS names Bakken play the largest oil accumulation in Lower 48.", (2008).

⁸ Trembath, Jenkins, Nordhaus, and Shellenberger, *"Where The Shale Gas Revolution Came From"*.

⁹ David F. Martineau, "History of the Newark East field and the Barnett Shale as a gas reservoir.", (The American Association of Petroleum Geologists, 2007).

¹⁰ Aga.org., "How to Measure Natural Gas - Natural Gas.", (American Gas Association, 2014).

allow for as much as 26.2 Tcf of undiscovered, technically recoverable gas in the central Fort Worth basin.¹¹

During the time when horizontal drilling began to substantially improve in development, new fracking technology geared towards the completion phase was explored to open up the first of several new giant gas fields in tight reservoirs. Among the first of these fields was the Jonah Field in the Green River Basin of southwestern Wyoming. Commencing in 1995, multi-state fracking was tested by McMurry Oil Company and subsequently produced positive results along the lines of raising productivity levels in vertical wells. Within two years, this technique became a prioritized technology and transformed Jonah into a highly productive area with estimates of up to one Tcf of field reserve.¹² Estimated ultimate reserves today are over ten Tcf. Similarly, the nearby Pinedale Field, overseen by Ultra Petroleum and reported to be the third largest gas field in the US,¹³ became the next target for multi-stage fracturing using water-based fluids. Horizontal well technology has been so effectively complemented by the water-based multi-stage stimulation that its conception was the mark of a brand new beginning for the gas and oil drilling industry in North America

Success in Newark East, as well as Pinedale and Jonah, solidly established the new drilling and completion approach. Expansion of shale gas development then spread to a number of other areas between 2003 and 2008, increasing total production in the US by over 30%.¹⁴ This rapid rise in supply, coupled with the economic crisis of 2008 and subsequent recession, led to a collapse in natural gas wellhead prices. These fell from an average of over \$7 per million Btu during the 2007-2008 period to below \$3 during 2010-2013.¹⁵ At such prices, shale gas drilling lost much of its profitability. This had two consequences: first, it shifted operators' attention to liquids-rich reserves, where prices and profits remained high. In this regard, shale oil stands out as the most viable alternative, hence the connection to the present shale oil boom. Second, it inspired continued innovation in fracking techniques for gas wells, to decrease costs and increase recoveries. In short, the shale gas and shale oil domain has continued to be a dynamic, evolving realm in the energy industry.

¹¹ Scott L. Montgomery, Daniel M. Jarvie, Kent A. Bowker, and Richard M. Pollastro, "Mississippian Barnett Shale, Fort Worth basin, north-central Texas: Gas-shale play with multi-trillion cubic foot potential." (The American Association of Petroleum Geologists, 2004).

¹² R. W. Finch, J. L. Skees, W. W. Aud, J. L. Johnson, C. Esphahanian, J. T. Hansen and Others, "Evolution of Completion and Fracture Stimulation Practices in the Jonah Field Sublette County WY." (Rocky Mountain Association of Geologists, 1996), 13.

¹³ Stephen R. Kneller, Sally G. Zinke, Robert W. Mcdermott, Troy G. Graham, and Sarah E. Shearer, "Unlocking the Potential of a Tight Gas Sand Giant: Pinedale Field, Wyoming." (Rocky Mountain Association of Geologist, 2006), 181.

¹⁴ Perry and Lee, "*Unconventional Gas Reservoirs*", 1.

¹⁵ Samantha Azzarello, "*Energy Price Spread: Natural Gas vs. Crude Oil in the US*." (CME Group, 2014), 1.

Section III: Development of Shale Oil and Fracking Technology

The growth of unconventional gas and oil production strongly correlates with the technological improvements that has allowed for the possibility of more extraction. Shale gas and oil follow this developmental pattern. The technology behind fracking has been continuously evolving under the objective of gaining access to more shale formations. In order to truly understand the technical aspect of the shale gas and oil industry and how it has developed over time, one would need to rely on academics and professionals who possess the relevant expert knowledge about fracking technology. Nonetheless, it is possible to narrow the analysis down to a number of physical components that could very well illustrate the great leap over which fracking technology has jumped through in its roughly 80 years of history, and subsequently, how such a great jump has allowed the industry to assume such a vital position within the US and international political economic arena today. Generally speaking, these components largely include fluids and proppants, pumping and blending equipment, and fracture treatment design.

[Fluids and Proppants]

During the initial years of fracking, the average fracture treatment typically consisted of approximately 750 gal of fluid and 400 lb of sand. Today, it is commonplace within the industry to have treatments that use around 60,000 gal of fluid and 100,000 lbm of propping agent (another technical term for ‘proppant’). Large-scale projects can consume a volume that exceeds one million gal of fluid and five million lbm of proppant.¹⁶

Despite popular belief, water was not the first option picked as a viable fracturing fluid during the early development of fracking. The first treatments used gelled crude, which was soon replaced by gelled kerosene. By 1952, the majority of fracking projects were executed with refined and crude oils. The attractive quality that these fluids had in common was their inexpensive price relative to other options, permitting large volumes to be reached at lower cost. A major innovative step that took place in the early 1970s which opened up a whole new horizon for fracturing fluids was the introduction of metal-based cross-linking agents to boost the viscosity of gelled fracturing fluids for wells that possessed higher temperatures. Technically speaking, this development made it possible to use a lower mass of gelling agent, while still being able to obtain the desired level of viscosity. With more and more treatments experiencing the involvement of high-temperature wells, cross-linkers such as gel stabilizers (the first of which used approximately 5% methanol) and later on, chemical stabilizers (those that could be used either alone or with methanol) began to be widely developed and accordingly applied.¹⁷

¹⁶ Carl T. Montgomery and Michael B. Smith, *Hydraulic Fracturing: History of An Enduring Technology*. *Hydraulic Fracturing: History of An Enduring Technology*, (Joint Production Technologies (JPT), 2010), 28.

¹⁷ Montgomery and Smith, *Hydraulic Fracturing*, 28.

Cross-linked gels and other fluids that have a higher viscosity level than water were believed to be necessary in the 1970s, 1980s, and early 1990s, in order to carry proppant efficiently. The growing size of fracking treatments at Newark East showed that this wasn't quite the case. Water was subsequently introduced as a fracturing fluid and it proved to be able to similarly carry large amounts of proppant into the fracture network. Today, aqueous fluids such as acid, water, and brines are relied on as the base fluid for fracking in roughly 96% of all treatments that employ a propping agent.¹⁸

Early fracking treatments used screened river sand as a proppant. Progress saw the usage of construction sand sieved through a window screen filter as an alternative in later years. The size of sand grains has greatly varied, from very large to small. The early history, however, saw the popularity of -20 +40 US-standard-mesh sand, and today around 85% of the sand used come in this size.¹⁹ Other than sand, various propping agents have been experimented with throughout the decades, including plastic pellets, steel shot, Indian glass beads, aluminum pellets, high-strength glass beads, rounded nut shells, resin-coated sands, sintered bauxite, and fused zirconium.

Until the mid-1960s, the period when viscous fluids such as cross-linked gels and viscous refined oil were introduced, the concentration level of sand lb/gal used in fracking was still relatively low. During those times, large-size propping agents were the more widely favored choice. The trend then moved on to the pumping of higher sand concentrations. As a consequence, the level of sand concentration has surged almost continuously, with an especially sharp increase in recent years. The cause that directly influenced the preference for such high sand concentrations can be largely attributed to the improvements in fracturing fluids analyzed above, as well as certain advances in pumping equipment. It is now not unusual to use proppant concentration averaging five to eight lb/gal throughout the whole treatment process.²⁰

[Pumping and Blending Equipment]

Similar to the application of fluid and proppants, technical composition of pumping and blending machinery has also substantially evolved since fracking first came to prominence. Hydraulic horsepower (hhp) per treatment has increased from an average of 75 hhp to more than 1,500 hhp today. In certain instances, where as much as 15,000 hhp is available for usage, more than 10,000 hhp could actually be used. This figure stands in stark contrast to what was once commonplace in some early jobs, where roughly only 10 to 15 hhp was employed.²¹

Original fracking treatments were typically performed at rates between two and three oil bbl/min. As development progressed up until the 1960s, these rates increased at a rapid pace

¹⁸ Montgomery and Smith, *Hydraulic Fracturing*, 28.

¹⁹ Ibid

²⁰ Ibid, 30.

²¹ Ibid

before stabilizing around 20 bbl/min. In 1976, Othar Kiel developed a technique that used high-rate “hesitation” fractures to cause what he called “dendritic” fractures. His ideas are used today in pump rates leveling at more than 100 bbl/min. Surface treating pressure are less than 100 pounds per square inch (psi) at times, yet can potentially boost up to 20,000 psi.²²

Conventional cement-and-acid-pumping equipment was formerly used to carry out fracking treatments. An adequate level for small volumes to be injected at low rates would have required one to three fracking units equipped with one pressure pump delivering 75 to 125 hhp.²³ During the early days, treatments of such scales were already generating phenomenal production increases as opposed to what could be previously extracted. The growing size of fracking treatments at Jonah, Pinedale, and Newark East, which typically came with a rise in treatment volumes and greater injection rates, demanded for the innovation of stronger pumping and blending equipment in order to reach higher hhp levels and extensively fracture the shale and open natural fractures as well. Within the shale oil fracking industry today, most treatments require that service companies invest several million dollars’ worth of equipment in order to effectively produce the most profitable results.

[Fracture-Treatment Design]

Designs of the first few treatments entail complex charts, nomographs, and calculations to work out the approximate size – which came close to 800 gallons of fluid, with sand concentration leveling between 0.5 and 0.75 lb/gal.²⁴ This was considered to be a largely hit-or-miss method and its application continued until the mid-1960s when programs were developed for use on simple computers. Original programs principally focused on fluid efficiency and the shape of a fracture system in two dimensions. These were based on the work developed by S. A. Khristianovic and Y.P Zheltov²⁵, T. K. Perkins and L.R. Kern,²⁶ and J. Geertsma and F. de Klerk.²⁷ Albeit great in improvement, these programs were still limited in their ability to predict fracture height.

With advances in computer capabilities, fracking design programs have evolved to include fully gridded finite-element programs that can predict fracture geometry and flow properties in three dimensions. Modern programs today can obtain a temperature profile of the treating fluid during a fracturing treatment. It is a great add-value as it can assist in designing the concentrations of the gel, gel-stabilizer, breaker, and propping-agent during different stages of

²² Montgomery and Smith, *Hydraulic Fracturing*, 30.

²³ Ibid

²⁴ Ibid, 30-31.

²⁵ S. A. Khristianovic, and Y. P. Zheltov, "Paper 6132: Formation of Vertical Fractures by Means of Highly Viscous Liquid.", (1955).

²⁶ T. K. Perkins, L. R. Kern and Others, "Widths of hydraulic fractures.", (1961), 937-949.

²⁷ H. K. Van Poolen, John M. Tinsley, Calvin D. Saunders and Others, "Hydraulic Fracturing-Fracture Flow Capacity vs Well Productivity.", (1958).

the treatment. Models have been developed to simulate the way fluids travel through the fracture and how the propping agent is distributed. Production increases can, in turn, be determined and measured based on these models. These models can also be used to match production historically following a fracturing treatment to find out which treatment achieved which actual result.

Emphasizing the importance of fracture designs and the continuous push to produce more and better designs is considered to be a principal key to the future success of the fracking industry. In this regard, good progress has been formulated in the improvement of processes such as after-closure analysis to characterize reservoir properties and three-dimensional microseismic imaging, initially developed by Sandia National Laboratories,²⁸ to define fracture extent.

Section IV: Historic Success and the Boom

When discussing the origins of the shale gas and oil boom, it is necessary to examine developments from the 1970s to now. Although developments initially focused on gas, they later came to involve oil, as well, and proved essential to the current oil boom. With key roles played by the US Department of Energy and the US Geological survey, these developments can be generally listed as follows:

- Advances in geoscientific and engineering knowledge about shale
- Testing of new hydraulic fracture technologies
- Growth in use of, and advances in, horizontal drilling, including activity in the Bakken Formation of North Dakota and Montana
- Successful development of giant new gas fields using multi-stage fracking technology
- Reevaluation of Bakken oil reserves, establishing a multi-billion barrel recoverable resource
- Extending such reevaluation of other liquid-rich shales in the US

In the wake of the first oil crisis, the US government launched a major, long-term effort to formulate a close study of various shale formations in the country with the objective of enhancing their production levels. The Eastern Gas Shale Project, which operated from 1976 to 1992, was a product of this initiative. The newly established Department of Energy contracted with industry and academia to build a firm body of knowledge concerning the detailed geoscientific nature of shale gas and how it might best be produced. In this regard, the conception, testing, and evaluation of new fracking techniques served as a major component of this project. Any works and/or activities conducted in parallel with this mission were supported by governmental funds, which were distributed partially through the Gas Research Institute by

²⁸ Trembath, Jenkins, Nordhaus, and Shellenberger, “*Where The Shale Gas Revolution Came From*”.

FERC and carried out by a selected group of industrial partners. Over a span of 16 years, the Eastern Gas Shales Project created an invaluable structure of expert knowledge about gas production from shale, all of which was made available for public analysis in a growing database. The Section 29 tax credit that started in 1980 also permitted the US to jump-start its tight gas and oil exploitation.²⁹ This allowed for a timely response to the supply shortages due to both the 1973 oil crisis, as well as previous federal price controls on natural gas. When the incentive ended in 2002, the resulting infrastructure, critical mass, and expertise were firmly implemented to continue profitably without any further incentives. It is important to note that such expert knowledge proved vitally useful and complementary for the subsequent boom in production of both shale gas and oil that began in the late 1990s and 2000s.

Illustrated by the fierce competition between contractors, accompanied by slim margins and large volumes, fracking activity in North America is currently at an all time high. In the US alone, there is an estimated four million hhp of equipment presently being built³⁰. Hence, it is not unusual to have long waiting lists for services and supplies, and project delays of up to nine months, which is a common occurrence within the industry. North America, and the US in particular, is home to an estimated 85% of the total number of fracking ‘spreads’, as illustrated in **Figure 2**, with a spread referring to a package of equipment needed to carry out a treatment that can accommodate four fracking pumps – including land and offshore equipment.³¹ Such a high percentage stems from the region’s strong infrastructure, fueled by the dependence of a population that is used to creating high levels of demand. Although shale gas and oil is similarly prevalent outside the US, the need in most countries – with perhaps the exception of the European Economic Union – to rely on them remains less urgent, as conventional resources remain far from depletion.

²⁹ Trembath, Jenkins, Nordhaus, and Shellenberger, “*Where The Shale Gas Revolution Came From*”.

³⁰ Robin Beckwith, *Hydraulic Fracturing: The Fuss, The Facts, The Future*. *Hydraulic Fracturing: The Fuss, The Facts, The Future*, (Joint Production Technologies (JPT), 2014), 34.

³¹ Beckwith, *Hydraulic Fracturing*, 35.

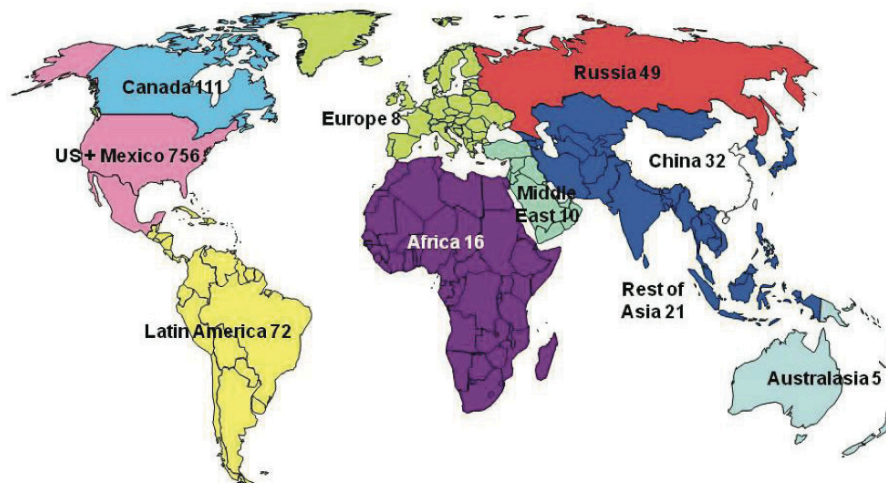


Figure 1: Estimated global distribution of fracturing equipment (fracking spreads), including land fracturing spreads and offshore vessels. (Source: www.jptonline.org)

Independent private companies have been one of the principal forces behind the development and application of fracking technology in the US. Specifically, those who have a low cost base and the critical mass necessary to learn and respond quickly to new developments in planning, modeling, fluids and proppants technology. In the early years, when private firms lacked the incentive to make large, risky research and development (R&D) investments, and when unconventional gas and oil still found it difficult to compete with conventional sources for investment dollars, the US government played a critical role. It encouraged the private sector to take the initial step via its many funded R&D programs as well as tax credits that stimulated the development of shale gas in numerous areas.³² This trend continues and has strongly contributed to the high level of competitiveness observed within the industry today. With the presence of dozens of operators, each striving to achieve a technical and economic advantage over the other, the rate of technological development in the US has been unsurprisingly fast. Such a rapid pace has been partially generated by regulatory requirements in most areas throughout North America to reveal fracking and production data within a period of six months following the treatment execution, allowing competitors to seek for informational insight.

Section V: The Future of Shale Oil

Both natural gas and oil found in shale formations, previously perceived to be unrecoverable and, until this past decade, considerably expensive to extract on a commercial scale, are now abundantly accessible. This development has been made possible by technological innovations that derive from a strong partnership between the energy industry and the US federal government. Stemming from the urgent necessity to maintain a sufficient energy supply in the

³² Zhongmin Wang and Alan Krupnick, "US Shale Gas Development: What Led to the Boom? .", (Resources for the Future, 2013), 2.

face of the debilitating natural gas shortages in the 1970s, accompanied by pressure from OPEC importers, the present success experienced by shale gas and oil is undoubtedly a result of the historical need for the US to find a viable alternative. With such high encouragement from the government to push for more technological advances that could tap into the invaluable and vast shale gas and oil reserves, fracking ultimately emerged as a greatly appealing approach.

Year	Nominal Price	Inflation Adjusted Price
1995	\$16.75	\$25.59
1996	\$20.46	\$30.35
1997	\$18.64	\$27.04
1998	\$11.91	\$17.01
1999	\$16.56	\$23.08
2000	\$27.39	\$37.01
2001	\$23.00	\$30.25
2002	\$22.81	\$29.49
2003	\$27.69	\$35.05
2004	\$37.66	\$46.37
2005	\$50.04	\$59.59
2006	\$58.30	\$67.30
2007	\$64.20	\$71.94
2008	\$91.48	\$98.58
2009	\$53.48	\$57.92
2010	\$71.21	\$76.01
2011	\$87.04	\$90.08
2012	\$86.46	\$87.68
2013 (Partial)	\$87.13	\$87.52

Figure 3: Annual Average Domestic Crude Oil Prices (\$USD/Barrel), 1995-2013. (Source: www.inflationdata.com)

From another perspective, given the rise in popularity of fracking technology, it is important to grant attention to shale oil as it holds the potential to produce an especially robust boom pattern. One final factor that strongly contributed to the shale oil boom can be attributed to the tremendous rise in oil prices after 2004. The market pushed up prices as high as \$147 per barrel in 2008, after which prices briefly fell to under \$50 due to the economic crisis, before rising again to over \$90 and having since maintained relatively similar prices from late 2009 to 2014 (itself an unprecedented stretch of high prices). **Figure 3** provides both the nominal and inflation adjusted price for crude oil from 1995 to 2013, allowing us to see the quick spike in prices. At the same time, the boost in the production of natural gas caused gas prices to fall from eight dollars per million Btu to below four dollars, reducing profitability at a drastic rate. In a

way, this impacted the realm of natural gas and shifted many companies' focus towards oil. Despite surging US production, the outlook for high oil prices remains steady in 2014. This will have the effect of not only spurring more drilling, but also new technological advances, particularly those in completion techniques and technology. In general, the goals of these advances entail the aspiration to reduce fracking water use, increase use of recycled waters, improved fracture penetration as well as aperture, and other features that will greatly aid to reduce well costs, improve productivity, and most importantly, prevent environmental damage.

Conclusion

The contemporary shale gas and oil phenomenon is a direct result of the government-backed technological development that has allowed for a significantly larger volume of trapped shale gas and oil to be extracted - as opposed to what was historically feasible. With the natural gas boom gradually reducing in pace, attention is shifting toward shale oil. Shale oil is undoubtedly producing its own boom. Despite surging US production, the outlook for high oil prices remains steady in 2014. This will spur more drilling and new technological advances, especially those in completion techniques and technology. These new technologies promise significant improvements in reducing well posts, improving productivity and also reducing potential environmental damage, which is currently the public's main concern regarding fracking.

Chapter Two

FEDERAL, STATE AND LOCAL REGULATIONS

Rebecca Snyder

Abstract

The following chapter provides a detailed look at recent legislation and the regulations that are in place for each stage of the fracking process, within the context of US federal, state and local governance. Many of the following regulatory frameworks apply to all parts of the oil and gas industry and are often not limited to fracking operations alone. This chapter demonstrates the inconsistencies and current friction that exists between varying levels of governance in regards to fracking policy. Beginning with an investigation of current geographical restrictions including moratoriums and regulations on land use, the chapter continues with an overview of water regulations, a major point of contention for policy makers at the federal level. Then, air quality standards are addressed, followed by current regulations dictating the reporting of on-site violations and inspections. The subsequent section explains the current taxation and fine-collection system employed predominantly at the state level. The final section provides a discussion on overall regulatory issues and what can be expected in future US policy pertaining to the fracking industry.

Introduction

Due to the fact that fracking has become a major part of the energy sector only within the last decade or so, regulatory bodies have been slow to respond, or, have conversely shut the process down altogether. Although attempts have been made to establish all-encompassing federal regulations, currently, regulatory responsibility mainly lies within the hands of state governments. Some state and local governments have put in place moratoriums outright, while others have maintained relatively weak regulatory institutions, resulting in, some cases, environmental degradation. Public criticism and lawsuits from individuals and organizations concerned about the impact of fracking have become a substantial catalyst for policy action. Oil and gas industries, however, are pushing back, often taking their own legal action against stringent policy measures.

As the world's frontrunner in the shale fracking boom, the US stands as an integral testing ground for regulatory response. As such, it is important for US interests to establish a sound regulatory framework at the federal level. Based on **Figure 1** shown below, fracking regulations have been a central topic of state policy discussions within recent years. However, the slew of regulations that has thus far resulted lacks consistency across state borders, creating new difficulties for companies engaged in shale drilling, as well as a number of inter-state disputes over everything from air pollution to wastewater disposal. A comprehensive set of

federal standards has the potential to alleviate such inconsistencies and disputes by providing more uniformity.

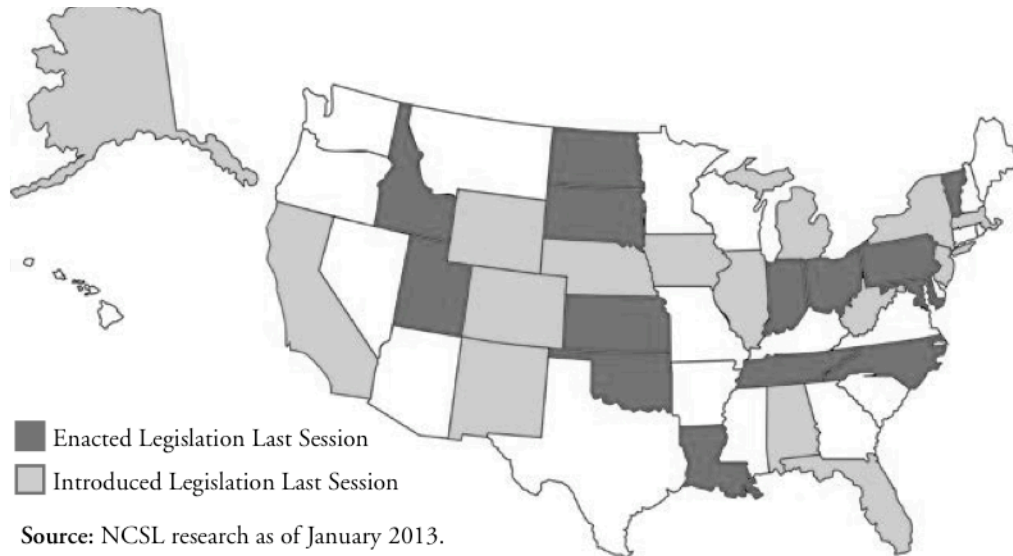


Figure 1: Natural Gas Legislation Last Session (Source: National Conference of State Legislators)

Section I: Geographical Laws and Restrictions

[Moratoriums]

Federal: Although leaders in the environmental movement have often called for a nationwide moratorium on fracking, the federal government and the majority of state governments promote fracking, citing the potential economic benefits and energy security it can provide.

State: New York was the first to pass a statewide ban on the practice of fracking in 2010. The moratorium specifically placed a temporary hold on the issuing of permits to oil and gas companies until further research could be conducted on the possible environmental impacts that increased fracking may inflict.¹ Although the moratorium is designated to last through May 2015, opposition to the legislation has sought to shorten the five-year time period. From 2010 to 2011, oil and gas industries spent a total of \$ 3.2 million to support lobbying efforts aimed at ending New York’s moratorium, a common practice throughout most fracking states and at the federal level as well.² Environmental groups have also been involved in lobbying efforts on the opposite

¹ Charles Davis and Katherine Hoffer. "Federalizing energy? Agenda change and the politics of fracking." *Policy Sciences* 45, no. 3 (2012): 221--241.

² Thomas Kaplan. "Millions Spent in Albany Fight to Drill for Gas." *The New York Times*, November 26th, 2011.

side, albeit with significantly fewer financial resources. Although Governor Andrew Cuomo of New York has sought to overturn the ban by opening up private lands to fracking companies, as of now, the moratorium remains in place.³

Pennsylvania also introduced a new bill in September 2013 to instate a moratorium on fracking, similar to that of New York. Senator Jim Ferlo sponsored the bill in an attempt to buy time for a commission of seven to investigate the effects that fracking has on the environment, economy and society and thereby provide a sound platform for future regulatory policies. The bill, in an effort to remain objective, specifies that the commission be comprised of representatives from the non-profit sector, oil and gas industry and academia, as well as a public health official, geologist, and the two Secretaries of Environmental Protection and Conservation and Natural Resources.⁴ However Senator Ferlo's bill, unlike New York's, does not designate an end-date for the moratorium but rather leaves it "open-ended". Although the bill is unlikely to pass, it does extend the political discussion on the fracking debate.⁵

Local: Mora County, located in the Northeast portion of New Mexico, recently adopted a community rights ordinance that bans fracking within county boundary-lines. The county is now facing legal action as Shell Western E&P Inc. and local landowners demand that the ordinance be repealed and seek reparations for incurred damages.⁶ Nearby Santa Fe County, rather than employing an outright ban, has instead instated a strict set of regulations. In so doing, Santa Fe County has avoided lawsuits and has yet to become the host of any drilling projects.⁷

As of November 2013, three Colorado cities: Boulder, Lafayette and Fort Collins, approved similar initiatives that placed moratoriums on fracking within city lines. However, such policy measures have also come at a cost as Lafayette and Fort Collins now face similar lawsuits to that of Mora country, in this case by the Colorado Oil and Gas Association.⁸ Such legal battles may discourage other counties from seeking similar bans on fracking in the future. Other citywide moratorium initiatives, in places like Youngstown and Bowling Green, Ohio, were struck down by voters because of the fear of the economic shortfalls that such a ban may cause, along with the potential for increased utility costs.⁹

³ Danny Hakim and Nicholas Confessore. "Cuomo Will Seek to Lift Ban on Hydraulic Fracturing." *The New York Times*, 30th June, 2011.

⁴ "Press Release: Senator Ferlo Announces Fracking Moratorium Legislation « State Senator Jim Ferlo." *Senatorferlo.com*. <http://www.senatorferlo.com/press-release-senator-ferlo-announces-fracking-moratorium-legislation> (accessed 22 Feb 2014).

⁵ Katie Colaneri. "Ferlo Introduces 'Open-Ended' Fracking Moratorium Bill", *StateImpact*, 2013. <http://stateimpact.npr.org/pennsylvania/2013/09/18/ferlo-introduces-open-ended-fracking-moratorium-bill/> [Accessed: 11 Feb 2014].

⁶ Staci Matlock. "Mora County faces new lawsuit over drilling ban." *Santa Fe New Mexican*, January 20, 2014.

⁷ Ibid.

⁸ Harris, Andrew. "Colorado Cities Sued Over Fracking Bans by Oil, Gas Group" *Bloomberg Sustainability*, 2013. <http://www.bloomberg.com/news/2013-12-04/colorado-cities-sued-over-fracking-ban-by-oil-gas-group.html>

⁹ Wines, Michael. "Colorado Cities' Rejection of Fracking Poses Political Test for Natural Gas Industry." *The New York Times*, November 7th, 2013.

[Zoning Ordinances]

State and Local: Moratoriums, although comprehensive in scope, are still temporary restrictions. Zoning laws provide more permanent and authority-backed modes through which fracking operations can be geographically restricted. Such authority, however, has been increasingly called into question in recent years. Because zoning ordinances are typically enacted and enforced at the county or municipality level, a fair amount of power lies in these local forms of governance to determine where and if fracking operations can occur. However, as with the state of New York, state and federal governments have the ability to overrule zoning determinations if the local regulating bodies are found to be targeting a specific kind of industry, such as oil and natural gas production.¹⁰ This is a major point of contention in the struggle between federal, state and local governance. New York's law determining where authority lies and when it can be superseded does not directly specify or explicitly state the scenarios in which such preemption is applicable, seen here,

“The provisions of this article shall supersede all local laws or ordinances relating to the regulation of the oil, gas and solution mining industries; but shall not supersede local government jurisdiction over local roads or the rights of local governments under the real property tax law.”¹¹

The differing interpretations of what constitutes “ordinances relating to the regulation of oil, gas and solution mining industries” has sparked a wide range of legal battles across the state of New York, in counties which have independently adopted strict zoning laws affecting oil and gas production. Generally the consensus by lawmakers has been that ordinances relating to regulation must pertain to drilling “operations” rather than general land use, in order to be considered for preemption.¹²

Pennsylvania's Act 13, which was passed in February 2012, pertains exclusively to unconventional oil and natural gas drilling and serves to greatly curtail the power that municipalities currently have to dictate zoning restrictions, among other things. It has since seen a considerable amount of opposition and subsequent revision as a result of lawsuits questioning its constitutionality in specific reference to the state's Environmental Rights Amendment, which declares rights to “clean air, pure water, and to the preservation of the natural, scenic, historic and aesthetic values of the environment.”¹³ If Act 13 were to take effect, local government could

¹⁰ John R Nolan and Victoria Polidoro. "Hydrofracking: Disturbances Both Geological and Political: Who Decides?." *The Urban Lawyer* 44, no. 3 (2012).

¹¹ New York's Environmental Conservation Law § 23-0303(2).

¹² Charles Gottlieb. "Regulating Natural Gas Development Through Local Planning and Land Use Controls." *New York Zoning Law and Practice Report* 12, no. 6 (2014).

¹³ "The oil and gas law of the land: your guide to Act 13." *StateImpact Pennsylvania*, 2014.

still instate additional permits that may limit oil and natural gas operations as well, although not at the level of zoning ordinances.

[Split-Estate Laws]

Federal: Although the US federal government has long since permitted the separation of subsurface mineral rights and surface ownership, the law is just now becoming a major source of political and legal dispute as the technological advancements made through fracking operations have opened up vast tracks of land to oil and gas industry. Subsurface formations that were once considered unviable for oil and gas production are now considered precious commodities as they can be leased out to oil and gas companies who, in turn, must pay royalties to the owner.¹⁴ The problem, however, lies in the process of home buying.

In conventional oil drilling locations like Texas and Oklahoma, it has historically been a fairly common practice for home-sellers to try and retain subsurface mineral rights or for oil and gas companies to try and obtain such rights. The US federal government, too, retains rights to a large portion of the nation's subsurface minerals, as originally set forth in the Stockraising Homestead Act of 1916.¹⁵ As a result of this long-standing practice, more individuals looking to buy a house in areas such as these are aware of Split-Estate practices when closing on a home. But in neighborhoods where resource extraction has only recently become possible, homebuyers are unknowingly signing away their subsurface rights. Several states do not require sellers to notify the homebuyer of their intent to sever the property and retain mineral rights. Many individuals do not realize that this is even possible. Numerous lawsuits have sprung up as a result in multiple states including North Carolina, Colorado and Louisiana where fracking operations have recently been growing abundant.¹⁶

As outlined by the Bureau of Land Management, "mineral rights are considered the dominant estate, meaning they take precedence over other rights associated with the property, including those associated with owning the surface."¹⁷ As a result, if the owner of the subsurface mineral rights decides to lease out the property to an oil or gas company, surface owners have no choice but to comply. Although they do have some say in the manner in which subsequent drilling and related well activities may be conducted, their property is nonetheless subject to operations at the subsurface owner's discretion.

State: In order to limit the number of homeowners who are unaware of the legality of such practices, the Colorado Senate approved a consumer protection bill in January 2014 to

¹⁴ Michelle Conlin and Brian Grow. "They own the house, but not what lies beneath." *Reuters*, October 9th, 2013.

¹⁵ "Split Estate," *Bureau of Land Management*, http://www.blm.gov/wo/st/en/prog/energy/oil_and_gas/best_management_practices/split_estate.html (accessed 5 Feb 2014).

¹⁶ Conlin and Grow.

¹⁷ "Split Estate," *Bureau of Land Management*.

require sellers to disclose, in bold-faced lettering, “that a separate mineral estate may subject the property to oil, gas, or mineral extraction”¹⁸ on every sale contract.¹⁹ This bill will likely help create more informed homebuyers within the state and alleviate public discontent.

Section II: Water

Fracking requires vast quantities of water, a portion (about 30%) of which, known as “flowback water,” returns to the surface, along with additional “produced water” previously trapped deep within the earth.²⁰ Both types of wastewater contain materials that may be toxic to human and environmental health, and therefore require proper disposal or treatment.

[Waste Classification]

Federal: Congress passed the Resource Conservation and Recovery Act (RCRA) in 1976 in order to identify hazardous wastes and regulate their disposal. In the midst of two oil crises, an exemption was provided for oil and gas waste, precluding it from being classified as hazardous waste. Such waste was instead listed as “special waste”. The 1980 Bentson Amendment, as it is known, prevented special wastes from being regulated as hazardous waste until “further study and assessment of risk could be performed”. The EPA determined in 1988 that such wastes did not warrant regulation under Subtitle C dedicated to regulating hazardous waste.²¹ This determination was based primarily on production muds and brines used at the time, the compositions of which are very different from the fluids used in today’s slick-water fracking, a technique that was not developed until 1998.²²

Regardless, this exemption, based on the 1988 findings, remains in place and includes wastewater produced from fracking.²³ The EPA states that although such wastes may not be regulated as hazardous, they can still potentially pose a hazard to human and environmental health. “In general, the exempt status of an E&P (Exploration and Production) waste depends on how the material was used or generated as waste, not necessarily whether the material is hazardous or toxic.²⁴” Instead, the EPA regulates fracking wastewater as they would a solid waste, a program less stringent than the hazardous waste program.

¹⁸ Mary Hodge and Dominick Moreno. *A bill for an act concerning a disclosure of possible separate ownership of 101 the mineral estate in the sale of real property*. Senate Bill 14-009, Colorado General Assembly, Denver. 2014.

¹⁹ Shelby Kinney-Lang. “Colorado senators rally round fracking-awareness home-buyer protection bill” *The Colorado Independent*, January 29th, 2014.

²⁰ Rebecca Hammer and Jeanne Vanbriesen. "In Fracking's Wake: New Rules are Needed to Protect Our Health and Environment from Contaminated Wastewater." *National Resources Defense Council*, 2012 (3).

²¹ “Crude Oil and Natural Gas Waste.” *U.S. Environmental Protection Agency*, 2013.

²² Alex Trembath, Jesse Jenkins, Ted Nordhaus and Michael Shellenberger. "Where the Shale Gas Revolution Came From." *The Breakthrough Institute* (2012).

²³ “Crude Oil and Natural Gas Waste.” *U.S. Environmental Protection Agency*, 2013.

²⁴ "Exemption of Oil and Gas Exploration and Production Wastes from Federal Hazardous Waste Regulations." *U.S. Environmental Protection Agency*, 2002.

[Underground Injection]

Federal: In 2005, the federal government agreed to exempt the injection of fracking fluids from the Safe Drinking Water Act's (SDWA) Class I well program.²⁵ This decision was purportedly based partially on the findings of the EPA's 2004 report, which concluded that fracking of coalbed methane reservoirs posed little or no threat to drinking water reservoirs.²⁶ However, coalbed methane extraction involves a very different process than the shale fracking. Rather than injecting chemically-treated water into the ground as is done during the fracking process, water that is already underground is pumped out in order to release gas during the coalbed methane extraction process. Furthermore, the water produced from methane injection does not contain many of the chemical additives that fracking wastewater does.²⁷ These are significant differences that warrant separate investigations. This report did not include a shale fracking investigation but was interpreted by Congress as applicable to all types of fracking, thus becoming the foundation for ensuing policy decisions like the SDWA exemption.²⁸

The EPA's Underground Injection Control Program regulates underground injection of fracking flowback within the Class II well program due to its classification as a solid waste rather than a hazardous waste. However, the oil and natural gas fluids managed within this broad category vary greatly in their composition and toxicity levels. "The construction, permitting, operating, and monitoring requirements are more stringent for Class I hazardous wells than for the other types of injection wells."²⁹ Holding pits containing hazardous waste as classified by the EPA, for example, must be lined sufficiently in order to prevent spillover into nearby soil or water. No such requirement exists for wells regulated under the solid waste program in which fracking wastewater is included.³⁰

State: While many states follow the minimum standards set forth by the EPA in regards to Class II underground injection, some differences exist in state classifications of Underground Sources of Drinking Water (USDW) thereby altering their implementation of the SDWA. California's Division of Oil, Gas and Geothermal Resources, for example, classifies USDWs as containing less than 3,000 ppm of dissolved solids, whereas the EPA classifies USDW's as containing less than 10,000 ppm of dissolved solids. This means that fewer wells than what would have been prescribed directly by the EPA have been subject to SDWA depth and

²⁵ Davis, Charles. "The politics of "fracking": Regulating natural gas drilling practices in Colorado and Texas." *Review of Policy Research* 29, no. 2 (2012): 177-191.

²⁶ John Manuel. "Mining: EPA tackles fracking." *Environmental health perspectives* 118, no. 5 (2010): 199.

²⁷ Lennon, L. 2013. *Coalbed Methane*. http://serc.carleton.edu/research_education/cretaceous/coalbed.html [Accessed: 22 Feb 2014].

²⁸ Manuel, 2010.

²⁹ "Industrial & Municipal Waste Disposal Wells (Class I)." *U.S. Environmental Protection Agency*, 2012.

³⁰ Brady, William. "Hydraulic Fracturing Regulation in the United States: The Laissez-Faire Approach of the Federal Government and Varying State Regulations." Denver: University of Denver, Sturm College of Law, (45).

cementing regulations within the state California.³¹ California's differing interpretation of USDW's is demonstrative of the numerous nation-wide issues that can arise as a result of existing disparities between state and federal policy in combination with a lack of proper communication and coordination between these two levels of governance.

[Contamination Monitoring and Wastewater Discharge]

Federal: Fracking, specifically, is not subject to parts of the 1979 "Oil and Gas Extraction Effluent Guidelines and Standards", and has been repeatedly left out of subsequent amendments in 1993, 1996 and 2001.³² However, the EPA plans to announce the proposal of a new amendment that will make the extraction of unconventional resources, namely by means of fracking, subject to similar regulations on wastewater management to that of conventional methods of extraction.³³ As of now, the sections that do apply, forbid the onsite direct discharge of untreated wastewater into bodies of water, but do allow treatment at and discharge from public or private water treatment centers that often aren't equipped to handle the contaminants present in fracking fluid.³⁴

The Clean Water Act (CWA), enacted by Congress in 1972, provides a regulatory framework that serves to minimize the discharge of unwanted substances into the country's waterways. A 1987 revision to the act introduced storm water runoff as a discharge pathway in need of regulation. However, the Energy Policy Act of 2005 defined "oil and gas exploration, production, operations, process or treatment operations and transmission facilities" as construction activities, thereby exempting all of the above from the storm water runoff section of the Clean Water Act. Although the amendment was found to be illegal, the EPA has not yet updated their regulations, meaning the exemption still stands until further assessment can be done.³⁵

As public concern has grown over the last decade, Congress called upon the EPA to begin a more comprehensive study on the effects of fracking, not limited to coalbed methane extraction, on drinking water. The new report, scheduled to be released early this year, plans to look at all steps in the fracking process including the disposal and treatment of wastewater, and the impacts of initial freshwater inputs on local supplies.³⁶ Such a report will likely become the new standard for federal policymaking on fracking within the coming years.

³¹ Kiparsky, Michael and Jayni Foley Hein. "Regulation of Hydraulic Fracturing in California: A Wastewater and Water Quality Perspective." *Berkeley: Wheeler Institute for Water Law & Policy*, 2014.

³² "Oil and Gas Effluent Guidelines." *U.S. Environmental Protection Agency*, 2013.

³³ "Unconventional Extraction in the oil and gas Industry" *U.S. Environmental Protection Agency*, 2013.

³⁴ *Ibid.*

³⁵ Brady 49.

³⁶ "PROGRESS REPORT Study of the Potential Impacts of Hydraulic Fracturing on Drinking Water Resources." *U.S. Environmental Protection Agency*, 2012.

State: Some states have already moved ahead, taking a precautionary approach when it comes to water. Wyoming approved a major bill in November 2013, which, once in effect, will address public concerns over the possibility of ground and surface water contamination, stating,

“The new water rule, which takes effect in March, will require oil and gas companies to test wells or springs within a half-mile of their drilling site, both before and after drilling. The tests will measure a range of factors, including temperature, bacteria, dissolved gases like methane and propane, and roughly 20 chemical compounds and elements including barium, benzene, strontium and nitrates.”³⁷

While other states, including Colorado and Ohio, have some rules on water testing in place for oil and gas drillers, Wyoming’s new legislation puts forth the most comprehensive and stringent testing requirements to date, subsequently motivating companies to comply to the best of their abilities to existing regulations so to avoid unfavorable test results. However, in addition to a \$15,000 per well testing cost, company officials are concerned that any change in ground water measurements that could have been naturally induced will immediately be seen as the fault of oil and gas drilling, ultimately creating a need for extensive baseline studies.³⁸

[Additives Disclosure]

Federal: The Emergency Planning and Community Right-To-Know Act, established in 1986, created a regulatory framework to provide information on chemical hazards to the public so that communities could take proper steps to prepare and be able to appropriately respond in case of an emergency and so that the public could understand the risks associated with toxins in general. The oil and gas industry, however, is not subject to regulation under this act as the EPA Administrator has the option of adding or subtracting certain “Industrial Classifications” from reporting such requirements.³⁹ Thus, the federal government does not require oil and gas companies to disclose the chemical composition of fracturing solutions. Most recently though, the US Department of the Interior has proposed a new set of regulations applicable to the 700 million acres of subsurface public lands and 56 million acres of subsurface Indian lands, both of which fall under the jurisdiction of the Bureau of Land Management (BLM).⁴⁰

The initial 2012 proposal most notably stipulated that oil and gas companies conducting operations on federal lands must disclose to the BLM and the public all information about chemical agents used in the fracking process following the completion of fracking operations. Any assertion of trade secrets had to be justified to the BLM, making trade secrets more difficult

³⁷ Kate Galbraith. "Strong Rules on Fracking in Wyoming Seen as Model." *The New York Times*, November 22nd, 2013.

³⁸ Ibid.

³⁹ Brady, 8.

⁴⁰ John Broder. "New Fracking Rules Proposed for U.S. Land." *The New York Times*, May 16th, 2013.

to claim. This proposal has undergone significant revision due to industry criticism and now permits companies to withhold chemical information, provided that companies present an affidavit affirming that such information is “entitled to withholding from the public under Federal statute or regulation,”⁴¹ without further justification. While this may streamline the process for oil and gas companies, it has significantly reduced public approval as many feel an affidavit alone is inadequate verification and will be used excessively as a means of circumventing the new disclosure laws altogether.⁴²

State: Recently, many states have independently begun adopting stricter disclosure requirement policies. Wyoming became the first to do so in 2012, followed by Michigan and Texas shortly after. Several states use *FracFocus*, an online registry that is open to the public, where oil and gas companies can provide either voluntary or mandatory disclosure of chemical additives information, depending on the regulatory framework of each state.⁴³ **Figure 2** shows the most up to-date-map reflecting the current status of disclosure regulation across the US. While many have some sort of disclosure requirements already in place, some key fracking states are just now implementing legislation to regulate disclosure requirements or have no regulations or legislation at all.

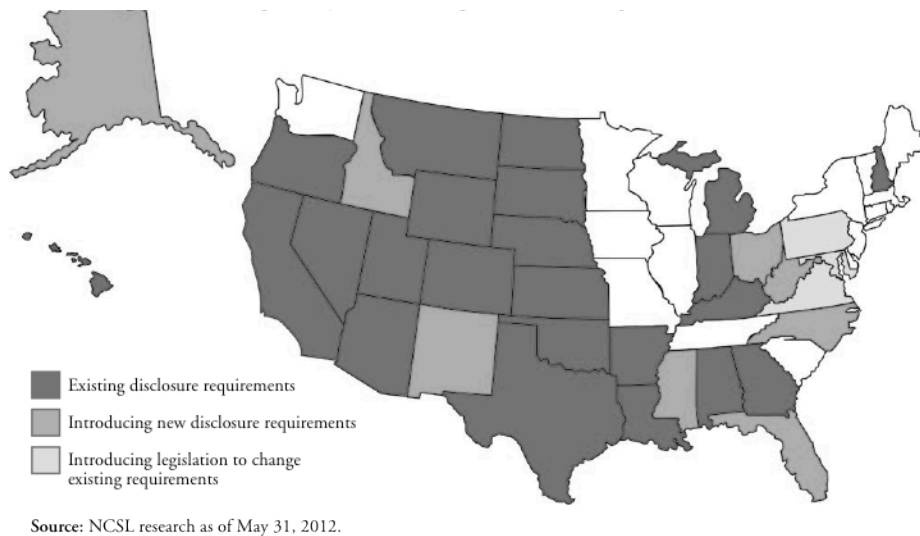


Figure 2: Hydraulic Fracturing Fluid Disclosure Requirements (Source: National Conference of State Legislators)

⁴¹ "Oil and Gas; Hydraulic Fracturing on Federal and Indian Lands." *US Department of the Interior*, 2013.
⁴² Steven Mufson. "Obama administration issues draft fracking regulations." *The Washington Post*, May 16th, 2013.
⁴³ Pless, Jacquelyn. "Natural Gas Development and Hydraulic Fracturing A Policymaker's Guide." *National Conference of State Legislatures*, (2012): 2.

Section III: Air Quality

Federal: Oil and natural gas extraction within the US is the country's biggest industrial emitter of volatile organic compounds (VOCs), which are currently classified as air toxins by the EPA.⁴⁴ After facing legal action for failing to review and update the National Emission Standards for Hazardous Air Pollutants (NESHAP) and the New Source Performance Standards (NSPS) within the required eight-year time period, in 2012, the EPA issued new air pollution regulations to require companies engaged in fracking to reduce their VOC emissions. New emissions-reducing equipment known as green completions, that capture and sort incoming substances from underground wells, will be required for all natural gas and oil extraction sites in the US by 2015 and will have the added benefit of minimizing methane emissions as well.⁴⁵

Companies that do not make the transition to green completions prior to 2015 must instead burn-off emissions in a process known as flaring. Although flaring is more preferred than the release of VOC's, the process still emits harmful pollutants and is thus not a sustainable long-term solution.⁴⁶ The EPA has other resources in place such as the Natural Gas STAR program and Clean Construction USA program to help oil and gas companies minimize their air emissions through the implementation of new technologies, better fuels and cleaner practices. However, these programs are voluntary.⁴⁷ Under the latest 2012 Source Performance Standards Review conducted by the EPA, emissions coming from onsite holding tanks among other forms of processing equipment are also subject to VOC reductions requirements as well. Storage vessels with yearly VOC emissions at or above 6 tons are obligated to reduce such emissions by 95%.⁴⁸

State: Many states, like Wyoming, already require "flare-less completions" as a means of minimizing oil and gas well emissions. Some states have implemented stricter regulations and better means of detection than federally mandated air quality standards. Arkansas, for example, has begun utilizing infrared cameras and frequent well-site inspections to detect leaks and thereby mitigate unintended emissions.⁴⁹

⁴⁴ Bob Weinhold. "The future of fracking: new rules target air emissions for cleaner natural gas production." *Environmental health perspectives* 120, no. 7 (2012): 274.

⁴⁵ "Oil and Natural Gas Sector: New Source Performance Standards and National Emission Standards for Hazardous Air Pollutants Reviews." *U.S. Environmental Protection Agency*, 2012.

⁴⁶ Weinhold 275.

⁴⁷ "Natural Gas Extraction - Hydraulic Fracturing." *U.S. Environmental Protection Agency*, 2013.

⁴⁸ "Oil and Natural Gas Sector: New Source Performance Standards and National Emission Standards for Hazardous Air Pollutants Reviews." *U.S. Environmental Protection Agency*, 2012.

⁴⁹ Weinhold 277.

Section IV: Violations

In order to ensure that oil and gas companies adhere to environmental laws set forth by the federal government, the EPA employs two enforcement programs: civil and criminal enforcement. Civil enforcement pertains to well violations in which the operators were unaware any such violation occurred or were accidental. Criminal enforcement pertains to violations in which a party knowingly or intentionally violates environmental laws. Although not specific to fracking operations, every three years the EPA chooses a set of initiatives to address specific environmental law violations.⁵⁰ Although the EPA has successfully filed suit against many violators, the consequences remain relatively low for those found guilty.

Considering that states have their own regulations pertaining to fracking, it is up to their own environmental agencies to enforce compliance. However, this can be problematic because states are often short on funding for such enforcement projects.⁵¹ Other issues persist particularly in the case of reporting violations. In Pennsylvania for instance, the Department of Environmental Protection does not require fracking companies to directly notify landowners of violations that occur on their property during the drilling process.⁵² This has become a sore point for landowners and has the potential to gain wider recognition within the anti-fracking movement, thereby necessitating a more thorough look at landowner rights from a policy standpoint.

Section V: Taxation and Fees

Federal: One of the major government incentives for fracking is the potential for it to generate widespread tax revenues. Within the 2014 Fiscal Year Budget Proposal, the Obama administration proposed the elimination of a lengthy set of tax breaks currently enjoyed by the oil and gas industry. This could raise an estimated \$24.2 billion extra in federal funds between 2014 and 2018.⁵³ Critics, however, point out that such a move could be passed on to consumers in the form of heightened oil and electricity prices. Critics also suggest that small oil and fracking companies may suffer disproportionately as the elimination of the break will narrow the tax advantage gap between independent oil and gas producers and the big name oil companies.⁵⁴ However, putting this money towards research and improved regulatory frameworks has the potential to ease public concerns, which presumably could enable smoother development.

⁵⁰ "Oil and Gas Effluent Guidelines." *U.S Environmental Protection Agency*, 2013.

⁵¹ Barbara Warner and Jennifer Shapiro. "Fractured, Fragmented Federalism: A Study in Fracking Regulatory Policy." *Publius: The Journal of Federalism* (2013): 476.

⁵² "Few Answers on Fracking Violations." *CNN*, 2012.

⁵³ Pirog, Robert. "CRS Report for Congress Prepared for Members and Committees of Congress Oil and Natural Gas Industry Tax Issues in the FY2014 Budget Proposal." *Congressional Research Service*, 2013.

⁵⁴ *Ibid.*

State: At the state level, governments gain significant revenues through severance taxes. In a report published by the National Conference of State Legislatures, it was estimated that in 2010, severance taxes produced approximately \$11 billion in state revenues alone, keeping in mind that several states do not have such severance tax systems.⁵⁵ As of June 2013, 35 states had in place a severance tax specifically pertaining to the oil and gas industry, a number that has increased by four just within a year's time.⁵⁶ This number is likely to change further as more states seek to cash in on the booming fracking industry.⁵⁷



Figure 3: Oil and Gas Severance Taxes and Recent Legislation (Source: National Conference of State Legislators)

As demonstrated in **Figure 3**, many states situated above the Marcellus shale have no such severance tax in place. Pennsylvania, a major natural gas producer, instead, levies an impact fee upon oil and gas producers. This is a set fee, rather than a tax on either the value or volume of produced oil/gas as is commonly used in other states' severance systems.⁵⁸ However the situation could change in Pennsylvania as it has in other states. One representative has proposed a bill to put an end to the impact fee and switch over to a low-rate severance fee.⁵⁹ Indeed, had a switch been made to an approximate 5% severance tax in 2012, it is estimated it would have generated over \$500 million more in state revenue by 2015.⁶⁰ This money can be crucial for state governments who are often faced with budget cuts.

⁵⁵ Pless. "Natural Gas Development and Hydraulic Fracturing A Policymaker's Guide." 6.

⁵⁶ Brown, Cassarah. "State Revenues and the Natural Gas Boom: An Assessment of State Oil and Gas Production Taxes." *National Conference of State Legislatures*, 2013.

⁵⁷ Pless. "Natural Gas Development and Hydraulic Fracturing A Policymaker's Guide." 6.

⁵⁸ Brown.

⁵⁹ Colaneri.

⁶⁰ Brown.

Conclusion

Current regulations are a patchwork of federal, state and local policy. The EPA continues to update various standards and frameworks traditionally applied to conventional forms of oil extraction. However, a comprehensive federal framework for fracking remains elusive. President Obama requested in 2011 the establishment of a subcommittee within the Department of Energy's Secretary of Energy Advisory Board to address the fracking of natural gas. This independent body of experts in coordination with the EPA and DOI, was tasked with providing a comprehensive set of recommendations based on independent research and assessment of existing information. However the subcommittee was given a 90 day period to complete their task, and was thus not suited to address new challenges that have since arisen and may arise in the future.⁶¹

Ultimate power to regulate extraction operations remains predominantly within state governments. As societal concern over fracking grows, more pressure is being put on policy-makers to appease the public. Environmental groups are increasingly calling on the EPA to step up federal regulations on fracking, while oil industry leaders push back, pressing for continued regulation by the state. Many oil and gas companies argue that federal regulations would be too broad pointing out that they would be unable to take into account the geologic differences that can exist between fracking locations.⁶² Policy-makers often support the stance taken by oil and gas companies on the grounds that state governments are more geared towards the interests of their citizens and are therefore more receptive than the federal government.⁶³ It is ironic that many of those who argue on the basis that localized regulation at the state level provides a framework that is more attuned to local interest have often rejected highly localized regulation campaigns at the county or municipality level as demonstrated by the enactment of Article 13 and various lawsuits filed against places like Mora county and the cities of Fort Collins and Lafayette.

State-level regulation is preferable for oil and gas companies, as states are more limited by financial constraints in their ability to conduct research that may support the introduction of new and possibly more stringent environmental laws and in their ability to enforce such laws. As environmental standards are often costly for a company to implement, it is financially preferable for oil and gas companies to forestall new laws by backing state control.⁶⁴ Based on the number of federal law exemptions made for fracking, preferences for state-led regulation have left a clear mark on policy making.

⁶¹ Chu, Steven. "Charge to Secretary of Energy Advisory Board Natural Gas Subcommittee to Examine Fracking Issues." *Department of Energy*, 2011.

⁶² Barbara Warner and Jennifer Shapiro. "Fractured, Fragmented Federalism: A Study in Fracking Regulatory Policy." *Publius: The Journal of Federalism* (2013): 476.

⁶³ Ibid.

⁶⁴ Ibid.

While these exemptions may have initially helped to boost the oil and gas industry, the criticism stemming from such actions is beginning to have very real consequences on production itself as more and more states, counties and municipalities consider moratoriums or outright bans on fracking. Although federal deregulation has succeeded in shifting the burden of responsibility into the hands of states, it has no doubt provoked public condemnation and mistrust of the federal government's ability to properly manage fracking. Many critics regard such exemptions as indicative of a larger-scale influence wielded by oil and gas industries within federal politics, which can be detrimental to the credibility of the US in its ability to objectively and effectively lead the way in large-scale fracking development.

Chapter Three

GLOBAL PERSPECTIVE: WORLD OIL RESERVES

Chieh-Hsi Wang

Abstract

This chapter discusses the current and projected future global oil status by comparing data and graphs, examining how these will have an impact on the global political and economic situation. Section I will discuss the current oil reserves by comparing oil reserves between OPEC and non-OPEC countries and other regions with several case studies. Section II will talk about world oil demand by comparing regions' oil demand over time, such as in the Asia Pacific, North America, and Europe. Section III will examine world oil consumption and the gradual shifts in demand from West to East. Lastly, in Section IV, this chapter will present a world oil outlook that includes world oil trends, uncertainties, challenges and opportunities in the world oil industry.

Introduction

Although its overall share in global energy use has declined since 2000, oil is still the world's main energy source. In large part, this is because oil is the single source for over 90% of global transportation and has no alternatives, making it the one energy resource without which advanced civilization could not exist. Oil is also the most traded commodity in the world⁶⁵. For all these reasons, oil can be seen as political capital and a key concern for energy security in most of the world's nations. The recent shale oil boom in the US is a crucial event because it enables the US to become a potential game changer in the global oil industry. As recently as 2007, the United States was the world's number one oil importer, and its dependence on such imports seemed assured for decades, destined to support a dominant position for OPEC. By 2012, these circumstances no longer held true. US imports from mainly OPEC countries fell rapidly and instead, the US became a top exporter of petroleum products. This transformation has the potential to change North America into self-sufficient region, particularly if the shale oil boom further spreads to Canada. Such changes are altering the politics and economics of the world oil

⁶⁵ Mieke Reece. "The IEA oil data system." *The IEA oil data system*. (Moscow: International Energy Agency, 2012): 6.

<http://www.iea.org/media/workshops/2012/trainingmoscow/Session3Reece.pdf>. (accessed 9 Feb 2014).

market. In order to understand this transition, it is necessary to examine the disposition of oil reserves, production, consumption, and demand, as well as compare information between OPEC and non-OPEC countries and discusses the key players. The examination of the current world oil outlook, including major trends, uncertainties, challenges, and opportunities, is needed to assess what the long-term impact of shale oil might be.

Section I: World Oil Reserves

Data shows that there were estimated to be 1.67 trillion barrels of proven oil reserves in the world by the end of 2012⁶⁶. This represents more than a 60% increase over the figure for 1992, which was 1.04 trillion barrels, and a 21% rise over the 2002 number of 1.32 trillion barrels.⁶⁷ Global proven oil reserves have increased about 1.6 times, or around 630 billion barrels over the past 20 years—an average annual increase of 31.5 billion barrels.

In short, the world does not lack available oil resources. Forecasts by the International Energy Agency (IEA) in 2013 show total world oil production rising from 89 million barrels per day (mb/d) in 2012 to 101 mb/d by 2035.⁶⁸

A main reason for the increase in global proven reserves has been that, as technologies become more advanced, costs decrease and more exploitation is possible. In recent years, this

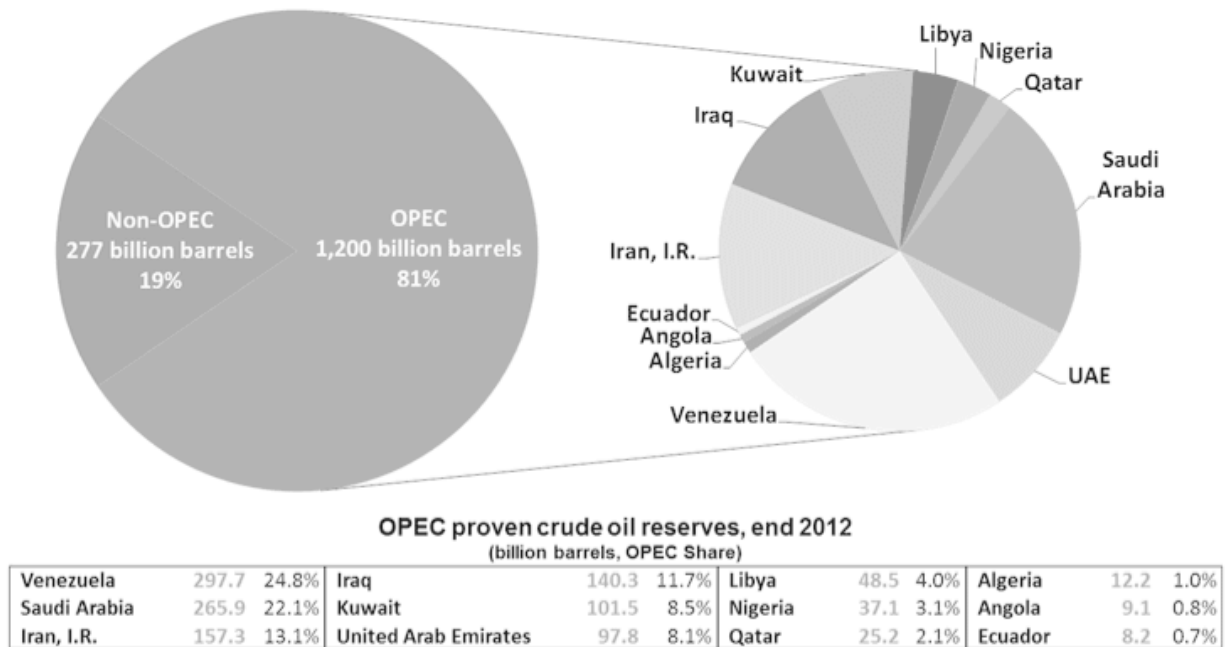
⁶⁶ BP Statistical Review of World Energy. *BP Statistical Review of World Energy*. BP, (2013): 3. http://www.bp.com/content/dam/bp/pdf/statistical-review/statistical_review_of_world_energy_2013.pdf. (accessed 5 Feb 2014).

⁶⁷ It is important to note that talking about oil reserves, it is referring to proven oil reserves that have more than 90% potential to be produced in the future. Since the actual amount of oil that exists underground and the amount that has the potential to be produced in the future are uncertain, all numbers that are given by countries are basically estimations (BP.com, n.d.). Therefore, some oil companies may exaggerate the numbers of oil reserves to influence investors to make them be confident about long-term investments, while some may underreport the numbers to save on taxes. As a result, the number of oil reserves can influence global oil situation, which is what makes the number of world oil reserves a crucial factor in oil industry.

⁶⁸ World Energy Outlook 2013 Factsheet. *World Energy Outlook 2013 Factsheet*. International Energy Agency, (2013): 3. http://www.iea.org/media/files/WEO2013_factsheets.pdf. (accessed 21 Feb 2014).

process has been strengthened by higher oil prices, which have aided the use of more sophisticated technology.

This chapter will compare shares of world crude oil reserves between OPEC member countries and non-OPEC countries and go into detail by comparing different regions in the world. As illustrated by **Figure 1**, one estimate, by an OPEC report for 2012 shows member countries holding 81% of total global proven crude oil reserves.⁶⁹ Another estimate by BP shows that OPEC member countries hold about 73% of the total.⁷⁰ Using these estimates as representing upper and lower limits, it remains apparent that OPEC member countries possess the major portion of global proven crude oil reserves. Nations in the Middle East possess most of this, possibly as much as two-thirds. In 2012, OPEC member countries produced 41% of the total oil supply.⁷¹ Non-OECD nations therefore account for the larger part of global production at present, suggesting that OPEC reserves are being depleted at a rather low rate.



⁶⁹ Opec.org. "OPEC : OPEC Share of World Crude Oil Reserves." 2013. http://www.opec.org/opec_web/en/data_graphs/330.htm (accessed 21 Jan 2014).

⁷⁰ "BP Statistical Review of World Energy," 6.

⁷¹ Eia.gov. "Energy & Financial Markets - U.S. Energy Information Administration (EIA) - U.S. Energy Information Administration (EIA)." 2013. <http://www.eia.gov/finance/markets/supply-opeccfm> (accessed 08 Feb 2014).

Figure 1: Share of world crude oil reserves of non-OPEC and OPEC countries in 2012. (Source: OPEC)

When analyzing global reserves, the Middle East accounted for nearly half of the proven oil reserves through 2012, in which Saudi Arabia, Iran, and Iraq made up 70% of the total share. In contrast, South and Central America together, following the Middle East, hold 19.7% of the world's proven oil reserves. From which, Venezuela, also an OPEC member, accounts for 17.8%, which is about 90% of the total amount of proven oil reserves of that region. It is important to note that the contributions of global proven oil reserves from the Middle East have decreased in the past 20 years. The Middle East used to hold 63.7% of the total world proven oil reserves, but decreased to 56.1% in 2002 and dropped below 50% in 2012. However, it will become the greatest increase later in the future.⁷² The Middle East is expected to see an increase of more than 35% in its liquids production, mainly as a result of Iraq's conventional oil development, increase in NGLs (Natural Gas Liquids), and growth in tight oil production in the next decades.⁷³

There was a slight decline in the amount of world proven oil reserves that North America held in the past decade. North America's proven oil reserves dropped from 228.3 billion barrels in 2002 to 220.2 billion barrels in 2012. The North American decline is largely related to the decline in Canada's proven oil reserves, which dropped from 180.4 billion barrels to 173.9 billion barrels. It is important to note that there was a slight increase in the US, where the amount increased from 30.7 billion barrels in 2002 to 35 billion barrels in 2012. The recent shale oil boom can explain this increase.⁷⁴

South and Central America have seen a huge increase in their share of world oil proven reserves. Venezuela's reserves of unconventional heavy oil are mainly responsible for this growth. Even though the Middle East has the most proven oil reserves, Venezuela now exceeds Saudi Arabia as the world's largest reserve holder.⁷⁵ The great majority of Venezuela's reserves remain undeveloped at present, and its exports are moderate and decreasing, due to lack of investment in infrastructure. Thus its impact on the global market is far smaller than Saudi Arabia's, which is the world's top exporter.

⁷² "BP Statistical Review of World Energy," 6.

⁷³ The Outlook for Energy: A View to 2040. *The Outlook for Energy: A View to 2040*. Exxon Mobil Corporation, (2014): 37. <http://corporate.exxonmobil.com/en/energy/energy-outlook>. (accessed 9 Feb 2014).

⁷⁴ "BP Statistical Review of World Energy," 6.

⁷⁵ "BP Statistical Review of World Energy," 6.

According to the IEA, although reserves in non-OPEC member countries have played an important part in satisfying net oil demand growth this past ten years, OPEC member countries will play a much more important role after 2020.⁷⁶ The influence of OPEC's role in meeting the world's demand for oil is projected to decrease temporarily in the next decade, due to the increasing production of light tight oil in US and deepwater in Brazil. The share of conventional crude oil in world's total oil production is expected to decrease from 80% in 2012 to 66% over the next two decades. However, the share of OPEC member countries in world oil output will increase again in the 2020s since they are expected to be able to provide a large amount of relatively cheap oil.⁷⁷ The Middle East is expected to have its oil supply increase by 50% by 2035 due to the rapid rise in oil demand in developing countries in the Asia Pacific, such as China and India.⁷⁸ Therefore, being a major region of oil production, the Middle East will still maintain its importance in international standing even though the recent massive exploitation of unconventional oil in the US can enable the US to become one of the biggest oil exporters.

Section II: World Oil Demand

By 2035, Asian nations will account for over 90% of net energy demand growth. The center of gravity of energy demand in the world is shifting towards Asian economies. Due to the rapid increase in energy demand in the Asia Pacific, the center of world energy trade is also shifting from the Atlantic basin to the Asia Pacific region. Specifically, China has been leading oil demand growth in Asia for the past ten years. This same shift will gradually move towards India and Southeast Asia in the next decade, though to a smaller degree.⁷⁹ The overall oil demand in the Asia Pacific is expected to continue along the increasing trend. One of the factors that drive up oil demand in Asia is urbanization. China is an example of a developing country where many places have gone through urbanization. During urbanization, many manufacturing and other industries located around cities require large amounts of oil. Furthermore, since there are usually less people per household in urban sites, it often results in a greater number of actual households in developing economies. All of this will drive oil consumption up, resulting in increased

⁷⁶ World Energy Outlook 2013. *World Energy Outlook 2013*. London: International Energy Agency, (2013): 1.
<http://www.worldenergyoutlook.org/pressmedia/recentpresentations/LondonNovember12.pdf>. (accessed 10 Feb 2014).

⁷⁷ "World Energy Outlook 2013 Factsheet," 3.

⁷⁸ "World Energy Outlook 2013," 8.

⁷⁹ "World Energy Outlook 2013 Factsheet," 1.

demand. The estimation of the percentage of people living in urban areas in non-OECD countries is expected to be around 60% by 2040, increasing from 45% in 2010 and 30% in 1980.⁸⁰ Another trigger for growth in world oil demand is the transport sector. World oil demand in the transport sector will continue to rise as the amount of light duty vehicles doubles worldwide to 1.7 billion. In addition, the demand for transportation can account for about two-fifths of oil demand growth in the world.⁸¹ Even though the growing pace for oil demand has slowed down because of the increasing oil efficiency of vehicles, the demand from the transportation sector and for petrochemicals will continue to retain demand for oil, a rising trend in the next few decades.⁸² Since the oil used in the transport sector can hardly be replaced by any other energy resource because of its many advantages, including reasonable prices compared to other energy sources, accessibility, transferability, and high energy density in the near future. Also, since more than half of all oil used is used by the transport sector, global demand for oil will continue to grow. Gasoline, diesel, jet fuel and fuel oil, and other such liquid fuels will remain the most used energy sources in the transportation sector and continue to maintain their importance in the world energy mix.⁸³ Since the transport sector accounts for a large part of world oil demand growth, looking at how the Asia Pacific region uses the mix of fuels in the transport sector will give us a clearer idea of how the status of oil demand in the Asia Pacific is and how the region is important in the world oil industry. In the Asia Pacific, gasoline and ethanol will continue to grow slowly and are projected to flatten later on, by 2040, because light-duty vehicles have become more efficient, while other fuels will all increase steadily by 2040. Furthermore, **Figure 2** shows that the demand for liquid fuels in the transport sector, such as gasoline, diesel, fuel oil, and jet fuel, altogether will continue to rise sharply by 2040. Oil demand for commercial transportation will grow throughout 2040, not only in the Asia Pacific but also in almost every other nation. Among these nations, China will have the greatest growth, with an expected demand of over four mb/d. Four years ago, China's energy demand for commercial transportation was still behind Europe, the US, and the Middle East, however, China is expected to be at the top by 2040. India and Brazil are both expected to have big growths as well, with India expected to grow the fastest.⁸⁴ Since the transport sector drives world oil demand up, this

⁸⁰ "The Outlook for Energy: A View to 2040," 11, 13, 22.

⁸¹ World Energy Outlook 2012. *World Energy Outlook 2012*. International Energy Agency, (2012): 4. <http://www.iea.org/publications/freepublications/publication/English.pdf>. (accessed 30 Jan 2014).

⁸² "World Energy Outlook 2013," 4.

⁸³ "The Outlook for Energy: A View to 2040," 22.

⁸⁴ "The Outlook for Energy: A View to 2040," 21, 22.

indicates that Asia Pacific will become the region that demands the most oil, as clearly shown in **Figure 2**.

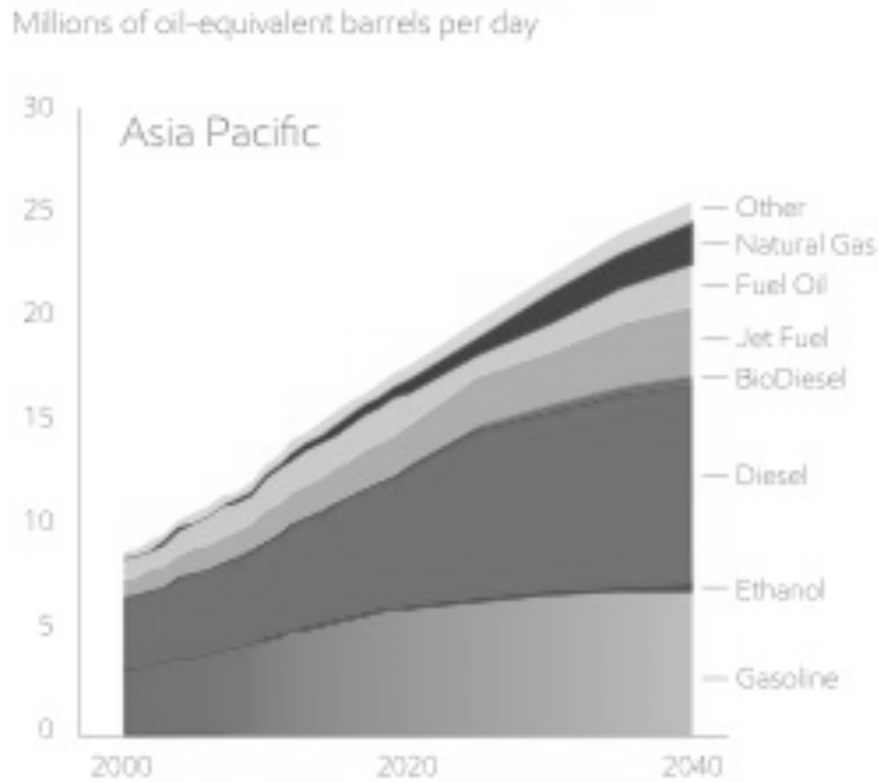


Figure 2: Mix of fuels used for transportation by Asia Pacific from 2000 to 2040 (Source: ExxonMobil)

World oil demand continues to increase but the pace of growth is slowing down. The world oil demand is rising at a rate of an average of 0.8% per year, which is the slowest growth rate among other fossil fuels, such as gas, which has the fastest growth rate at 1.9% per year. The slow growing pace of oil is mainly due to the increasing oil efficiency of vehicles. Despite the pace, the demand for oil and other liquid fuels will still increase to approximately 19 mb/d, which is higher in 2035 than in 2012. In world oil demand, all the net demand growth is not expected to come from the OECD countries because oil demand in OECD countries will decrease due to an increase in efficiency and fuel switching. As illustrated in **Figure 3**, demand will be primarily driven by fast growing emerging economies in non-OECD member countries.

China, India, and the Middle East, in particular, are the countries that will account for almost all of the net global oil demand growth.⁸⁵

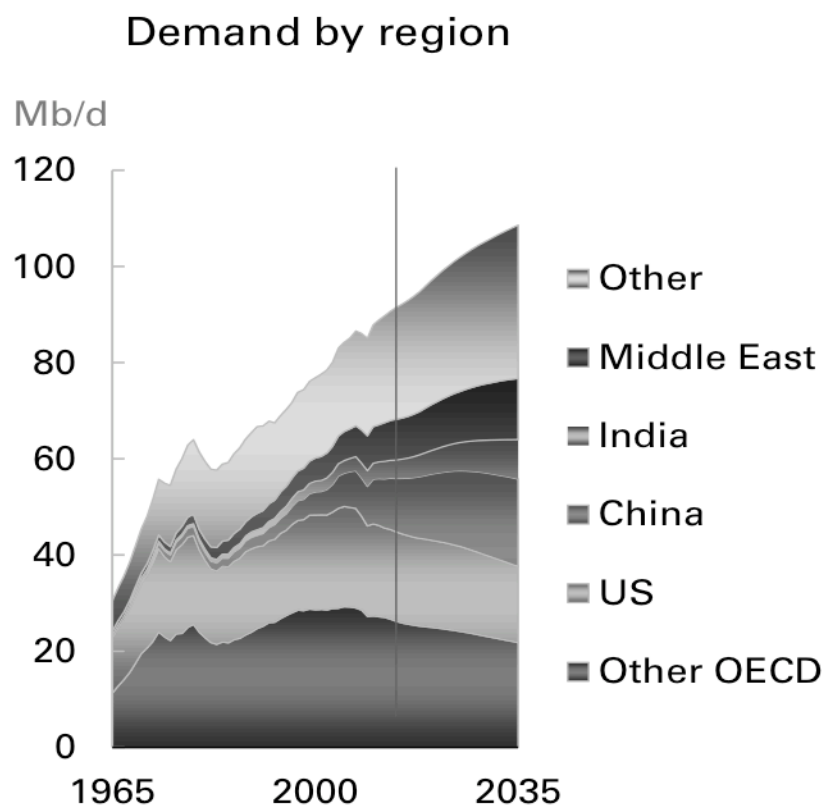


Figure 3: Energy outlook of oil demand by region to 2035 (Source: BP)

Figure 3 shows that demand for oil in OECD countries has already reached its peak, while demand in non-OECD countries will continue to increase over the next few decades. Demand for oil in China has increased from 4.6 mb/d in 2000 to more than eight mb/d in 2009.⁸⁶ Furthermore,

⁸⁵ BP Energy Outlook 2035. *BP Energy Outlook 2035*. BP, (2014): 13, 25-26.
http://www.bp.com/content/dam/bp/pdf/Energy-economics/Energy-Outlook/Energy_Outlook_2035_booklet.pdf.

⁸⁶ Oil & Gas Security Emergency Response of IEA Countries. *Oil & Gas Security Emergency Response of IEA Countries*. International Energy Agency, (2012): 5.
http://www.iea.org/publications/freepublications/publication/China_2012.pdf. (accessed 21 Feb 2014).

China's oil demand is projected to increase by eight mb/d to 18 mb/d in 2035, which will surpass the US's oil demand in 2029 as its oil demand is projected to decrease from 2.7 mb/d to 15.8 mb/d over the next few decades. India and the Middle East are the other two regions that are expected to contribute most to world oil demand, with both growing by 4.6 mb/d as other non-OECD Asia countries increase by 3.1 mb/d. Although the largest growth in world oil demand is mainly from China over the next decade until 2035, the capacities of its growth will slow down compared to those observed over the last decade.⁸⁷ The total oil demand in China in 2009 had an average of around eight mb/d, and has been growing at a fast pace, from 4.6 mb/d in 2000, in which the compound average growth rate is 6.7%.⁸⁸ Oil demand in China sees an increase of only 0.9 mb/d during the period of 2030 to 2035, while it had increased by 2.3 mb/d from 2005 to 2010. As a result, India will surpass China to become the largest contributor to world oil demand growth. It will increase by 1.3 mb/d from 2030 to 2035. The Middle East is also expected to increase 0.9 mb/d from 2030 to 2035 and surpasses the US in 2033, becoming the major per capita consumer of oil.⁸⁹

In addition to China being projected to have the largest oil demand by 2035, it is also one of the important oil producing countries in the world. Crude oil production in China increased to 4.1 mb/d in 2010, which was also the first time that China's oil production has exceeded 4mb/d. Nonetheless, China's demand for oil will exceed its production capabilities for oil as the economy continues to grow. In the New Policy Scenario, a baseline scenario presented in the IEA's World Energy Outlook, taking other countries' announced policies into consideration, the primary oil demand in China will increase to 12.2 mb/d in 2020 and to 15.5 mb/d in the following 15 years.⁹⁰ Though China is now the forth-largest oil producer in the world, sharing 5% of the world total oil production in 2012 just behind Saudi Arabia, Russia Federation, and the US, it has been a net oil importer since 1993 and a net crude oil importer since 1996.⁹¹ ⁹² Data from the General Administration of Customs of China showed that China imported 4.7 mb/d of crude oil in 2010, which accounted for around 53.8% of its total oil demand. In the following year, data from China, Oil, Gas and Petrochemicals showed that China imported more than five

⁸⁷ "BP Energy Outlook 2035," 26-27.

⁸⁸ "Oil & Gas Security Emergency Response of IEA Countries," 5.

⁸⁹ "BP Energy Outlook 2035," 27.

⁹⁰ "Oil & Gas Security Emergency Response of IEA Countries," 5.

⁹¹ "BP Statistical Review of World Energy," 8.

⁹² "Oil & Gas Security Emergency Response of IEA Countries," 6.

mb/d of crude oil, which was around 54% of its total oil demand. Among the size of China's crude oil imports, more than half of the total crude oil imports were from the Middle East, followed by Africa. China imported around 24% of its total crude oil from Africa. China imported about 20% of its total crude oil, from which 12% came from Saudi Arabia, 11% from Angola, 11% from Iran, 7% from Oman, 7% from Russia, 5% from Sudan, and 5% from Iraq. With a sustained oil demand growth until 2035, under the expectations of the New Policy Scenario in the World Energy Outlook 2011 presented by IEA, oil imports in China are expected to increase constantly as well. From the data, it is clear that China is highly dependent on the Middle East, and again, the Middle East will continue to be a major provider of crude oil to China as well as other countries, thus it will retain its importance in the world oil industry.⁹³

Section III: World Oil Consumption

World oil consumption was 89.8 mb/d by 2012, rising to 91 mb/d in the first quarter of 2014.⁹⁴ World oil consumption grew at a faster pace between 2002 and 2004, when the consumption rates rose from 78.47 mb/d to 82.99 mb/d in only two years. Since 2004, the growth rate of global oil consumption has decreased gradually, due to the decline in oil consumption in OECD member countries, which has accounted for over half of the total world oil consumption. The oil consumption growth rate of OECD member countries between 2011 and 2012 was -1.3%, while the growth rate of EU was -4.6%.⁹⁵ Increasing oil prices, slower economic growth, and development in transportation sectors were some of the major factors that caused this decline.⁹⁶ Regionally, looking back to 2005, North America used to have the highest oil consumption in the world, with 25.1 mb/d, followed by Asia Pacific, with 24.5 mb/d. Since then, however, the Asia Pacific has surpassed North America by becoming the top oil-consuming region in the world. Consumption in North America had a -1.8% growth rate, decreasing from 23.4 mb/d in 2011 to 23 mb/d in 2012 and sharing 24.6% of the total world oil consumption. More specifically, though, despite the fact that the US was still the country that consumed the most oil in the world by

⁹³ "Oil & Gas Security Emergency Response of IEA Countries," 3, 5-6.

⁹⁴ Short-Term Energy Outlook (STEO). *Short-Term Energy Outlook (STEO)*. U.S. Energy Information Administration, (2014): 29. http://www.eia.gov/forecasts/steo/pdf/steo_full.pdf. (accessed 26 Feb 2014).

⁹⁵ "BP Statistical Review of World Energy," 9.

⁹⁶ Eia.gov. "Energy & Financial Markets – What Drives Crude Oil Prices?" n.d.. <http://www.eia.gov/finance/markets/demand-oecd.cfm> (accessed 08 Feb 2014).

sharing 19.8% of the total oil consumption, it had a negative growth rate of 2.3% between 2011 and 2012.⁹⁷ This is a result of the increase in US production of oil and gas and increased energy efficiency. The advancement in upstream technologies has allowed the US to open up a new market for tight oil and shale gas that has helped the US stimulate its economy and gradually replace the role of North America as an oil producer in the global oil industry. The US is expected to become the largest oil producer in the world in less than ten years and is likely to overtake Saudi Arabia's place in around the mid-2020s as their oil imports continue to decline, making them a net oil exporter by 2030.⁹⁸

Oil demand in emerging economies, such as China, India, and the Middle East is expected to increase continually in the next few decades because of high rates of development. In the Asia Pacific, oil consumption is growing almost twice as fast as in the world as a whole. Also, the amount of oil that the region consumed was three times more than the amount it produced in 2006.⁹⁹ Oil consumption by the Asia Pacific increased by 3.7%, rising from 28.8 mb/d in 2011 to 29.8 mb/d in 2012 and sharing 33.6% of the total world oil consumption.¹⁰⁰ Transport and petrochemicals are the two main sectors where oil consumption is increasingly concentrated in. Oil demand in China has increased the most, up to six mb/d, which it is expected to overtake the US as the world's largest oil consumer by about 2030. The second largest oil consumer will be India, as its oil demand grows up to 4.5 mb/d, followed by the Middle East, which is expected to become the third largest oil consumer in the world. Its oil demand is expected increase to ten mb/d in 2035, reinforced by a fast-growing population and by oil subsidies, which were equivalent to \$520/person in 2012.¹⁰¹ China, in particular, is likely to become the largest consumer of oil by 2030 as oil consumption of OECD member countries continue to drop by eight mb/d.¹⁰² While the Asia Pacific only shares 2.5% of the world total proven oil reserves in 2012, and since there are not many options available for increasing oil production, the result is that the region is getting more dependent on importing oil from the Middle East.¹⁰³ The decline

⁹⁷ "BP Statistical Review of World Energy," 9.

⁹⁸ "World Energy Outlook 2012," 1.

⁹⁹ Kang Wu, Fereidun Fesharaki, Sidney Westley and Widhyawan Prawiraatmadja. "Oil in Asia and the Pacific: Production, Consumption, Imports, and Policy Options." *Asia Pacific Issues* no. 85 (2008): 1, 2.

¹⁰⁰ "BP Statistical Review of World Energy," 9.

¹⁰¹ "World Energy Outlook 2013 Factsheet," 3.

¹⁰² "BP Energy Outlook 2035," 25, 29.

¹⁰³ "BP Statistical Review of World Energy," 6.

of oil consumption in OECD member countries and the rise of oil consumption in the Asia Pacific as well as Middle East have helped facilitate the shift of international oil trade from the West towards Asia. This shift has raised concerns about the oil security of strategic routes that transport oil from Middle Eastern oil to markets in the Asia Pacific.¹⁰⁴

Section IV: Outlook

World oil trends show that oil will maintain its importance in the long term even if energy resources, such as renewables and natural gas together, are projected to meet nearly 70% of incremental energy demand in the next few decades. Forecasts show that from 2035 to 2040, oil will continue to have the largest share at 28% of the fuel mix.¹⁰⁵ Moreover, there will be about 65% of recoverable crude and condensate oil in the world that will not yet have been produced by 2040.¹⁰⁶ Oil prices will remain high due to increasing demand in the transport sector of developing countries, including China and India. Rising oil supply to satisfy oil demand growth will come mainly from non-OPEC unconventional resources and from OPEC later in the outlook period. Non-OPEC oil supply is projected to increase by 10.8 mb/d, while oil production of OPEC countries will increase by 7.4 mb/d in the next decades to 2035. Oil supply in the US will increase by 3.6 mb/d, while Canada will increase by 3.4 mb/d, and Brazil will increase by 2.4 mb/d. These three countries are the main sources of the largest growths of non-OPEC oil supply, which offset declines in more developed regions like the North Sea, for example. In addition, crude oil in Iraq will increase by 2.6 mb/d, which is one of the main sources that accounts for growth in OPEC oil supply.¹⁰⁷

¹⁰⁴ “World Energy Outlook 2012,” 1.

¹⁰⁵ Global Energy Trends: Focus on oil & gas. *Global Energy Trends: Focus on oil & gas*. Mexico City: International Energy Agency, (2012): 7. http://www.iea.org/media/mvdh/Mexico_Seminar.pdf. (accessed 13 Feb 2014).

¹⁰⁶ “The Outlook for Energy: A View to 2040,” 36.

¹⁰⁷ “BP Energy Outlook 2035,” 25.

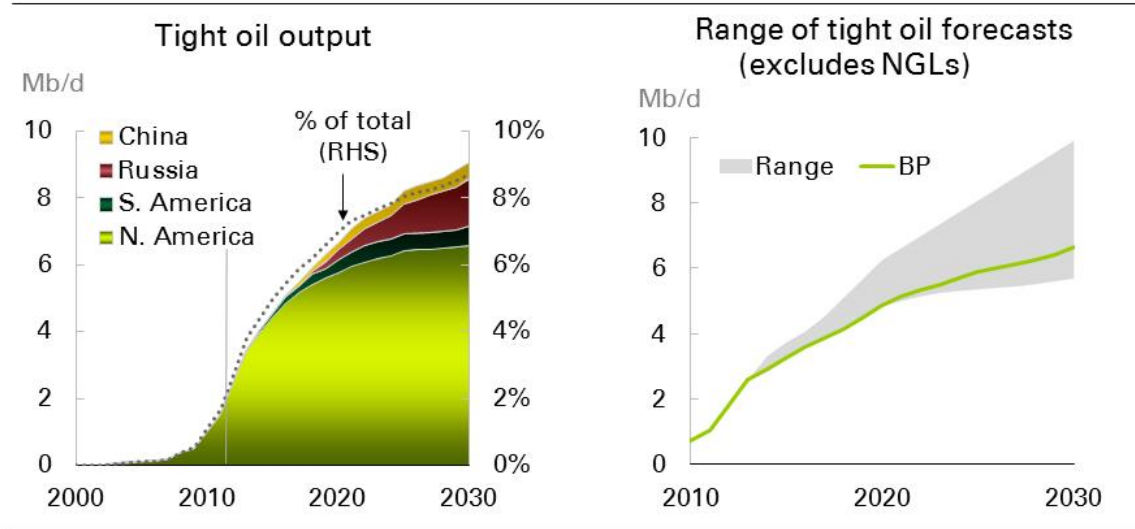


Figure 5: Global tight oil output by regions from 2000 to 2030 (Source: BP)

Iraq will have the largest growth in oil production, followed by Brazil, Canada, and Kazakhstan. They are countries that have the potential to significantly contribute to production growth in the next 25 years.¹⁰⁸ For much of the time through 2035, the US is the largest oil producer in the world. In the future, the US, whose tight oil production is continually rising, will be a key producer as well, as seen in Figure 5, by shifting its role from a dominant importer to a significant exporter of refined petroleum liquids. For much of the time through 2035, the US is the largest oil producer in the world. China, India, along with other countries from Southeast Asia are going to be the countries that dominate future demand and trade of energy over the next few decades. While improvement in technologies, such as horizontal drilling, has allowed for the unlocking of new types of oil resources, particularly in the US, the Middle East is still forecasted to be the long-term center of world in production increases.¹⁰⁹ Such forecasts, however, could be dramatically inverted if tight oil becomes a major new source of production outside the US. The recovery rates in existing fields have been improved by using new technologies, which increase estimates of the amount of oil that remains to be produced, even though there remains uncertainty about how much new oil this will yield. Estimated technically recoverable reserves

¹⁰⁸ “Global Energy Trends: Focus on oil & gas,” 11.

¹⁰⁹ “World Energy Outlook 2012,” 1.

for the world as a whole, including the US, range from about 300 to 345 billion barrels.¹¹⁰ In addition, high oil prices at about \$128 per barrel (in year-2012 dollars) in 2035 will sustain the development of these new resources. This resource is large enough that, if significantly brought into development, it could alter future production scenarios entirely. At present, most forecasts are conservative with regard to tight oil, including that from shale plays. While global production of petroleum liquids is predicted to rise from about 92 mb/d in 2014 to 105 to 110 mb/d by 2035, forecasts show tight oil comprising only about 6% to 8% of this, as illustrated by **Figure 5**. Looking at only four countries out of the top ten countries with shale oil resources, Russia, China, Argentina, and Canada beginning to produce shale oil by the mid-late 2020s, would change the outlook for non-OPEC and OPEC influence on the global market a great deal.¹¹¹

Conclusion

Both regional and global trends strongly suggest four main points regarding the future of oil production and consumption over the next several decades. These points also emerge from current forecasts, which must be considered preliminary. The points are: 1) the world will not run short of available oil, 2) tight oil production, mainly from shale, will continue to rise in North America, where it will reach a peak or plateau of six to nine mb/d sometime in the mid-2020s and then begin a fairly slow decline, 3) by the late 2020s, tight oil will become an important new element in production for Russia, China, parts of South America, and 4) the importance of tight oil in global markets will most likely be temporary and will not exceed 9% to 10% of total supply by the late 2020s and early 2030s, after which the importance of OPEC will grow more assertively.

Based on these forecasted developments, tight oil has the potential to serve a useful economic and political purpose. It may act as a buffer in global markets against rising prices, thereby protecting the US and its allies, along with the rest of the world, against related impacts. Politically, it may help to stem the growth of OPEC dominance, while advanced nations, perhaps in combination with China, continue to advance the technology of alternative vehicles, including new, more efficient hybrids, electric vehicles, and fuel cell versions.

¹¹⁰ Technically Recoverable Shale Oil and Shale Gas Resources: An Assessment of 137 Shale Formations in 41 Countries Outside the United States. *Technically Recoverable Shale Oil and Shale Gas Resources: An Assessment of 137 Shale Formations in 41 Countries Outside the United States*. U.S. Energy Information Administration, (2013): 2. <http://www.eia.gov/analysis/studies/worldshalegas/pdf/overview.pdf>. (accessed 27 Feb 2014).

¹¹¹ “World Energy Outlook 2013,” 3.

PART II

Status of the Shale Oil “Revolution”: US and Beyond

Part II focuses on the current status of shale oil development and resources within the US and how the revolution has affected countries globally. Chapter Four examines key shale and tight oil formations in the US and their production potential. The chapter assesses the economic and social impacts of the 2008 boom. Chapter Five examines the current state of fracking outside the US and explains why the shale oil boom has thus far been unique to the US. Case studies of Poland and China are used to illustrate the potential for success globally, while also highlighting the challenges faced by countries outside of the US hoping to enter the shale oil industry. Through the comparison of the status of shale oil in the US with other countries, Chapter Five demonstrates the areas in which the US might act as a leader in shale oil and hydraulic fracturing development.

Chapter Four

CURRENT DEVELOPMENT OF SHALE OIL IN THE U.S.

Davita Gurian

Abstract

This chapter discusses shale oil development in the US since 2008 through analysis of EIA and government documents, company reports, and current news and statistical sources. The first section will provide an in-depth examination of the current development of the five major shale oil plays in the US. The second section discusses other tight oil plays that are essential in understanding the US oil boom. The third section discusses how this boom has affected the US economically and socially. The US shale boom has revitalized the US petroleum industry but being a new development, has left many cautions and unanswered questions that must be seriously considered as this boom continues to move through the US.

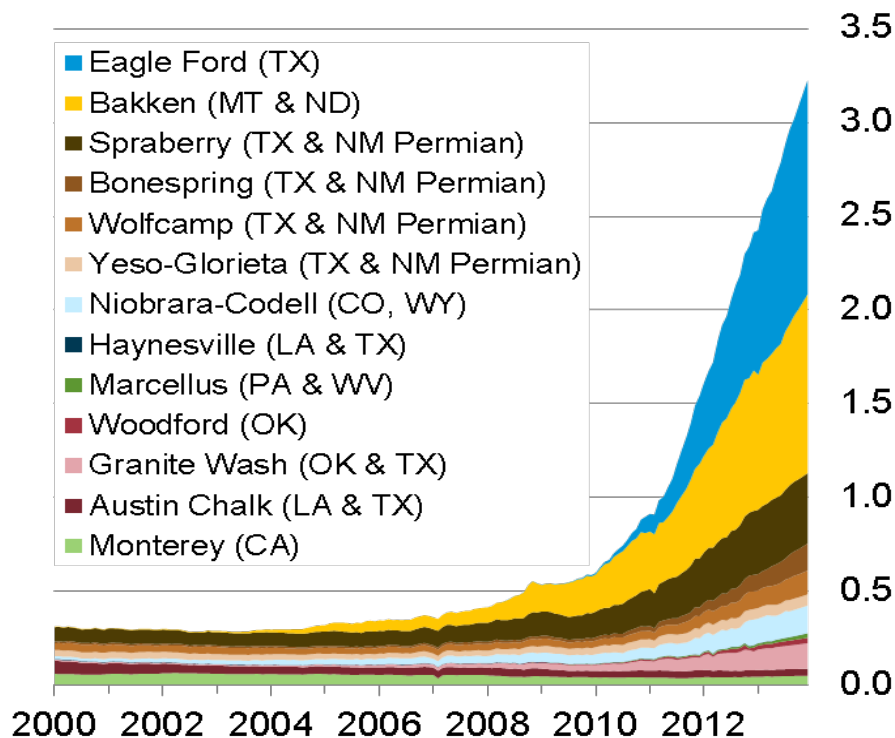
Introduction

The US is by far the leader in the development and utilization of fracking technology. Since 2008, US annual crude oil production has risen by 3 million barrels per day, as shown in **Graph 1**. About 92% of that increase arose from shale and other tight oil formations.¹ In 2012, the US Energy Information Association (EIA) announced that, “29% of total US crude oil production” came from tight oil and shale formations.² In 2012, there were 1,919 active drilling rigs for all oil and gas resources in the US, “more than the rest of the world combined.”³ The EIA forecasts that tight oil will rise to approximately 4.5 million bbls/day by 2016, maintain a plateau until 2022, and then decline as shown in **Graph 2**.

¹ Michael Ratner and Mary Tiemann, *An Overview of Unconventional Oil and Natural Gas: Resources and Federal Actions*, Congressional Research Service, 2013, p. 1.

² US Energy Information Administration, *Technically Recoverable Shale Oil and Shale Gas Resources: An Assessment of 137 Shale Formations in 41 Countries Outside the United States*, US Department of Energy, 2013, p. 11.

³ Cunningham, Nick and Warren Dym, *The U.S. Tight-Oil Boom Geopolitical Winner or Long-Term Distraction?*, American Security Project, 2013 p. 2.

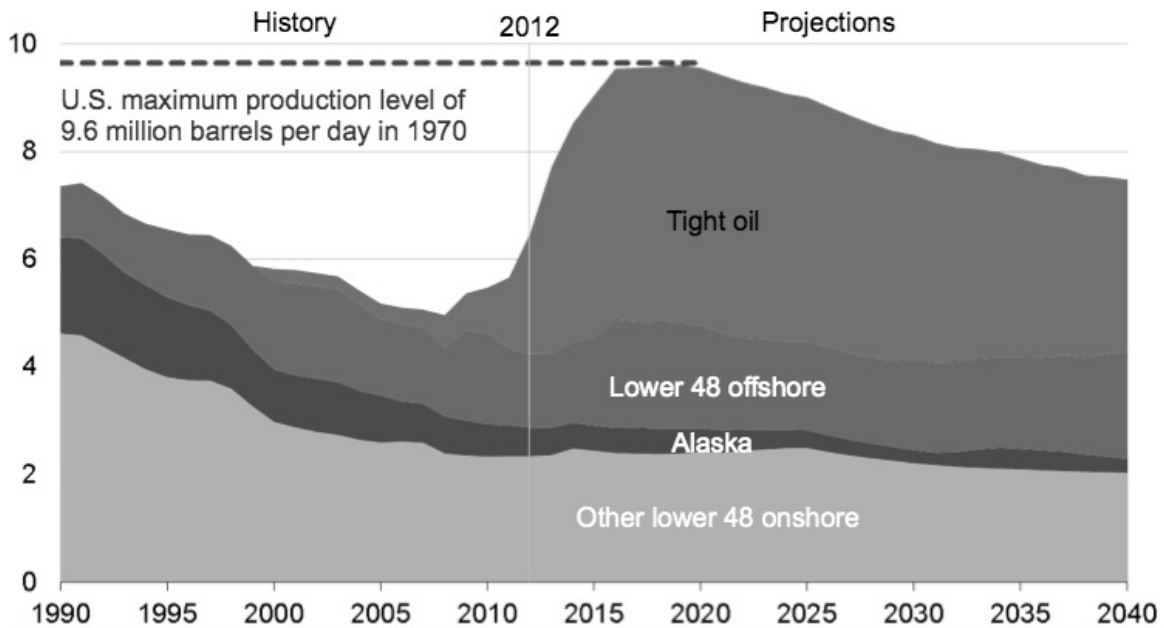


Graph 1: US Tight Oil Production Millions of Barrels of Oil Per Day (US Energy Information Administration Outlook Presentation)

The two dominant shale oil plays contributing to this boom are the Bakken and the Eagle Ford. Four other plays—the Cline, Wolfcamp, Utica, and Niobrara—are expected to grow significantly in coming years. Though less productive than these major basins, numerous other tight oil plays are important in understanding US oil growth since 2008. These plays are the Granite Wash, Tuscaloosa, and Bone Spring.

This boom has produced multiple economic and social impacts including job creation, increased household income, economic output that increases state and local tax revenues, and population growth in communities surrounding major plays.⁴ Additionally, fracking has affected landowners who possess oil rich land and their neighbors, as well as local environments. Since this oil boom is very recent, the effects that will be felt by the US petroleum industry, the US economy, as well as local US citizens are not yet fully understood.

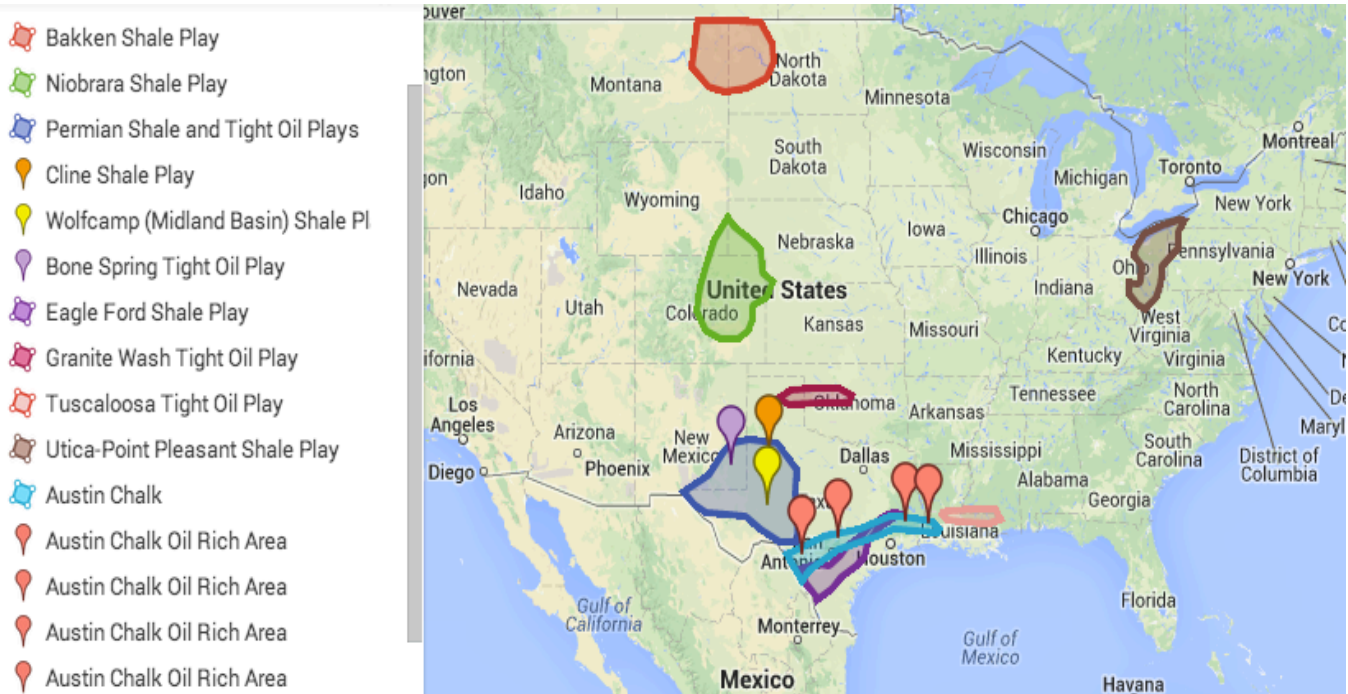
⁴ Jacquelyn Pless, *Regulating Hydraulic Fracturing: States Take Action*, National Conference of State Legislatures, 2010, 2.



Graph 2: Projection of Total US Crude Oil Production (Source: US Energy Information Administration's Outlook Presentation)

Section I: Major US Shale Oil Plays

Five shale oil plays within the US are major contributors to shale oil production, shown in **Map 1**: the Bakken, the Eagle Ford, Utica, the Niobrara, Wolfcamp, and the Cline. Each play lies within geologic formations. A formation refers to the actual sedimentary rock, rich in organic matter, that lies deep underground. A shale oil play refers to a specific location within a formation where petroleum companies have invested research, exploration and development of the shale. The Bakken and Eagle Ford significantly take the lead in oil production. The Permian formation, consisting of multiple oil plays—most importantly the Cline and Wolfcamp M—has substantial potential for future production. The Utica and the Niobrara will experience increased oil production in the year 2014 and beyond.



Map 1: US Shale and Tight Oil Plays in 2014 (Source: Davita Gurian via Google Maps)

[Bakken Play]

The Bakken-Three Forks formation lies in the Williston Basin stretching from Montana and North Dakota into Canada and spans 300,000 square miles in two major layers—the Upper Bakken Shale and the Three Forks Formation.⁵ The Three Forks Formation “is overlain by the Bakken Formation throughout the central portion of the Williston Basin” as shown in **Map 2**.⁶ The majority of the oil play is currently centered in northwestern North Dakota. The production area amounts to 12,000 square miles and will expand as exploration delves into the Three-Forks.⁷

The Bakken play began producing oil in 1951, yet its shale development began in the 1970s, reaching 100,000 barrels per day (bbl/d) and remaining at that level until around 2008.⁸ By November 2013, estimated crude oil production for the overall Bakken region in North Dakota and Montana “shows total wellhead output topping at 1 million barrels of oil per day next month.”⁹ Thus, the Bakken oil play accounts for just over 10% of total US oil production.¹⁰

⁵ The Belfer Center for Science and International Affairs, *US Shale Oil Report*, Harvard Kennedy School, 2013 29. And Nordeng and Helms, *Bakken Source System Three Forks Formation Assessment*, 2.

⁶ Nordeng and Helms, *Bakken Source System Three Forks Formation Assessment*, 2.

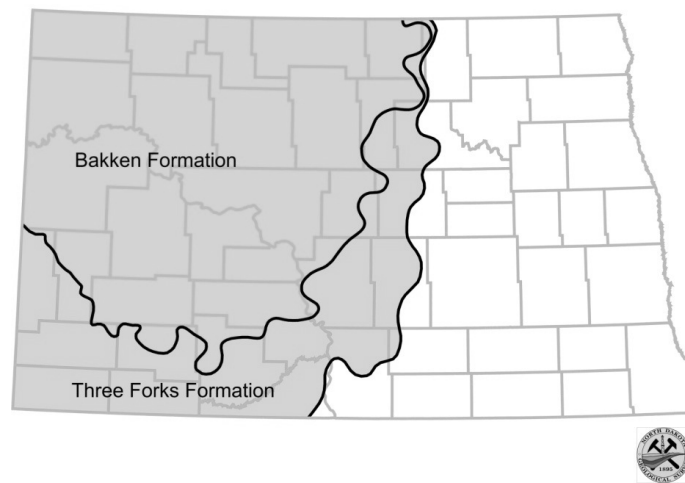
⁷ The Belfer Center for Science and International Affairs, *US Shale Oil Report*, 30.

⁸ James Mason, "Bakken's maximum potential oil production rate explored Social Media Tools," *Energy* no. 4 (2012): 02. And The Belfer Center for Science and International Affairs, *US Shale Oil Report*, 31.

⁹ Eia.gov, “Bakken oil production forecast to top 1 million barrels per day next month - Today in Energy - U.S. Energy Information Administration (EIA),” 2013 <http://www.eia.gov/todayinenergy/detail.cfm?id=13811> (accessed 21 Feb 2014).

¹⁰ Eia.gov, <http://www.eia.gov/todayinenergy/detail.cfm?id=13811> (accessed 21 Feb 2014).

Nearly all of this increase in oil production is credited to fracking and horizontal drilling—99% of new wells drilled in the Bakken since 2008 are horizontal wells.¹¹



Map 2: Bakken and Three Forks Formations in North Dakota (Source: North Dakota Department of Mineral Resources)

As of February 18, 2014 there were 185 active drilling rigs within the Bakken.¹² This has increased since February 1, 2010, but has decreased by 14 rigs since February 18th 2012.¹³ The number of wells drilled within the Bakken in 2003 was 216.¹⁴ This well number increased just over five times by the year 2012 when well count amounted to 1,995, and it is predicted to continue to increase. Predictions suggest that by 2030, there will be over 40,000 oil wells in the state of North Dakota—see **Map 3**, which shows all oil and gas wells in North Dakota.¹⁵

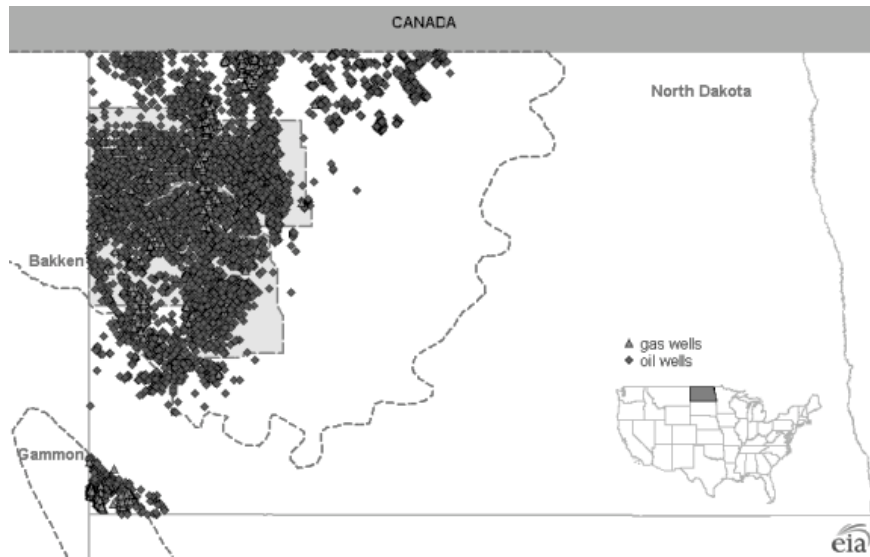
¹¹ The Belfer Center for Science and International Affairs, *US Shale Oil Report*, 31.

¹² Dmr.nd.gov, "Active Drilling Rig List," <https://www.dmr.nd.gov/oilgas/riglist.asp> (accessed 21 Feb 2014).

¹³ Dmr.nd.gov, <https://www.dmr.nd.gov/oilgas/riglist.asp> (accessed 21 Feb 2014).

¹⁴ Dmr.nd.gov, "North Dakota Drilling and Production Statistics," <http://www.dmr.nd.gov/oilgas/stats/statisticsvw.asp> (accessed 21 Feb 2014).

¹⁵ Federal Reserve Bank Of Minneapolis, *Data on Demographic, Economic and Financial Activity in the Bakken*, Federal Reserve Bank of Minneapolis, 2012, 4.



Map 3: Bakken Oil and Gas Wells (Source: EIA).

Like nearly all other shale oil plays, the Bakken is dominated by independents. The largest operator at present is Continental Resources with 1.2 million net acres and plans to drill approximately 300 new well completions in 2014.¹⁶ Another major player, EOG Resources, accounts for about 90,000 net acres in the core area of the Bakken shale. EOG completed approximately 53 new wells in 2013 and plans to increase its overall productivity through 2014.¹⁷

These two mid-sized operators are indicative of current Bakken and related Three Forks activity. Both have shifted earlier shale operations from gas to oil, due to low gas prices, and have plans for continued expansion through 2015. They are reflective of the dozens of other independents with smaller lease holdings now active in the Bakken. Well-funded and successful companies, such as EOG, are active in all three major shale oil plays—the Bakken, Eagle Ford, and Permian Basin—and plan for aggressive expansion throughout the rest of the current decade.

A recent decrease in rig count within the Bakken has become a growing concern in the petroleum community, and some fear that the Bakken has peaked and will begin to slowly decline in the next decade. This is false. Drilling speed and well productivity have continued to rise, despite decreased rig count, showing increased drilling efficiency.¹⁸ The number of rigs has decrease since the beginning of 2014, but rigs are drilling wells 30% faster than before and are drilling more wells on fewer pads.¹⁹ Companies will continue to innovate and find new ways to

¹⁶ Drillinginfo - Oil & Gas Intelligence | better, faster decisions, "Secret of 5 Top Bakken Shale Producers – Drillinginfo," <http://info.drillinginfo.com/5-top-bakken-shale/> (accessed 21 Feb 2014).

¹⁷ Drillinginfo - Oil & Gas Intelligence | better, faster decisions, <http://info.drillinginfo.com/5-top-bakken-shale/> (accessed 21 Feb 2014).

¹⁸ DailyFinance.com, "Is the Bakken Beginning to Wither Away? – DailyFinance," <http://www.dailyfinance.com/2013/11/11/is-the-bakken-beginning-to-wither-away/> (accessed 19 Feb 2014).

¹⁹ DailyFinance.com, <http://www.dailyfinance.com/2013/11/11/is-the-bakken-beginning-to-wither-away/> (accessed 19 Feb 2014).

reduce costs by cutting the amount of infrastructure (rigs and other tools) needed for high production.

[Eagle Ford Play]

The Eagle Ford shale formation is located in the south of Texas. Due to higher carbonate content, it is more brittle and easier to frack than the Bakken play.²⁰ Its oil rich resources are at depths ranging from roughly 4,000 to 12,000 feet.²¹ The Eagle Ford play is younger than the Bakken and emerged in 2008 when Petrohawk drilled the first horizontally fractured well in the area.²²

Growth in this play has been spectacular. Between the years 2008 and 2010, there was little increase in production due to the US financial crisis. After 2010, when natural gas prices fell dramatically and operators began to look for liquid-rich opportunities, drilling and production increased. By 2011, news of major drilling successes drew an increasing number of operators and investor capital, leading to large-scale drilling programs. Abundant rig availability supported a continued rapid increase in drilling activity into 2012 and 2013. Moreover, innovations such as “zipper” fracks (fracking two adjacent wells, alternately, with the same equipment) reduced overall equipment demands.²³ The play went from 352 bbl/d in 2008 to approximately 1.3 million bbls/day by February 2014.²⁴ During this same period, well counts rose from a handful to over 5,500 as shown in **Map 4**.²⁵ This map shows all oil and gas wells in the Eagle Ford. Monthly rig counts have remained very high, averaging about 260, up from 230 in 2013.²⁶

²⁰ The Belfer Center for Science and International Affairs, *US Shale Oil Report*, p. 33.

²¹ Rrc.state.tx.us, "Eagle Ford Information," <http://www.rrc.state.tx.us/eagleford/> (accessed 22 Feb 2014).

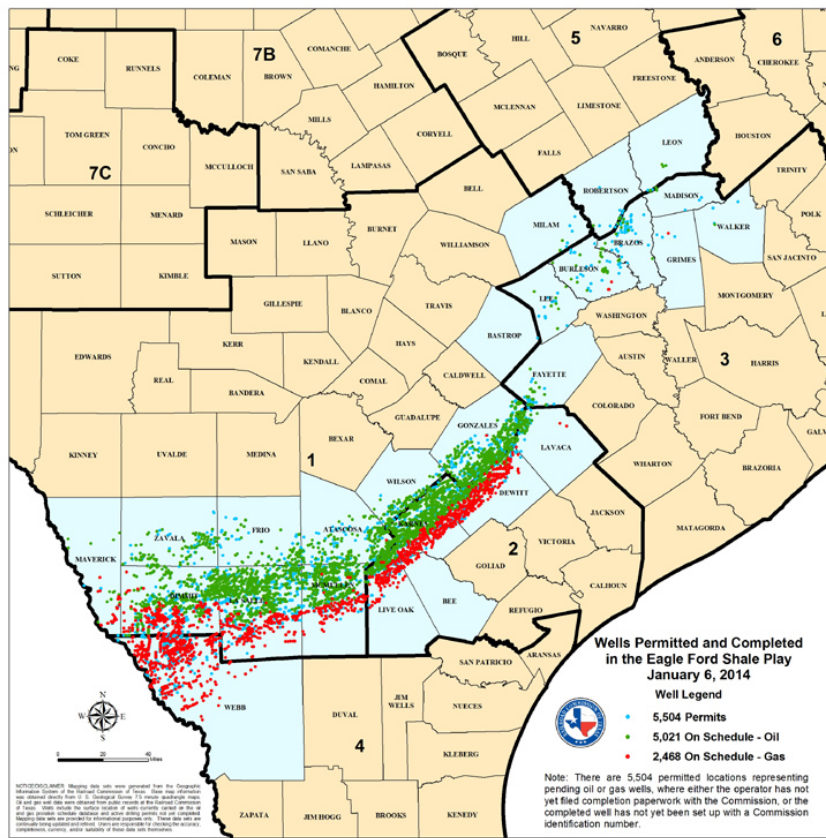
²² The Belfer Center for Science and International Affairs, *US Shale Oil Report*, p. 33.

²³ Rrc.state.tx.us, <http://www.rrc.state.tx.us/eagleford/> (accessed 22 Feb 2014).

²⁴ US Energy Information Administration, "*Drilling Productivity Report*," US Energy Information Administration, 2014, 1. And Rrc.state.tx.us, <http://www.rrc.state.tx.us/eagleford/> (accessed 22 Feb 2014).

²⁵ Rrc.state.tx.us, <http://www.rrc.state.tx.us/eagleford/> (accessed 22 Feb 2014).

²⁶ David Porter, "*Eagle Ford Shale Task Force Report*," Railroad Commission of Texas, 2013, 2.



Map 4: Eagle Ford Shale Play Oil (green) and Gas Wells (red) (Source: Railroad Commission of Texas).

Similar to the Bakken, there are dozens of companies drilling and producing in the Eagle Ford. There are two dominant independents in the Eagle Ford, the first of which is EOG Resources. EOG owns 650,000 net acres in the Eagle Ford and produced 29,503,410 bbls of oil from January to November 2012.²⁷ The second major operator is Chesapeake Operating Inc., which owns over 600,000 net acres in the Eagle Ford and produced 15,354,886 bbls of oil between January and November 2012.²⁸

New trends have the potential to profoundly impact the future of Eagle Ford development, and shale oil development more generally. Innovations in frack technology and in drilling approaches stand to improve oil recovery significantly, reducing the rapid declines often observed in shale oil wells. As shown in **Figure 1**, this has already been occurring; oil production on a per-rig basis has increased by as much as 20-25% between 2013 and 2014, a direct result of adjustments to frack techniques based on experience and continued testing of new

²⁷ Eaglefordshale.com, "EOG Resources | Eagle Ford Shale," <http://eaglefordshale.com/companies/eog-resources/> (accessed 21 Feb 2014).

And Bizjournals.com, "Largest oil producers in the Eagle Ford Shale, slideshow - San Antonio Business Journal," http://www.bizjournals.com/sanantonio/blog/2013/02/largest-oil-producers-in-the-eagle.html?s=image_gallery&date=2013-02-07 (accessed 21 Feb 2014).

²⁸ Eaglefordshale.com, "Chesapeake Energy | Eagle Ford Shale," <http://eaglefordshale.com/companies/chesapeake-energy/> (accessed 21 Feb 2014).

And Bizjournals.com, http://www.bizjournals.com/sanantonio/blog/2013/02/largest-oil-producers-in-the-eagle.html?s=image_gallery&date=2013-02-07 (accessed 21 Feb 2014).

approaches. **Figure 1** compares oil production per rig between March 2013 and 2014, showing an increase in oil recovery from the four major shale oil plays (Bakken, Eagle Ford, Niobrara, and Permian). One such innovation that appears likely to continue this trend is downspacing, i.e. drilling wells closer together, in order to improve total recovery. In this approach, more horizontal laterals are drilled from a single location. Pilot tests have shown little or no production interference between wells spaced at less than 500 feet apart. Coupled with other innovations in frack treatments, such as simultaneous stimulation (fracking multiple horizontals at the same time), this has the capability to increase efficiency in concert with improved recovery.

Although the Bakken and the Eagle Ford are currently producing at such high rates, it is unclear how long this will continue. Because these shale oil plays are quite new, their long-term productivity has not been confirmed and economically recoverable oil may change if the global oil price changes.²⁹ The EIA has stated that production from these shales using fracking has been mostly confined to the “sweet spots” in each shale play where the highest known production rates have occurred.³⁰ This does not show production rates for the rest of shale within each formation, which could be quite different.

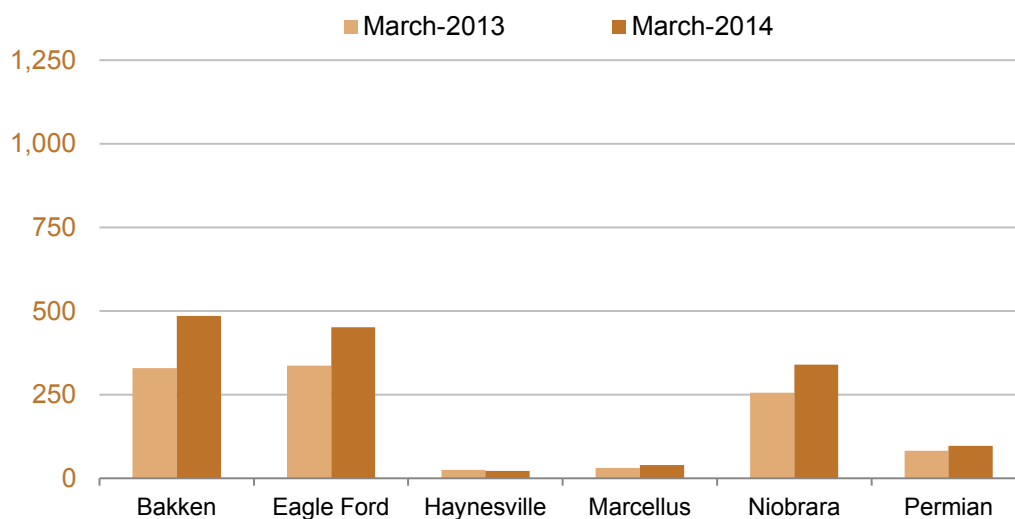


Figure 1: New-well Oil Production Per Rig in March 2013 and March 2014 Barrels of Oil Per Day (Source: EIA)

²⁹ Eia.gov. "Analysis & Projections - U.S. Energy Information Administration (EIA) - U.S. Energy Information Administration (EIA)," <http://www.eia.gov/analysis/studies/usshalegas/> (accessed 24 Feb 2014).

³⁰ Eia.gov, <http://www.eia.gov/analysis/studies/usshalegas/> (accessed 24 Feb 2014).

[Permian Basin]

The Permian Basin is a large basin that includes many formations and oil plays. It stretches 250 miles wide and 300 miles long from southeastern New Mexico into west Texas.³¹ The two most essential shale oil plays are the Cline and the Wolfcamp (M) within the Midland Basin (see **Map 5**).

The Permian has a substantial history of oil and gas production dating back to the 1920s.³² It experienced a peak in the 1970s and faced a steady decline until the mid-2000s.³³ Total Permian Basin production for the year 2013 climbed to 29 billion barrels of oil.³⁴ The majority of this production increase is credited to horizontal drilling and fracking, which is fairly new in the basin. Permian shale oil plays using fracking began between the years 2010 and 2011—making them very young.³⁵ Because fracking entered the Permian Basin very recently, this leaves a substantial growth outlook for the basin in 2014 and the coming decades.

Rig counts and overall well counts have increased within the basin. Rig count in 2005 amounted to 129 but exceeded 415 in 2012 (leveling back to 378 at the beginning of 2013).³⁶ Most of this increase is due to fracking. To date, there are a total of 133,000 wells on schedule in the Permian--22,000 of which are listed as active injection/disposal wells. These are shown in **Map 5**.³⁷

³¹ Rrc.state.tx.us, "Permian Basin for RRC - Content Page," <http://www.rrc.state.tx.us/permianbasin/> (accessed 22 Feb 2014).

³² The Belfer Center for Science and International Affairs, *US Shale Oil Report*, 37.

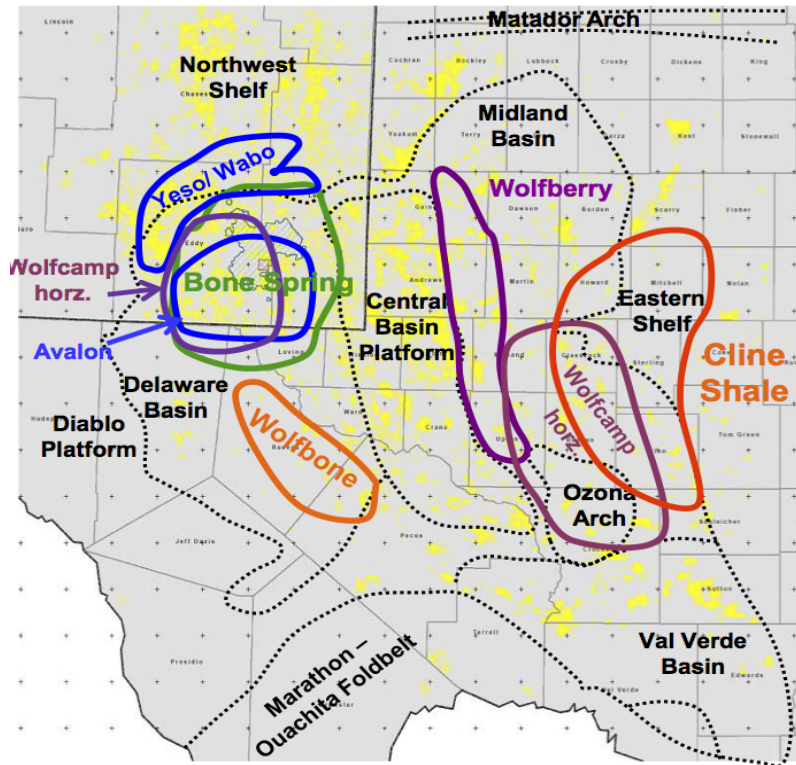
³³ The Belfer Center for Science and International Affairs, *US Shale Oil Report*, 37.

³⁴ Rrc.state.tx.us, <http://www.rrc.state.tx.us/permianbasin/> (accessed 22 Feb 2014).

³⁵ The Belfer Center for Science and International Affairs, *US Shale Oil Report*, 37.

³⁶ Rrc.state.tx.us, <http://www.rrc.state.tx.us/permianbasin/> (accessed 22 Feb 2014) And The Belfer Center for Science and International Affairs, *US Shale Oil Report*, 37.

³⁷ Rrc.state.tx.us, <http://www.rrc.state.tx.us/permianbasin/> (accessed 22 Feb 2014).



Map 5: Permian Basin Plays (Source: seekingalpha.com)

Within the Permian Basin, operators such as Pioneer Natural Resources (PNR) have recorded immense potential in the Cline shale play. This particular play is located in the eastern part of the Permian Basin in west Texas and extends 140 miles long and 70 miles wide with depths ranging from 5,000 feet to 9,500 feet.³⁸ Some experts have estimated that total recoverable reserves could amount to 30 billion barrels, making the Cline larger than the Bakken and Eagle Ford combined.³⁹ However, this estimate identifies only total recoverable reserves, not “economically recoverable reserves (ERRs),” which are likely to change if the global oil price changes. Potential ERRs in the Cline are difficult to determine because Cline shale contains higher clay content in its eastern sections and lower clay content in its western sections, making an estimate difficult to determine.⁴⁰

³⁸ Seekingalpha.com, "Permian Basin's Cline Play Reinforces Growth Potential," <http://seekingalpha.com/article/1852711-permian-basins-cline-play-reinforces-growth-potential> (accessed 22 Feb 2014).

³⁹ Cline Shale Site, "Cline Shale Site - The latest and greatest on the Cline Shale," <http://clineshalesite.com/> (accessed 21 Feb 2014).

⁴⁰ Seekingalpha.com, <http://seekingalpha.com/article/1852711-permian-basins-cline-play-reinforces-growth-potential> (accessed 22 Feb 2014).

Wolfcamp M are estimated to be 50 billion boe (barrels of oil equivalent).⁴⁴ This play is defined as a horizontal play, meaning that most of its development is due to horizontal drilling.⁴⁵

Wolfcamp M may hold the potential to become the largest oil field in the US.⁴⁶ Two companies have dominated this play. As well as its development in the Cline play, PNR holds the most acreage in the Wolfcamp M with about 730,000 net acres.⁴⁷ PNR operates on the northern end of the play, which is expected to be anywhere from 2,000-4,000 feet thick—giving it massive potential.⁴⁸ This estimate compared to the Eagle Ford shale, which is approximately 300 feet thick, “begins to dwarf the Eagle Ford”.⁴⁹ Producing alongside PRN, Apache Corporation is a major stakeholder. Apache drilled and completed 55 horizontal wells in 2013.⁵⁰

The Permian Basin contains multiple targets that require adjustments in fracking techniques, therefore building up considerable knowledge and experience in different formations is necessary. This will attract more companies to move into new areas and new formations within the basin majorly expanding production and output for the plays within the basin.

[Utica-Point Pleasant Formation Play]

The Utica Formation lies within the northeastern corner of Ohio and spreads into Pennsylvania. It is illustrated in **Map 7**. Ohio began producing oil and gas in the 1850s.⁵¹ Despite the states long history, it only recently entered the fracking forefront, and it has only produced resources from its shale in the last few years. The Point-Pleasant is a formation that lies directly below the Utica shale—“forming a two-level rock layer that is from 87 to 250 feet thick”.⁵² The Point-Pleasant has been labeled as the liquid-rich sweet spot of the Utica shale play.⁵³ The Utica-

⁴⁴ Ogj.com, "Wolfcamp shale graduates to 'world class' play," <http://www.ogj.com/articles/uogr/print/volume-1/issue-3/urtec-wolfcamp/wolfcamp-shale-graduates-to-world-class-play.html> (accessed 22 Feb 2014).

⁴⁵ Shaleexperts.com. "Wolfcamp Shale Overview - Maps - Geology - Counties." 2014. <http://www.shaleexperts.com/plays/wolfcamp-shale/Overview?nav> (accessed 22 Feb 2014).

⁴⁶ Ogj.com, <http://www.ogj.com/articles/uogr/print/volume-1/issue-3/urtec-wolfcamp/wolfcamp-shale-graduates-to-world-class-play.html> (accessed 22 Feb 2014).

⁴⁷ Ogj.com, "URTeC: Wolfcamp play dwarfs Bakken, Eagle Ford," <http://www.ogj.com/articles/2013/08/urtech-wolfcamp-play-dwarves-bakken-eagle-ford.html> (accessed 22 Feb 2014).

⁴⁸ Shaleexperts.com. "Wolfcamp Shale Overview - Maps - Geology - Counties." 2014. <http://www.shaleexperts.com/plays/wolfcamp-shale/Overview?nav> (accessed 22 Feb 2014) And Ogj.com, <http://www.ogj.com/articles/uogr/print/volume-1/issue-3/urtec-wolfcamp/wolfcamp-shale-graduates-to-world-class-play.html> (accessed 22 Feb 2014).

⁴⁹ Ogj.com, <http://www.ogj.com/articles/2013/08/urtech-wolfcamp-play-dwarves-bakken-eagle-ford.html> (accessed 22 Feb 2014).

⁵⁰ Ogj.com, "Apache fracs Wolfcamp wells without fresh water in dry Barnhart project area," <http://www.ogj.com/articles/uogr/print/volume-2/issue-1/wolfcamp/apache-fracs-wolfcamp-wells-without-fresh-water-in-dry-barnhart-project-area.html> (accessed 18 Feb 2014).

⁵¹ Oilindependents.org, "www.oilindependents.org » Utica – The Shale Revolution Coming to Ohio," <http://oilindependents.org/utica-the-shale-revolution-coming-to-ohio/> (accessed 22 Feb 2014).

⁵² The Belfer Center for Science and International Affairs, *US Shale Oil Report*, 41.

⁵³ Oilindependents.org, <http://oilindependents.org/utica-the-shale-revolution-coming-to-ohio/> (accessed 22 Feb 2014).

Point Pleasant exists in the Appalachian Basin, which is the longest producing petroleum province in the US to date.⁵⁴

The Utica shale geologic composition has been compared to that of the Eagle Ford and is therefore suited well for fracking due to its rich carbonate content.⁵⁵ Development is in its early stages within this play, but potential is large. The Ohio Geological Survey determined the Ohioan Utica Point Pleasant to hold 5.5 billion barrels of recoverable oil, which is a smaller estimate than both the Cline and Wolfcamp M plays but still majorly profitable.⁵⁶

The Ohio Department of Natural Resources (ODNR) released production data for 2012, which pulled from 85 wells within the Utica play. Based on these findings, total oil production within the state of Ohio was 635,876 bbl in 2012.⁵⁷ Production data for this play was difficult to determine for any time since 2012 because it has not yet been disclosed by the ODNR. Production is much higher than estimates from the ODNR, because within the Utica play there are far more than 85 wells. Currently, there are 697 horizontal wells drilled within the Utica play as represented in **Map 8**.⁵⁸ There were 40 active rigs in the Utica play as of January 25, 2014.⁵⁹

⁵⁴ Usgs.gov, "USGS Release: USGS Releases First Assessment of Shale Gas Resources in the Utica Shale: 38 trillion cubic feet (10/4/2012 5:24:04 PM)." <http://www.usgs.gov/newsroom/article.asp?ID=3419#UvBSYXddUpE> (accessed 22 Feb 2014).

⁵⁵ The Belfer Center for Science and International Affairs, *US Shale Oil Report*, p. 41 And Oilindependents.org, <http://oilindependents.org/utica-the-shale-revolution-coming-to-ohio/> (accessed 22 Feb 2014).

⁵⁶ The Belfer Center for Science and International Affairs, *US Shale Oil Report*, 41.

⁵⁷ ODNR Division of Oil & Gas Resources, "Shale Well Drilling & Permitting," <http://oilandgas.ohiodnr.gov/shale#SHALE> (accessed 22 Feb 2014).

⁵⁸ ODNR Division of Oil & Gas Resources, <http://oilandgas.ohiodnr.gov/shale#SHALE> (accessed 22 Feb 2014).

⁵⁹ ODNR Division of Oil & Gas Resources, <http://oilandgas.ohiodnr.gov/shale#SHALE> (accessed 22 Feb 2014).

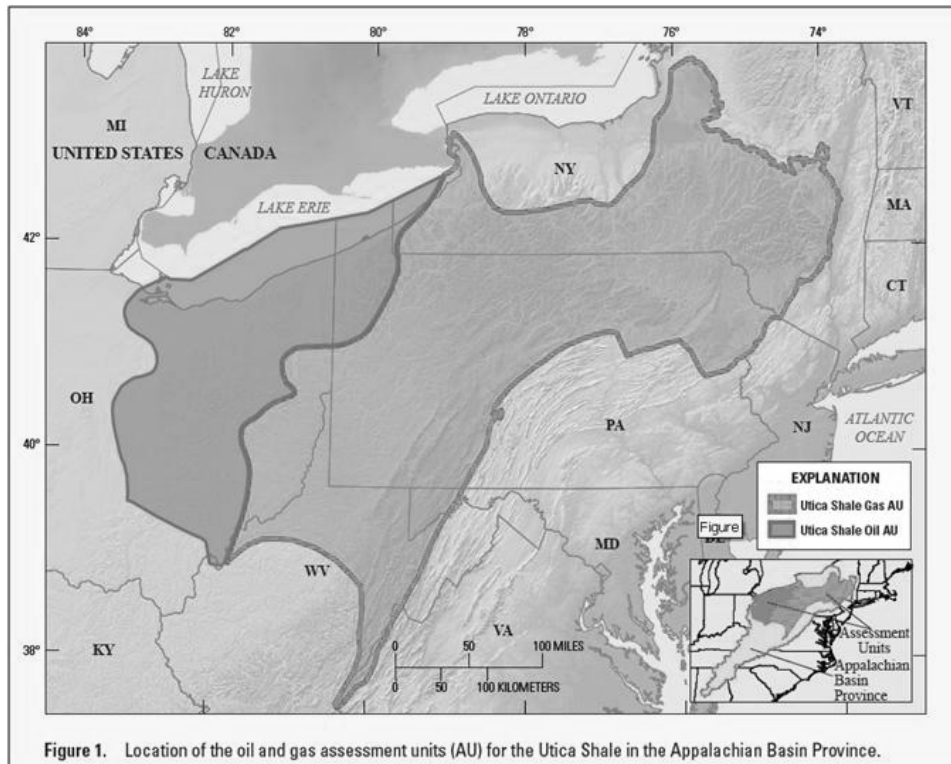


Figure 1. Location of the oil and gas assessment units (AU) for the Utica Shale in the Appalachian Basin Province.

Map 7: Utica Formation, Green = Oil (Source: US Geological Survey)

Leading development in this play is Chesapeake Energy. Chesapeake drilled 377 wells by September 2013, and it expects to increase this by 208 wells in the next year.⁶⁰ Another major company in the region is Gulfport Energy, which drilled the most productive oil well in 2013.⁶¹ This well, named The Boy Scout well, produced 41,617 barrels of oil in the first 70 days whereas, on average, other wells in this area during their first 90-day period only produced 5,439 barrels of oil per day.⁶²

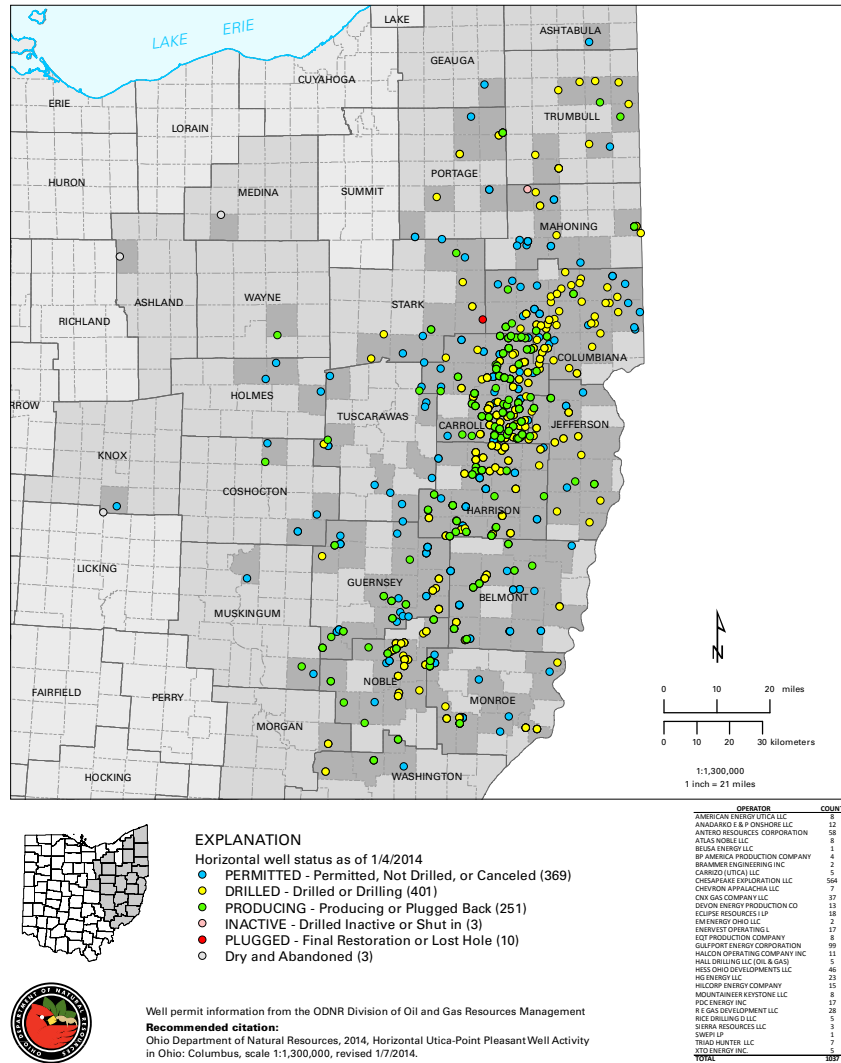
The Utica Shale will see extensive growth in the next decade. Many wells will utilize existing Marcellus wells meaning much of the infrastructure that a company needs to pay for in order to drill is already in place. In accordance with this, there is a willing and able workforce within Ohio, and it is close to the dense population markets of the east coast. Companies have already incurred the costs for acreage, roads, surface location, water management, gas lines, and

⁶⁰ DailyFinance.com, "Ohio More Than Doubles Oil and Gas Production in 2013 – DailyFinance," <http://dailyfinance.com/2014/01/06/oil-production-in-ohio-more-than-doubled-in-2013/> (accessed 21 Feb 2014).

⁶¹ DailyFinance.com, <http://dailyfinance.com/2014/01/06/oil-production-in-ohio-more-than-doubled-in-2013/> (accessed 21 Feb 2014).

⁶² DailyFinance.com, <http://dailyfinance.com/2014/01/06/oil-production-in-ohio-more-than-doubled-in-2013/> (accessed 21 Feb 2014) And Mariettatimes.com, "Eastern Ohio leads state in gas production - MariettaTimes.com | News, Sports, Jobs, Ohio, Community Information - The Marietta Times," <https://www.mariettatimes.com/page/content.detail/id/556281/Eastern-Ohio-leads-state-in-gas-production.html?nav=5003> (accessed 24 Feb 2014).

compression. Therefore, the incremental costs to develop the Upper Devonian and Utica will be reduced by approximately one-third versus developing these zones on a stand-alone basis.



Map 8: Utica Oil Play Wells (Source: Ohio Department of Natural Resources)

[Niobrara Play]

The Niobrara is a 70,000 square mile formation located in the Denver-Julesburg Basin and the Piceance Basin.⁶³ This large formation “spans northeast Colorado, northwest Kansas, and parts of Nebraska and Wyoming” (see **Map 9**).⁶⁴ Currently, shale production has been centered in northeast Colorado.⁶⁵ Although conventional drilling has existed in the Niobrara since the late 1800s, major activity did not begin until 2009 with the “Jake well” owned by EOG Resources. Production from the Jake well was 50,000 bbls of oil in its first 90 days.⁶⁶ The Niobrara showed great potential, but its full productivity was not taken advantage of at that time due to the overshadowing performance of the Bakken in 2010 and 2011.⁶⁷ This makes the Niobrara play a very young and underdeveloped play.

The Niobrara is a diverse formation consisting of crude oil, natural gas, and NGLs (natural gas liquids) with crude oil consisting of about 30% to 40% of production.⁶⁸ Most oil is located approximately 7,000-8,000 feet under ground with formation thickness ranging from 200 to 400 feet, which is thicker than the Eagle Ford in some sections.⁶⁹ Recoverable reserves for the Niobrara are approximately 2 billion bbls of oil.⁷⁰ Since 2009, Colorado oil production spiked 46% to 47.9 million barrels of oil in 2012.⁷¹ Total horizontal rig count as of 2014 was 50—of which 37 were allocated to oil wells.⁷² There are 18,000 wells within Weldon County in Colorado—the epicenter of the Niobrara play.⁷³

The number one acreage holder in the Niobrara is Anadarko Petroleum, which owns over 1 million acres.⁷⁴ Anadarko’s wells were estimated to produce between 300,000 to 600,000 bbls of oil per well.⁷⁵ Another major company is Noble Energy, which holds 610,000 net acres in

⁶³ The Belfer Center for Science and International Affairs, *US Shale Oil Report*, p. 38.

⁶⁴ The Belfer Center for Science and International Affairs, *US Shale Oil Report*, p. 39.

⁶⁵ The Belfer Center for Science and International Affairs, *US Shale Oil Report*, 40.

⁶⁶ Coga.org, "Colorado Oil & Gas Association,"

<http://www.coga.org/index.php/FastFacts/Niobrara#sthash.VDwEyGpy.dpbs> (accessed 21 Feb 2014).

⁶⁷ The Belfer Center for Science and International Affairs, *US Shale Oil Report*, 40.

⁶⁸ The Belfer Center for Science and International Affairs, *US Shale Oil Report*, 39.

⁶⁹ The Belfer Center for Science and International Affairs, *US Shale Oil Report*, 39.

⁷⁰ Coga.org, <http://www.coga.org/index.php/FastFacts/Niobrara#sthash.VDwEyGpy.dpbs> (accessed 21 Feb 2014).

⁷¹ Energyandcapital.com, "Niobrara Shale Stocks," <http://www.energyandcapital.com/articles/niobrara-shale-stocks/3618> (accessed 21 Feb 2014).

⁷² Shaleexperts.com, "Niobrara Shale, News, Companies, Drilling Rigs, Acreage, Well Permits, Operators," <http://www.shaleexperts.com/plays/niobrara-shale> (accessed 22 Feb 2014).

⁷³ Wyomingenergynews.com, "The Niobrara Shale Drives Colorado Oil Production to 50-Year High — Wyoming Energy News," <http://www.wyomingenergynews.com/2013/03/regional-update-the-niobrara-shale-drives-colorado-oil-production-to-50-year-high/> (accessed 22 Feb 2014).

⁷⁴ Energyandcapital.com, <http://www.energyandcapital.com/articles/niobrara-shale-stocks/3618> (accessed 21 Feb 2014).

⁷⁵ Energyandcapital.com, <http://www.energyandcapital.com/articles/niobrara-shale-stocks/3618> (accessed 21 Feb 2014).

northern Colorado.⁷⁶ Noble Energy had 200 horizontal wells in 2012, and the company increased that total by 300 in 2013.⁷⁷

The Niobrara, along with the Bakken, also shows increased well productivity and decreasing well costs due to downspacing. The utilization of this innovation will increase through the coming year and decade. For the year 2014, Noble Energy will be performing a basin wide downspacing, condensing 24-32 wells per section.⁷⁸ Because of down spacing technology, costs will continue to decrease making the oil market ever more profitable. Better efficiency and experience are driving down well costs by 20% over two year periods.



Map 9: Niobrara Shale Formation (Source: Colorado Oil & Gas Association)

⁷⁶ Nobleenergyinc.com, "DJ Basin - nobleenergyinc.com," <http://www.nobleenergyinc.com/Operations/U-S-Onshore/DJ-Basin-265.html> (accessed 24 Feb 2014).

⁷⁷ Nobleenergyinc.com, <http://www.nobleenergyinc.com/Operations/U-S-Onshore/DJ-Basin-265.html> (accessed 24 Feb 2014).

⁷⁸ The Niobrara News, "Noble Energy Niobrara Plan Focuses on Optimal Downspacing," <http://www.niobraranews.net/niobrara-geology/noble-energy-niobrara-plan-focuses-optimal-downspacing/> (accessed 24 Feb 2014).

Section II: Other Tight Oil Plays

[Tuscaloosa Formation]

The Tuscaloosa Marine Shale (TMS) lies within mid-Louisiana and runs through mid-Mississippi (see **Map 1**). Potential productive areas are presently being explored from the Vernon Parish to Tangipahoa Parish in Louisiana.⁷⁹ Oil within this shale exists between 11,000 to 15,000 feet under ground and the formation is approximately 200 to 800 feet thick.⁸⁰ Potential oil reserves in the TMS are about 7 billion barrels—not economically recoverable—but with alternative sources producing different statistics, this is not a concrete estimate.⁸¹ Currently there are only 20 producing wells in the play. TMS is very much in an exploratory phase, and, therefore, it is not considered a producing shale play, even though it is a shale formation similar to that of the Eagle Ford.

[Granite Wash]

The Granite Wash spans from southwest Oklahoma through the northern Texas Panhandle, lying within the Anadarko Basin as shown in **Map 1**. This play currently produces more gas than oil, but oil exploration and production are expanding.⁸² The Granite Wash is a sandstone formation that is approximately 160 miles long, 30 miles wide, and has a thickness of 1,500 to 2,300 feet.⁸³ There are over 2,600 operating wells and 57 rigs in the Granite Wash with multiple operators.⁸⁴ Gas and oil resources can be found at depths up to 17,000 feet in this formation.⁸⁵ Due to low gas prices in 2013, operators in the Granite Wash turned attention to shallower, oil-rich targets in the play.⁸⁶ As oil prices remain high and gas prices remain low, producers will further explore and exploit oil rich resources in the Granite Wash.

⁷⁹ Dnr.louisiana.gov, "Newest Successful Well Project Completed in Tuscaloosa Marine Shale - Department of Natural Resources | State of Louisiana," <http://dnr.louisiana.gov/index.cfm?md=newsroom&tmp=detail&aid=946> (accessed 21 Feb 2014).

⁸⁰ P2energysolutions.com. "The Tuscaloosa Marine Shale Brings New Attention to Louisiana | P2 Energy Solutions." 2014. <http://www.p2energysolutions.com/tobin-talk/tuscaloosa-marine-shale-brings-new-attention-louisiana> (accessed 22 Feb 2014) And Dnr.louisiana.gov, "Tuscaloosa Marine Shale - Department of Natural Resources | State of Louisiana," <http://dnr.louisiana.gov/index.cfm?md=pagebuilder&tmp=home&pid=909> (accessed 21 Feb 2014).

⁸¹ The Belfer Center for Science and International Affairs, *US Shale Oil Report*, 42.

⁸² Ogfj.com, "Granite Wash News, Wells, Formation, Markets and Resources: Oil & Gas Financial Journal," <http://www.ogfj.com/unconventional/granite-wash.com.html> (accessed 22 Feb 2014).

⁸³ Ogfj.com, <http://www.ogfj.com/unconventional/granite-wash.com.html> (accessed 22 Feb 2014) And Shaleexperts.com, "Granite Wash, News, Companies, Drilling Rigs, Acreage, Well Permits, Operators," <http://www.shaleexperts.com/plays/granite-wash/?menu> (accessed 22 Feb 2014).

⁸⁴ Ogfj.com, <http://www.ogfj.com/unconventional/granite-wash.com.html> (accessed 22 Feb 2014) And Shaleexperts.com, <http://www.shaleexperts.com/plays/granite-wash/?menu> (accessed 22 Feb 2014).

⁸⁵ Shaleexperts.com, <http://www.shaleexperts.com/plays/granite-wash/?menu> (accessed 22 Feb 2014).

⁸⁶ Unconventional Gas Center, "Granite Wash Operators Await Better Gas Prices, Target Oilier Zones," http://www.ugcenter.com/Granite-Wash/Granite-Wash-Operators-Await-Gas-Prices-Target-Oilier-Zones_116704 (accessed 22 Feb 2014).

[Bone Spring]

The Bone Spring lies within the Permian Basin in New Mexico and west Texas. This is primarily an oil play consisting of different sand and shale formations.⁸⁷ The Bone Spring consists of sub-plays, which include the Avalon Shale/Leonardo Shale. Avalon/Leonardo is the most profitable sub-play in the Bone Spring.⁸⁸ Overall, drilling has spiked since the first wells were drilled 10 years ago due to the promising results from the Avalon/Leonardo sub-play.⁸⁹ Most active operators in the Bone Spring are EOG resources and Occidental Petroleum. Depths of the Bone Spring are different for each specific sub-play and interval. Along interval three, recoverable reserves were estimated at 10,500-11,500 feet deep.⁹⁰ Production in the overall Permian Basin is rapidly increasing with high estimated production. The Bone Spring and its sub-plays will add to this overall production as companies expand and develop each sub-play.

[Austin Chalk]

The Austin Chalk formation lies in south Texas near the Gulf of Mexico and curves into Louisiana and Mississippi (see **Map 1**). The formation consists of chalk and marl and lies above the Eagle Ford.⁹¹ Its average targeted depth is roughly 1,700 meters.⁹² This play has existed since the 1960s but has been experiencing significant revitalization in the last few years, primarily due to high activity by Aurora Oil & Gas. During the fourth quarter of 2013 Aurora drilled their first Austin Chalk pilot wells.⁹³ These wells are meant to investigate Austin Chalk composition.⁹⁴ Investigation, exploration, and revitalization will continue in 2014 and beyond.

⁸⁷ Seekingalpha.com, "Occidental Petroleum In The Permian," <http://seekingalpha.com/article/1960521-occidental-petroleum-in-the-permian> (accessed 22 Feb 2014).

⁸⁸ Ogfj.com, "IHS describes complexity of Bone Spring oil play," <http://www.ogfj.com/articles/2012/03/ihs-describes-complexity-of-bone-spring-oil-play.html> (accessed 22 Feb 2014).

⁸⁹ Ogfj.com, <http://www.ogfj.com/articles/2012/03/ihs-describes-complexity-of-bone-spring-oil-play.html> (accessed 22 Feb 2014).

⁹⁰ Ogj.com, "Texas: Energy adds Bone Spring/Avalon acreage," <http://www.ogj.com/articles/2011/01/texas--energy-adds.html> (accessed 22 Feb 2014).

⁹¹ Shaleexperts.com, "Austin Chalk Overview - Maps - Geology - Counties," <http://www.shaleexperts.com/plays/austin-chalk/Overview?nav> (accessed 22 Feb 2014).

⁹² Shaleexperts.com, <http://www.shaleexperts.com/plays/austin-chalk/Overview?nav> (accessed 22 Feb 2014).

⁹³ Ogj.com, "Aurora reports Eagle Ford results with Marathon," <http://www.ogj.com/articles/2013/07/aurora-reports-eagle-ford-results-with-marathon.html> (Accessed: 24 Feb 2014).

⁹⁴ Ogj.com, <http://www.ogj.com/articles/2013/07/aurora-reports-eagle-ford-results-with-marathon.html> (Accessed: 24 Feb 2014).

Section III: Oil Boom Impacts on the United States

[Economic Impacts]

The US oil and gas boom has and will continue to increase employment, wages and household incomes, US exports, and government revenues. This boom is also expected to decrease the national deficit through increased exports and state and federal tax revenues. From 2007 “through the end of 2012, total US private sector employment increased by more than 1 million jobs” or about 1%.⁹⁵ This will continue to increase. The IHS reported in 2013 that, “more than 3.3 million jobs will be supported in 2020 as the unconventional oil and gas (boom) boosts industry competitiveness and manufacturing growth”.⁹⁶ This is expected to reach “nearly 3.9 million by 2025”.⁹⁷ Such job growth has occurred in North Dakota where the unemployment rate is 1%—lower than any other state.⁹⁸ Ohio has also experienced employment increases specifically in Carroll County where the petroleum and manufacturing industries created 38,000 jobs in 2013.⁹⁹ Manufacturing industry niches that support unconventional gas and oil development will be specifically impacted by the boom. 460,000 combined manufacturing jobs will be supported in 2020, which is expected to rise to 515,000 by 2025.¹⁰⁰

Household incomes of those employed by the industry have also increased due to heavier traffic and activity in towns surrounding production. Per capita household income in the Bakken rose above that in the rest of Montana, North Dakota, and the US as a whole.¹⁰¹ Per capita income increased from \$24,298 to \$27,590 and exceeded the US average of \$27,157 in 2012.¹⁰² As a result of wage and salaries increases, the poverty rate has decreased in specific counties and regions near major oil plays.¹⁰³

⁹⁵ Eia.gov, "Oil and gas industry employment growing much faster than total private sector employment - Today in Energy - U.S. Energy Information Administration (EIA)," <http://www.eia.gov/todayinenergy/detail.cfm?id=12451> (accessed 19 Feb 2014).

⁹⁶ Press.ihs.com, "U.S. Unconventional Oil and Gas Revolution to Increase Disposable Income by More than \$2,700 per Household and Boost U.S. Trade Position by More than \$164 billion in 2020, New IHS Study Says | IHS Online Pressroom," <http://press.ihs.com/press-release/economics/us-unconventional-oil-and-gas-revolution-increase-disposable-income-more-270> (accessed 22 Feb 2014).

⁹⁷ Press.ihs.com, <http://press.ihs.com/press-release/economics/us-unconventional-oil-and-gas-revolution-increase-disposable-income-more-270> (accessed 22 Feb 2014).

⁹⁸ townhall.com, "Sarah Jean Seman - North Dakota Oil Fields Spur Employment and Population Growth," <http://townhall.com/tipsheet/sarahjeanseman/2013/12/30/census-report-north-dakota-employment-and-population-grow-due-to-oil-fields-n1770016> (accessed 22 Feb 2014).

⁹⁹ Ohio.com, "Drilling is having population impacts on Great Plains," <http://www.ohio.com/blogs/drilling/ohio-utica-shale-1.291290/drilling-is-having-population-impacts-on-great-plains-1.381210> (accessed 24 Feb 2014).

¹⁰⁰ Press.ihs.com, <http://press.ihs.com/press-release/economics/us-unconventional-oil-and-gas-revolution-increase-disposable-income-more-270> (accessed 22 Feb 2014).

¹⁰¹ Federal Reserve Bank Of Minneapolis, *Data on Demographic, Economic and Financial Activity in the Bakken*, 2012, 2.

¹⁰² Federal Reserve Bank Of Minneapolis, *Data on Demographic, Economic and Financial Activity in the Bakken*, 2012, 20.

¹⁰³ Federal Reserve Bank Of Minneapolis, *Data on Demographic, Economic and Financial Activity in the Bakken*, 2012, 17.

This boom has immensely increased government revenues since 2008. Industrial activity and associated employment contributed more than \$74 billion to federal and state revenues in 2012.¹⁰⁴ This increase was accompanied by the addition of \$283 billion to US GDP, which is expected to increase by \$468 billion in the coming years.¹⁰⁵ Tax receipts will rise to more than \$125 billion annually by 2020 and reach \$138 billion by 2025.¹⁰⁶ This increase will impact each state differently due to state tax structures, which can vary from a low of 3.3% in Oklahoma to a high of 11.7% in Wyoming”.¹⁰⁷ Tax revenue increases due to unconventional oil have been most drastically felt in the Bakken and Eagle Ford regions, and will be increasingly felt in Ohio, Colorado, and west Texas as each play experiences a development boom.

Unconventional oil and gas development is expected to decrease the US deficit and increase exports of oil and NGLs (natural gas liquids). Strong boosts specifically in the manufacturing industry as well as other energy sectors “will cut the countries deficit by a third over the next decade”.¹⁰⁸ Furthermore, “total US exports hit the second-highest monthly level on record in July 2013, at \$189.4 billion,” which is expected to reduce the US national deficit by more than \$164 billion by 2020.¹⁰⁹

[Social Impacts]

As the boom has spread across the US, local communities and cities have been seriously impacted. Population growth near major oil plays has spiked. North Dakota has predominantly been impacted and was home to half of the ten fastest-growing US counties between 2011 and 2012.¹¹⁰ Furthermore, North Dakota attracted 22,000 residents within the past year, which is a higher percentage increase than from any other state.¹¹¹ Such population growth will be specifically felt by Carroll County within Ohio and communities in Colorado, and south and west Texas.

Such a massive population growth has beneficial effects on communities such as increased entrepreneurial activity and tax revenues, but it also has negative impacts such as increased traffic, housing units, and environmental effects such as gas flares, oil spills, and leaks.

¹⁰⁴ Press.ihs.com, <http://press.ihs.com/press-release/economics/us-unconventional-oil-and-gas-revolution-increase-disposable-income-more-270> (accessed 22 Feb 2014).

¹⁰⁵ Helen Robertson, "Shale a Boon for US Economy, 1.

¹⁰⁶ Press.ihs.com, <http://press.ihs.com/press-release/economics/us-unconventional-oil-and-gas-revolution-increase-disposable-income-more-270> (accessed 22 Feb 2014).

¹⁰⁷ Headwaters Economics, "Unconventional Oil Revenues to Local Governments,"

<http://headwaterseconomics.org/energy/state-energy-policies> (accessed 19 Feb 2014).

¹⁰⁸ Helen Robertson, "Shale a Boon for US Economy, " *Petroleum Economist* (2013): 1.

¹⁰⁹ Helen Robertson, "Shale a Boon for US Economy, 1.

¹¹⁰ Bloomberg, "Eagle Ford Shale Boom Fuels ‘Madhouse’ in South Texas Counties,"

<http://www.bloomberg.com/news/2013-03-14/eagle-ford-shale-boom-fuels-madhouse-in-south-texas-counties.html> (accessed 21 Feb 2014).

¹¹¹ townhall.com, <http://townhall.com/tipsheet/sarahjeanseman/2013/12/30/census-report-north-dakota-employment-and-population-grow-due-to-oil-fields-n1770016> (accessed 22 Feb 2014).

Such issues will be fully discussed in chapter six and the environmental chapters within this report.

Conclusion

Shale oil qualifies as a true “boom” in the traditional sense, meaning that it has happened suddenly, on a massive scale, and brings both positive and negative elements, creating opportunities and success even as it brings new risks and challenges. It is a real turnaround in the historic pattern of long-term oil production decline since the late 1980s. In November 2013, US oil production topped eight million barrels per day for the first time since January 1989, which signifies a complete transition from just five years ago.¹¹²

It must be noted that booms do not last; they are, by nature, temporary phenomena. This is the historical pattern (of sudden increase followed by decline), repeated many times, and so it makes sense to contemplate the best ways to deal with this truth, both on the upside and downside. At the same time, the total potential involved—if one includes all tight oil formations in the US, including Alaska—is immense and may not yet be fully appreciated. It is possible that the US stands at the threshold of a new era of true oil and gas abundance. That is, continued innovations in fracking technology have the long-term potential to open up a large number of new formations for commercial production.

Meanwhile, the extreme rate of production growth in the Eagle Ford and Bakken is indicative of how suddenly shale oil has appeared on the US energy scene. This suddenness itself brings major challenges. Infrastructure including, pipelines, roads, and housing, as well as proper environmental impact assessment, and even institutional adjustments at the county, state, and federal level have been seriously overwhelmed by the boom and require further development. While the flow of new oil appears enormously positive from the broader perspective of national energy concerns, economics, security, and international relations, people that it most immediately impacts may view it entirely differently. The US government therefore appears challenged in having to negotiate in multiple spheres of activity.

¹¹² AEIdeas, "Another US energy milestone: Daily oil production last week topped 8 million barrels for the first time since January 1989," <http://www.aei-ideas.org/2013/11/another-us-energy-milestone-daily-oil-production-last-week-topped-8-million-barrels-for-the-first-time-since-january-1989/> (accessed 19 Feb 2014).

Chapter Five

THE GLOBAL DIMENSION: RESOURCES, DEVELOPMENT, AND REGULATIONS

Ola Wietecha

Abstract

This chapter presents the current state of fracking outside the US through an examination of current events and official reports. It is divided into three sections: the first will give the most recent estimates of global shale oil resources, followed by an overview of countries that are currently involved in various stages of fracking. The section then explains major factors that have inhibited other countries from achieving a shale boom similar to North America's, and will explain existing fracking policies. The second and third sections provide case studies of Poland and China, which are expected to successfully develop fracking in the near future. These case studies are divided into subsections covering history and context, the current state of fracking, incentives to frack, greatest challenges, and future prospects. According to these findings, shale resource development will almost certainly take place in many parts of the world.

Introduction

Commercial production of shale oil and gas using fracking technology has not yet been developed anywhere outside of North America.¹ However, the U.S. shale boom along with recent reports estimating large worldwide shale reserves have prompted many other countries to consider exploring their domestic shale resources. The EIA lists as many as 41 countries that demonstrate “some level of relatively near-term promise.”² It is important to understand fracking in the US in the context of this global phenomenon in order to correctly assess what role the US should play as the current leader in this industry.

It must be noted that the case studies within this section, Poland and China, are currently focused on the extraction of shale *gas* whereas this report as a whole is focused on oil. These cases are necessary to study because the same fracking technology is used to produce both gas and oil. Shale gas, being cheaper to extract, is the first target and can lead to oil extraction once the proper technology and infrastructure are in place. It can be assumed that if these countries are able to successfully develop their shale gas industry, shale oil will follow.

¹ Eia.gov. "Shale oil and shale gas resources are globally abundant - Today in Energy - U.S. Energy Information Administration (EIA)." 2013. <http://www.eia.gov/todayinenergy/detail.cfm?id=11611> (accessed 21 Feb 2014). 5

² Eia.gov. "Shale oil"

Section I: Global Resources

[Introduction]

Studies of the global abundance of shale suggest technically recoverable reserves of 300 to 345 billion barrels from a total of 137-148 individual shale formations.³ According to these estimates, global shale resources hold about 10% of the world's recoverable oil and 32% of its natural gas. The locations of major shale basins can be seen in Figure 1. Many geoscientists believe that total reserves—particularly if extended to tight oil in general—are possibly twice this figure.⁴ The top ten countries with the highest estimated amount of shale oil according to the EIA report⁵ can be seen in **Table 1**:

Country:	Shale oil (billion barrels)
Russia	75
U.S.	58
China	32
Argentina	27
Libya	26
Australia	18
Venezuela	13
Mexico	13
Pakistan	9
Canada	9
Total	280

Table 1: Top Ten Nations in Assessed Shale Oil Resources (Source: EIA)

It is notable that these nations include the world's largest oil importers, China and the US, as well as exporters Russia and Venezuela. Furthermore, all three nations in North America appear in this list.

³ Eia.gov. "Shale oil"

⁴ Montgomery, Scott. Personal communication, 2014

⁵ *Technically Recoverable Shale Oil and Shale Gas Resources: An Assessment of 137 Shale Formations in 41 Countries Outside the United States*. Washington D.C.: EIA, 2013.

<http://www.eia.gov/analysis/studies/worldshalegas/pdf/overview.pdf>. (accessed 23 Feb 2014). 11

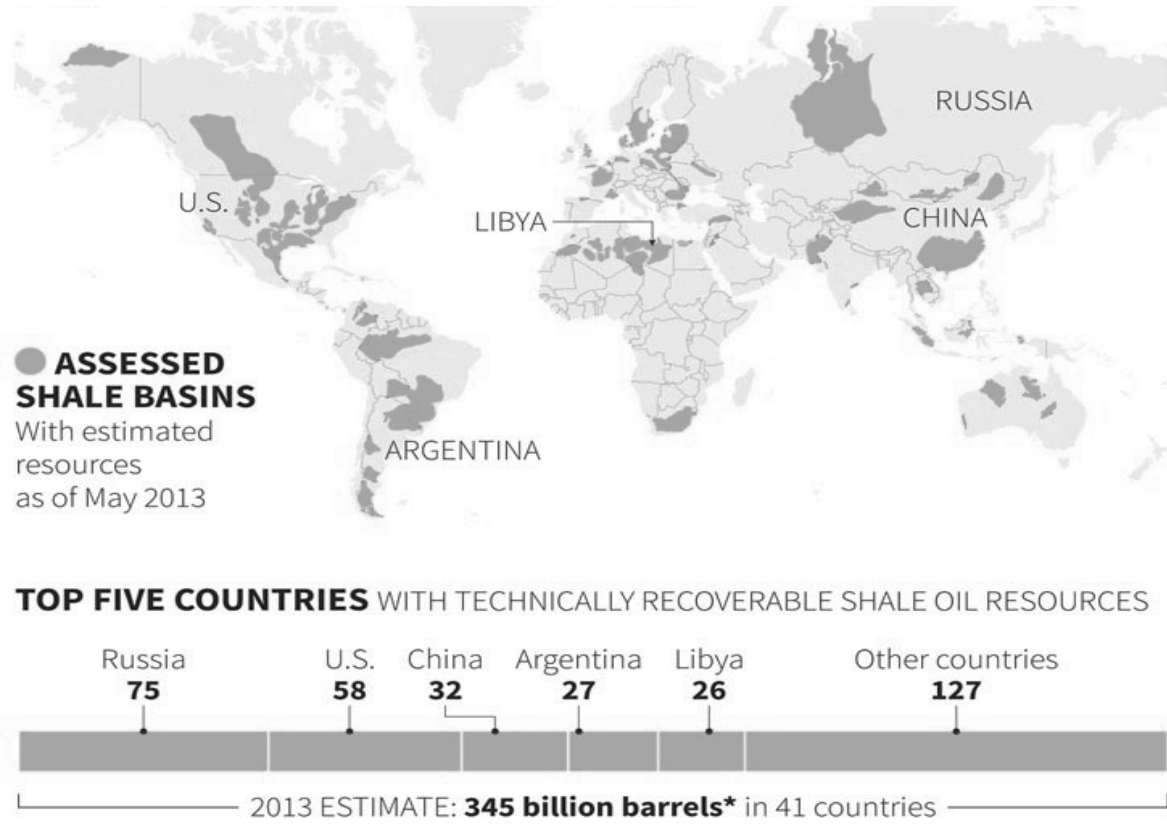


Figure 1: Assessed Shale Basins (source: <http://blog.thomsonreuters.com>)

[Development]

Several countries are in various stages of testing fracking on their own soil. The following section will give an outline of such activity, as of early 2014. This list is non-exhaustive, and there are many countries which are just beginning to discuss the possibility of tapping their potential shale gas and oil resources.

Production of shale resources is occurring in four countries: the US, Canada, Australia, and New Zealand.⁶ The US is the world leader, followed by Canada. Australia has recently been of major interest to investors due to low population density, among other factors.⁷ Australia is commercially producing a limited amount of shale gas, and New Zealand has fracked several dozen non-commercial wells.⁸

Several countries are at early stages of exploration/production.⁹ In Latin America, Mexico has expressed interest in drilling the Eagle Ford Basin, which crosses the US-Mexico border and has thus far been highly successful in the US.¹⁰ Argentina has attracted several large

⁶ Feodoroff, Timothe, Jennufer Franco and Ana Martinez. *Old Story, New Threat: Fracking and the global land grab*. 2013. http://www.tni.org/sites/www.tni.org/files/download/fracking_-_old_story_new_threat_oct13.pdf. (accessed 21 Feb 2014). 3

⁷ Ibid, 3

⁸ Ibid, 6

⁹ Ibid, 7

¹⁰ Dunnahoe, Tayvis. "Beyond US border, Mexico primes shale potential." *OGJ*, 1 May, 2013.

US companies such as Apache and Chevron.¹¹ In Brazil, Shell has begun initial drilling, and test drillings have already taken place in Uruguay.¹²

In Africa, one of the most sought-after shale basins is the Karoo in South Africa, which is scheduled to be fracked in the near future despite controversy surrounding it. In Egypt, large companies have started to frack in the Nile Valley.¹³ The Maghreb region has also been a target for investors.

In Europe, Poland has been most active in pursuing fracking. Ukraine and Romania have signed deals with several western oil companies.¹⁴ The UK is actively pursuing fracking after it recently lifted a moratorium that was put in place in November of 2011 in response to seismic activity.¹⁵

Russia is estimated to have the largest reserves of shale oil and signed its most recent deal with Shell in January of 2014 in order to start drilling for shale oil in Siberia.¹⁶ Unlike many other countries developing fracking, Russia's focus has largely been shale *oil*, not gas, and it is "near the top of the list of countries with the potential to replicate North America's shale revolution."¹⁷

In Asia, China is expected to be one of the leading future producers of shale resources due to its very large estimated technically recoverable reserves. Pakistan and India have also recently approved shale exploration.¹⁸

[Current Challenges Outside the US]

Despite geological potential and active pursuit, no country has yet come close to the oil production success that the U.S. has had.¹⁹ Several common challenges have impeded them. These challenges determine whether or not resources are economically recoverable, rather than just technically recoverable. They include both "below ground" factors (the natural geology of each shale basin) as well as "above ground" factors (the economic, political, and social framework of the country).

The composition and depth of shale varies greatly from basin to basin. Thus, fracking technology from the U.S. cannot simply be transported elsewhere; it will need to be adapted.²⁰ The level of understanding of different shale formations varies as well. Much more research is

¹¹ Feodoroff et.al, *Old Story, New Threat* 7

¹² Ibid, 7

¹³ Ibid.

¹⁴ Kramer, Andrew. "Chevron and Ukraine Set Shale Gas Deal." *New York Times*, 5 November, 2014.

¹⁵ Alessi, Robert and Jeffrey Kuhn. "British government lifts year-old fracking moratorium." *DLA Piper*, 12 December, 2012.

¹⁶ UPI. "Russian joint venture with Shell targets shale oil in Siberia." 2014.

http://www.upi.com/Business_News/Energy-Resources/2014/01/14/Russia-taps-into-Siberian-shale/UPI-59421389700671/ (accessed 23 Feb 2014).

¹⁷ Chazan, Guy. "Russia gears up for shale boom." *FT.com*, 31 March, 2013.

¹⁸ Feodoroff et.al, *Old Story, New Threat* 7

¹⁹ *Game Changer: How Shale Is Transforming Global Energy--And Affecting Industries And Ratings*. New York: Standard and Poor's, 2014. <http://marcelluscoalition.org/wp-content/uploads/2014/01/197319624-Untitled.pdf> (accessed 21 Feb 2014). 5

²⁰ *Game Changer: How Shale* 5

necessary before other countries involved in fracking have a clear understanding of their shales and the potential for gas and oil within them.²¹ Availability of large amounts of water is also vital. Shale basins, ideally, should be near a suitable water source, which is not always possible.²²

Private ownership of hydrocarbon subsurface rights has been a major component in the US boom. In a large number of other countries, by contrast, subsurface minerals are owned by the government.²³ To a large extent, Americans own the rights to subsurface minerals on private property. Any fracking activity on private land requires the consent of the owner and royalties paid to the owner. Landowners elsewhere thus do not have this same incentive to encourage fracking on their land.²⁴

The level of public support is also important in determining the likelihood of fracking; significant opposition can hinder efforts considerably. France, for instance, upheld their 2011 ban on fracking in 2013 when the issue was reassessed, largely due to the general public opinion against fracking.²⁵

The regulation framework of any country is incredibly important in determining whether or not it will be attractive to investors.²⁶ Unclear regulations, unfavorable contracts, and lack of government support can limit investors' involvement. This has been a significant hurdle for many countries attempting to frack.

Both the EIA and HIS reports address technically recoverable reserves; however they do not address the above-listed factors. These factors – the geological variation of the world's shale along with varying above-ground factors – will largely determine what non-U.S. shale resources can be profitably extracted.²⁷

[Regulation and Policy]

Thus far, there has been no global or regional consensus on fracking regulation; each country is responsible to decide its own policies. As a result, a wide range of policies has been developed, from outright ban of fracking to active encouragement of its development.

As mentioned above, France is an example of a country that has rejected fracking, despite having the second largest amount of technically recoverable reserves in Europe.²⁸

Countries like Poland and China, on the other hand, have fully embraced fracking. These will be discussed in detail later in the chapter.

²¹ *Focus on Tight Oil and Shale Gas Production Impact on Saudi Arabia*. Riyadh: Jawda Investment, 2013. http://www.jadwa.com/en/media/get/20131217_The-Outlook-for-Unconventional-Oil-Gas-Production-Full-report.pdf. (accessed 21 Feb 2014).

²² *Game Changer: How Shale 5*

²³ Ibid

²⁴ Frackinginjurylaw.com. "Landowner Rights

²⁵ The Guardian. "France cements fracking ban." 2013.

<http://www.theguardian.com/environment/2013/oct/11/france-fracking-ban-shale-gas> (accessed 23 Feb 2014).

²⁶ McMahon, Jeff. "Six Reasons Fracking Has Flopped Overseas." *Forbes*, 7 April, 2013.

²⁷ *Game Changer: How Shale 5*

²⁸ The Guardian. "France cements fracking ban."

Other countries have taken a more nuanced approach. In Germany, for instance, a moratorium has been put in place, but it is likely that the ban will be lifted in the future if environmental risks become better understood and controlled.²⁹

[Future Prospects]

The future of the global shale oil market is unclear, as further testing is needed for more accurate estimates of technically and economically recoverable shale resources. The EIA report did not assess possible shale formations in the Middle East and the Caspian region, or offshore shale formations, which likely hold “significant additional shale gas and shale oil resources.”³⁰

The US is likely to maintain its status as the top producer of shale gas and oil for the foreseeable future;³¹ however reports show huge potential for shale oil development outside of The US. According to the EIA report, the US holds only about 17% of global shale oil reserves.³² The IHS report claims that, “worldwide shale fields [contain] seven times the recoverable shale oil contained in North American basins.”³³

Given the huge economic incentive, it is very likely that fracking will continue to develop globally. Search for shale oil has hardly started outside of North America but, as the following case studies will show, interest is growing.

²⁹ Nicola, Stefan. "No Fracking in Germany for Now Backed in Merkel Coalition." *Bloomberg*, 8 November, 2013.

³⁰ “*Technically Recoverable Shale Oil*”28

³¹ Sykes, Justin. "The Future of Shale Gas is Bright in the U.S.." *Americans for Tax Reform*, 8 January, 2014.

³² *Game Changer: How Shale* 4

³³ Daltorio, Tony. "How to Invest in the Global Shale Oil and Gas Boom." *Money Morning*, 8 October, 2013.

Section II: Case Study: Poland

[History & Context]

Poland has been aiming to diversify its energy supplies since 1989 but had made little progress until the recent introduction of fracking.³⁴ Exploration for unconventional gas and oil began in 2005,³⁵ and has continued to grow rapidly. In 2007 and 2008, Poland was the main focus of large energy companies exploring global shales following the US boom.³⁶

The “shale rush” in Poland was initiated to a large extent by the publication of the EIA’s first global shale gas report in 2011, which estimated that Poland contained 148 trillion cubic feet of technically recoverable shale gas, the most in Europe.³⁷ The first successful horizontal shale gas well in Poland was completed in June of 2011 near Łebień.³⁸

Although later reports’ estimate Poland’s reserves to be 20% less than the 2011 EIA estimates,³⁹ Poland is still considered to have the most European shale gas reserves, and the second largest European shale oil reserves. Poland is currently one of the most active countries in developing shale fracking technology.

[Current Energy Use]

Poland’s primary energy source is coal, which generates over 90% of its electricity.⁴⁰ As the second largest coal producer in Europe (behind Germany), Poland is largely self-sufficient in electricity. In 2012 it produced 158 million short tons of coal, most of which was used domestically.⁴¹

On the other hand, Poland produces only small amounts of crude oil and natural gas, and imports nearly all of its gas and oil for heating and transportation. It has been ranked the lowest among EU countries in terms of energy dependency.⁴² Poland hopes to remedy this by increasing natural gas production from fracking.⁴³

[Current Fracking Status]

Fracking is still in an early, pre-commercial phase in Poland, but it is considered to be one of the most favorable locations for fracking and is “carrying out the most intensive program

³⁴ The Economist. "Mad and messy regulation." 2014.

<http://www.economist.com/blogs/easternapproaches/2013/07/shale-gas-poland> (accessed 23 Feb 2014).

³⁵ Poprawa, Paweł. "Poland Geology: USD 1bn v the Rocks." *CleanTech Poland*, 2013.

³⁶ Grealy, Nick. "Sea change for Poland shale gas." *No Hot Air*, 23 January, 2014.

³⁷ Eia.gov. "Poland - U.S. Energy Information Administration (EIA)." 2014. <http://www.eia.gov/countries/country-data.cfm?fips=PL> (accessed 21 Feb 2014).

³⁸ Msp.gov.pl. "Shale gas extraction in Poland – review of current works and prospects for coming years." 2012. <http://msp.gov.pl/en/polish-economy/economic-news/3374,Shale-gas-extraction-in-Poland-review-of-current-works-and-prospects-for-coming-.html> (accessed 22 Feb 2014).

³⁹ Cienski, Jan. "Eni joins shale gas exodus from Poland." *Financial Times*, 15 January, 2014.

⁴⁰ Nyga - Łukawska, Honorata. "Poland's Energy Security Strategy." *Journal of Energy Security*, 15 March, 2011.

⁴¹ "Poland: The Promise and Perils of Shale Gas Exploration." *Natural Gas Europe*, 8 September, 2013.

⁴² Nyga - Łukawska, Honorata. "Poland's Energy Security"

⁴³ Scotland Against Spin." 2014. <http://scotlandagainstspin.org/2014/01/great-polish-shale-fail-warning-britaingwpf/> (accessed 21 Feb 2014).

of exploration...in Europe.”⁴⁴ 113 exploration licenses have been issued and 51 exploratory wells have been drilled,⁴⁵ which is more than any other European country.⁴⁶ As of April 2013, nine of these exploratory wells have been fracked, and four have been successfully drilled horizontally.⁴⁷

Poland received significant attention from international energy companies after the EIA’s 2011 report was published, but initial test results have not met expectations, which has resulted in a major slowdown in the industry.⁴⁸ Four companies have abandoned efforts in Poland. Eni left in early 2014, along with ExxonMobil, Marathon Oil, and Talisman Energy in 2013. As a result, shale well drilling decreased 50% from 24 wells in 2012 to only 12 in 2013.⁴⁹ 14 companies still remain, however, and are “committed to continue...the development of Polish shale.”⁵⁰

Significant exploration is still needed to properly assess Polish shale. Only a small number of the 113 licenses have resulted in exploration, as companies with licenses, on average, are installing one drilling platform annually.⁵¹ It will take roughly 200 wells before shale gas potential can be properly assessed. If Poland’s fracking growth continues at its current rate, it will take 12 year before this is possible.⁵² The government is currently making efforts to once again attract investors and energy companies.

[Resources]

EIA estimates the amount of Poland’s technically recoverable shale reserves as 187 Tcf of gas and 3,300 million barrels of oil.⁵³ The Polish Geological Institute estimated the total recoverable shale gas reserves to be 346 to 768 Bcm.⁵⁴ According to even the most conservative estimates, Poland contains enough shale gas to make the country self-sufficient for 65 years.⁵⁵

There are three principle shale basins in Poland where exploration is currently taking place: The Baltic-Warsaw Trough, the Podlasie Depression, and the Lublin Basin. See **Figure 2**.⁵⁶

⁴⁴ Rutkowski, Mirosław. "Shale Gas in Poland." *Shale Gas Information Platform*, May, 2013.

⁴⁵ Polishshale.pl. "Grabowski: 40 new boreholes this year | polishshale.pl - Shale Gas in Poland." 2014. <http://polishshale.pl/grabowski-40-new-boreholes-this-year/> (accessed 23 Feb 2014).

⁴⁶ Platts.com. "Poland looks to give shale gas sector new boost." 2014. <http://www.platts.com/latest-news/natural-gas/warsaw/feature-poland-looks-to-give-shale-gas-sector-26594799> (accessed 23 Feb 2014).

⁴⁷ Shalegas-europe.eu. "Poland." 2013. <http://www.shalegas-europe.eu/en/index.php/resources/shale-opportunities-in-europe/poland> (accessed 23 Feb 2014).

⁴⁸ Poprawa, Paweł. "Poland Geology"

⁴⁹ Platts.com. "Poland looks to give"

⁵⁰ Opppw.com. "News - Press releases - OPPPW." 2014.

http://www.opppw.com/news/press_releases?more=528970946 (accessed 23 Feb 2014).

⁵¹ Polskie Radio dla Zagranicy. "Polish shale gas exploration 'too slow'." 2014.

<http://www.thenews.pl/1/12/Artykul/158440,Polish-shale-gas-exploration-too-slow> (accessed 23 Feb 2014).

⁵² Polskie Radio dla Zagranicy. "Polish shale gas"

⁵³ Eia.gov, "Poland - U.S. Energy"

⁵⁴ Shalegas-europe.eu. "Poland."

⁵⁵ Ibid.

⁵⁶ Eia.gov. "Poland - U.S. Energy Information Administration (EIA)." 2014. <http://www.eia.gov/countries/country-data.cfm?fips=PL> (accessed 23 Feb 2014).



Figure 2: Major Shale Basins in Poland (source: The Economist)

The Baltic-Warsaw Trough is considered the most promising shale basin in the country, containing between 8 and 22 Tcf of shale gas and between 1.6 and 1.9 billion barrels of oil.⁵⁷ The shale in this area also has a relatively uncomplicated structural setting, which makes it simpler to frack.⁵⁸

The Podlasie Basin has potential, but the geology is more seismically complex than the Baltic Basin.⁵⁹ Technically recoverable reserves are estimated to be 0.4 billion barrels of shale oil and condensate along with 0.7 Tcf of shale gas.⁶⁰

The Lublin Basin is the most structurally complex of the three, with closely spaced faults.⁶¹ The shale TOC also seems to be low. In addition, the basin is relatively deep, which makes extraction challenging as it requires more water and equipment. Despite this, it is still being actively developed.⁶²

⁵⁷ Search.rigzone.com. "Rigzone." 2014. http://search.rigzone.com/iPhone/article.asp?a_id=128441 (accessed 23 Feb 2014).

⁵⁸ Search.rigzone.com. "Rigzone."

⁵⁹ Eia.gov. "Poland - U.S. Energy Information"

⁶⁰ Ibid.

⁶¹ Ibid.

⁶² Eia.gov. "Poland - U.S. Energy Information"

[Policy and Regulation – Laws and Principle Bodies]

Poland's regulatory framework is weak and lacks specificity.⁶³ The current law is in the process of being amended, and is thus not clear or established. This has resulted in a long period of uncertainty for investors and exploration companies.⁶⁴

Until the beginning of 2012, fracking activity was regulated under the Geological and Mining Law of 1994. However, this regulatory framework was not suited for hydrocarbons, as Poland has traditionally produced coal. In 2012 changes were made to The Geological and Mining Law, which addressed hydrocarbons and formed the current legal framework for all shale activities in Poland.⁶⁵ The new hydrocarbon law of 2012 was created specifically for the purpose of better regulating hydrocarbon extraction. The proposed changes are meant to simplify regulations and speed up the pace of exploration.⁶⁶ The new law is expected to be ready in the spring of 2014.⁶⁷

In order to carry out shale exploration in Poland, companies must first obtain a license from the Ministry of the Environment,⁶⁸ which is the principle body for fracking decisions and licenses.⁶⁹ This is open to both Polish and foreign companies. Concessions are issued for three to five years and allow companies to drill a maximum of three exploratory wells in a specific area.⁷⁰

In addition to the changes to the Geological and Mining Law, the Polish government also plans to impose a special hydrocarbon extraction tax, with maximum rates of 40% which companies will have to pay on top of the general income tax. The tax will come into force in January of 2015 but companies will not be required to begin paying until 2020, a decision made to attract and maintain investors, as many companies have stated that a 40% tax would significantly lower exploration incentives.⁷¹

Companies are most concerned about the government's intention to create the National Operator for Energy Fossils (NOKE), a state-owned company that would be able to take capital stakes and participate in decision-making in all hydrocarbon production concessions. "The

⁶³ Paiz.gov.pl. "Formal and legal context for investments in shale gas fields and other natural resources | Inwestycje w Polsce." 2014. http://www.paiz.gov.pl/polish_law/shale_gas (accessed 23 Feb 2014).

⁶⁴ Taxand. "To Frack or Not to Frack." 2014. <http://www.taxand.com/sites/default/files/taxand/portal-documents/Taxand's%20Take%20-%20Global%20energy%20tax%20-%20to%20frack%20or%20not%20to%20frack%20-%20FINAL.pdf> (accessed 23 Feb 2014). 9

⁶⁵ Shale-gas-information-platform.org. "Rutkowska Article: SHIP - Shale Gas Information Plattform." 2014. <http://www.shale-gas-information-platform.org/categories/legislation/expert-articles/rutkowska-article.html> (accessed 23 Feb 2014).

⁶⁶ Msp.gov.pl. "Shale gas in Poland – review"

⁶⁷ EUCERS. *Newsletter*. London: EUCERS, 2014.

<http://www.kcl.ac.uk/sspp/departments/warstudies/research/groups/eucers/newsletter31.pdf>. (accessed 21 Feb 2014).

6

⁶⁸ Nyga - Łukawska, Honorata. "Poland's Energy Security"

⁶⁹ Cernoch, Filip and Lukasz Kister. *Shale gas in Poland and the Czech Republic: Regulation, Infrastructure and Perspectives of Cooperation*. International Institute of Political Science., 2012.

http://www.iips.cz/data/files/Publikace/Shale_Gas.pdf. (accessed 21 Feb 2014). 65

⁷⁰ Rutkowski "Shale Gas in Poland."

⁷¹ Wbj.pl. "Poland delays hydrocarbon tax until 2020 - Warsaw Business Journal - Online Portal - wbj.pl." 2014. <http://www.wbj.pl/article-62809-poland-delays-hydrocarbon-tax-until-2020.html> (accessed 23 Feb 2014).

government sees NOKE as a way of guaranteeing its return on future shale gas production.”⁷² Companies fear that state administrators with little knowledge of fracking will be hired by NOKE and “paralyze their current business activities.”⁷³

The Ministry of the Environment has opened discussions with the Polish Exploration and Production Industry Organization (OPPPW, an Employers’ Union involving the oil and gas companies involved in exploration in Poland). In December of 2013, the Minister of the Environment, Maciej Grabowski, held a meeting with the OPPPW members and listened to their concerns about proposed regulation changes,⁷⁴ during which OPPPW members expressed their disagreement with NOKE.⁷⁵ NOKE is still being discussed, and Grabowski has stated willingness to drop NOKE if doing so will hasten the exploration and drilling process.⁷⁶

[Incentives]

Poland’s main incentive to pursue shale resources is to strengthen its energy security.⁷⁷ Specifically, Poland plans to reduce dependency on Russia, from which it imports a majority of its gas and oil.⁷⁸ Russia supplies about 80% of Poland’s gas and over 90% of its oil,⁷⁹ but its reputation as an energy supplier has been weakened due to past use of energy cutoffs to the rest of Europe as a political tool.⁸⁰ Russia is also able to significantly alter Poland’s energy prices, “which are among the highest in Europe.”⁸¹ As a country so heavily dependent on a single, unreliable exporter, Poland is highly vulnerable.

This vulnerability was highlighted in the Russo-Ukrainian gas dispute of 2009, in which Russia and Ukraine failed to agree on the price of Russian gas. Russia cut off exports to Ukraine and significantly reduced exports to 16 EU countries.⁸² This has prompted European countries, including Poland, to intensify attempts to reduce dependence on Russian energy.⁸³

Poland also faces pressure from the EU to begin using cleaner energy.⁸⁴ Poland, which primarily depends on coal for energy, has repeatedly hindered EU attempts to cut greenhouse gases by reducing CO₂ emissions and increasing the use of renewable energy.⁸⁵

⁷² Easton, Adam. "Poland: shale investors warn against planned tough rule changes." *Beyond Brics* 7 June, 2013. <http://blogs.ft.com/beyond-brics/2013/06/07/poland-shale-investors-warn-against-planned-tough-rule-changes/#axzz2tvitoSFU> (accessed 21 Feb 2014).

⁷³ Easton, "Poland: shale investors warn"

⁷⁴ Naturalgaseurope.com. "Poland Fires Deputy Environment Minister over Slow Shale Gas Process." 2013. <http://www.naturalgaseurope.com/poland-shale-gas-deputy-environment-minister-fired> (accessed 22 Feb 2014).

⁷⁵ Opppw.com. "News - Press releases"

⁷⁶ Naturalgaseurope.com. "Poland Fires Deputy"

⁷⁷ Nyga - Łukawska, Honorata. "Poland's Energy Security"

⁷⁸ Johnson, Corey and Tim Boersma. "Energy (in) security in Poland the case of shale gas." *Energy Policy* 53, (2013): 389--399.

⁷⁹ Eia.gov, "Poland - U.S. Energy"

⁸⁰ Pirani, Simon, Jonathan Stern and Katja Yafimava. *The Russo-Ukrainian gas dispute of January 2009: a comprehensive assessment*. Oxford Institute for Energy Studies, 2009. <http://storage.globalcitizen.net/data/topic/knowledge/uploads/20110630223130533.pdf>. (accessed 23 Feb 2014). 5

⁸¹ Rutkowski "Shale Gas in Poland."

⁸² Shalegas-europe.eu. "Poland."

⁸³ Pirani et al, "The Russo-Ukrainian" 4

⁸⁴ The Economist. "Mad and messy regulation."

[Strengths]

In addition to large natural reserves, there are several factors which have made Poland one of the most likely countries to develop commercial fracking, most importantly its minimal public opposition and political will.

Unlike many surrounding European countries, Polish efforts to extract shale resources have not been met with significant public opposition.⁸⁶ A survey conducted by the EU found that less than three percent of Poles “are implacably opposed to fracking,”⁸⁷ while 73% are in favor of shale gas exploitation.⁸⁸ Public support “is likely related to a combination of factors, including the historical tensions and mistrust between Poland and Russia”⁸⁹ which has made energy independence even more attractive to the general public.

The Polish government has also shown significant amounts of political will. Prime Minister Donald Tusk has repeatedly “emphasized that shale gas exploitation is one of the government’s priorities.”⁹⁰ The government has been working to revive exploration by making changes to their shale policies, following the withdrawal of several major companies.⁹¹ In November 2013 Prime Minister Donald Tusk fired his Minister of the Environment, Marcin Korolec, as a result of his slow pace in developing these regulation changes. He was replaced by Maciej Grabowski, who lists accelerated exploration as one of his priorities.⁹²

[Challenges]

Polish shales are not very well understood and initial tests have shown several geological challenges. The exact locations of faults, which often interfere with drilling, are unknown. Exploration tests have also found that some shale formations contain high clay content (as high as 30-40 %) which makes fracking more difficult.⁹³ Additionally, tests have shown that Polish shales have relatively low permeability, which inhibits the flow of gas and oil through the shale rock.⁹⁴

One of the most significant above-ground challenges is the lack of clear, finalized regulations. For instance, it currently takes an average of 130 days to obtain a license, while the process should last 30.⁹⁵ Any changes to drilling programs take an additional eight months.⁹⁶

⁸⁵ Mock, Vanessa. "Brussels' new climate goals to fall short of EU green ambitions." *Wall Street Journal*, 16 January, 2014.

⁸⁶ Johnson et al "Energy (in) security" 1

⁸⁷ Evans-Pritchard, Ambrose. "Poland's shale drive will transform Europe, if it does not drop the ball." *Telegraph*, 21 August, 2013.

⁸⁸ Rutkowski "Shale Gas in Poland."

⁸⁹ Johnson et al "Energy (in) security" 9

⁹⁰ Rutkowski "Shale Gas in Poland."

⁹¹ Unconventional Gas Center. "Poland's Top Fracer Predicts First Commercial Gas Flows In 2014 As Eni Pulls Out." 2014. http://www.ugcenter.com/International-Shales/Polands-Top-Fracer-Predicts-Commercial-Gas-Flows-2014-Eni-Pulls-Out_128077 (accessed 23 Feb 2014).

⁹² Platts.com. "Poland looks to give"

⁹³ Eia.gov. "Poland - U.S. Energy Information"

⁹⁴ Poprawa, Paweł. "Poland Geology"

⁹⁵ Polskie Radio dla Zagranicy. "Polish shale gas"

⁹⁶ Platts.com. "Poland looks to give"

Companies are also concerned about their legal rights to commercialize, such as the ability to obtain production licenses, if they were to find commercial quantities of gas.⁹⁷“Clear and stable regulations are of key importance [for Polish shale]...as they will allow investors to calculate the future costs and benefits, assess the risk.”⁹⁸

The government is currently in the process of clarifying its laws, but one main concern has been the slow development of new regulations.⁹⁹ Simplifying administrative processes and clarifying taxation has been more complex to implement by the Polish government than originally anticipated.¹⁰⁰

Beyond regulation, Poland lacks the infrastructure necessary to utilize natural gas. Most Polish pipelines are located in the southwest whereas most shale reserves are in the north, east-central, and southeast. Also, “because of Poland’s dependence on coal, only half of households are currently connected to natural gas distribution networks.”¹⁰¹ Significant investment will be required to upgrade natural gas transmission.

[Future Prospects]

Despite the slowdown, Poland remains one of the most likely European countries to develop fracking. According to the Ministry of the Environment, there are plans to drill 308 exploration wells by the year 2021, of which 122 are obligatory and will certainly be drilled, and 186 are optional.¹⁰²

Due to recent developments, commercial production may start as soon as 2014.¹⁰³ In late January 2014, San Leon, a Dublin-based natural gas explorer, announced that they had drilled a vertical well into the Baltic shale from which they were able to extract 45,000-60,000 cubic feet of shale gas per day. The company has estimated a potential rate of 200,000-400,000 scf/d if cleanup of fracking fluid from the well is completed.¹⁰⁴ San Leon has stated that commercial gas flows can be expected along with a doubling of the number of shale wells drilled by the end of 2014. Other energy companies also plan on expanding: in the coming months, PGNiG, Chevron, and Lane Energy Poland plan to begin drilling work.¹⁰⁵

Much hinges on the policies currently being developed, and whether or not they will create or hinder incentives to frack. The lack of clarity has been a significant challenge, although it is clear that the government is eager to increase investment and they will likely create a more

⁹⁷ Snyder, Parker and Wojciech Kość. "Ecstasy to Agony." *CleanTech Poland*, 30 December, 2013.

⁹⁸ Msp.gov.pl. "Shale gas in Poland"

⁹⁹ *EUCERS Newsletter*, 14

¹⁰⁰ *Ibid*, 18

¹⁰¹ "Poland: The Promise and Perils"

¹⁰² Rutkowski "Shale Gas in Poland."

¹⁰³ Msp.gov.pl. "Shale gas in Poland"

¹⁰⁴ Sanleonenergy.com. "Lewino-1G2: Successful Vertical Frac Leads To Horizontal Well." 2014.

<http://www.sanleonenergy.com/media-centre/news-releases/2014/january/23/lewino-1g2-successful-vertical-frac-leads-to-horizontal-well.aspx> (accessed 23 Feb 2014).

¹⁰⁵ Polishshale.pl. "Karpinski: shale will still be our priority | polishshale.pl - Shale Gas in Poland." 2014.

<http://polishshale.pl/karpinski-shale-will-still-be-our-priority/>(accessed 23 Feb 2014).

favorable environment for investors. Prospects will likely become clearer in the next year when these new laws are finalized.

Outside of Poland, regional regulatory framework remains favorable for its shale development. The EU recently released a series of recommendations urging states to adopt minimum fracking regulations, but is not legally-binding. The declaration “ensures that exploration and development activities will proceed full-speed ahead in countries that want to reap the potentially vast benefits of fracking.”¹⁰⁶ These non-binding suggestions pose little threat to the Polish fracking industry.

Section III: Case Study: China

[History and Context]

Throughout the 1990s the Chinese government considered natural gas to be too expensive relative to domestic coal resources and did not take any significant steps to develop it.¹⁰⁷ In 1999, due to environmental and economic pressure, China began feasibility studies on domestic shale.¹⁰⁸

In 2008, the first sample shale gas wells were drilled, and shale drilling began in November of 2009 in Sichuan province after the state-owned PetroChina signed an agreement with Shell.¹⁰⁹ (*China's Shale Gas*, 2013) This was the first shale gas effort following the launch of the US-China Shale Gas Resource Cooperation Initiative, an agreement wherein the US agreed to provide guidance to China to develop its shale industry.¹¹⁰

In May 2010 the state-owned energy company Sinopec partnered with BP to conduct China's first successful fracking project, and in March 2011 PetroChina partnered with Shell and drilled the first horizontal shale gas exploration well in Sichuan Province.¹¹¹

In 2011 the government held its first auction of commercial development permits, which was open to six invited, state-owned energy companies. This further sped up development efforts.¹¹² The EIA's 2011 report showing that China had the greatest reserves of shale oil in the world also played a role in raising interest in fracking Chinese shale.¹¹³

The Chinese National Energy Bureau issued their latest five-year plan in 2012, which specified efforts to increase exploration with the goal of producing 6.5 bcm of shale gas.¹¹⁴

¹⁰⁶ Chelney, Stan. "European Union Decision Clears the Way For Fracking Investment." *Energy Legal Blog* 3 February, 2014. <http://www.energylegalblog.com/archives/2014/02/03/5099> (accessed 21 Feb 2014).

¹⁰⁷ Nakano, Jane. *Prospects for shale gas development in Asia*. Washington: Center for Strategic and International Studies, 2012.

¹⁰⁸ Cges.co.uk. "China's oil demand to 2020." 2014. <http://www.cges.co.uk/news/1026-chinas-oil-demand-to-2020> (accessed 21 Feb 2014).

¹⁰⁹ PIM LTD. "China's Shale Gas Development Briefing." Shanghai: *PIM LTD*, 2013. 10

¹¹⁰ Winning, David. "China Starts First Shale Gas Project." *Wall Street Journal*, 27 November, 2009.

¹¹¹ Hart, Melanie and Daniel Weiss. "Making Fracking Safe in the East and West Environmental Safeguards on Shale Gas Production Needed as China Begins Development." *Center for American Progress*, 21 October, 2011.

¹¹² Hart et al "Making Fracking Safe"

¹¹³ "Technically Recoverable Shale Oil" 20

¹¹⁴ PIM LTD. "China's Shale Gas" 21

[Current Energy Use]

China has been a net oil importer since the early 1990s and the largest global energy consumer since 2009. It is also the largest coal producer and consumer in the world. About 70% of China's energy comes from coal, which makes up about 50% of total world consumption. Oil accounts for 19% of China's energy, and demand continues to rise. It has been estimated that by 2020, China's oil imports will rise to 9.2 million barrels a day, mostly to supply transportation needs.¹¹⁵

Other sources remain a relatively small percent of China's energy mix: 6% of energy is hydroelectric, 4% is natural gas, 1% is nuclear power, and other sources account for 0.3%.¹¹⁶ According to the 12th 5-year-plan, the government aims to raise non-fossil fuel energy consumption to 11.4% by 2015.¹¹⁷

[Current Fracking Status]

The Chinese government has been actively working to promote shale resource extraction, but development is still in its early stages, as only about 130 wells have been drilled.¹¹⁸ The majority of horizontal shale gas wells in China still produce only several tens of thousands cm of gas per day whereas the breakeven output for a horizontal Chinese well is about 150,000 cm of gas daily.¹¹⁹

Gaining valuable fracking know-how and skills has been a priority in China, as Chinese companies with rights to shale basins have little drilling experience.¹²⁰ To do this, nearly all Chinese companies have formed partnerships with experienced international companies.¹²¹ Sinopec, one of the largest state-owned Chinese energy companies, has signed shale agreements with companies like Exxon in the Sichuan Basin, and with BP and Chevron in the Qiannan Basin.¹²²

Chinese companies have also begun acquiring major stakes in North American fracking companies by investing billions in American energy companies to learn the skills that led to the US shale boom.¹²³ Chinese companies have already invested US\$7.3 billion in shale resource extraction deals with the US such as Sinopec's acquisition of a 33.3% interest from the Canadian energy company, Devon Industry.¹²⁴

¹¹⁵ Rapoza, Kenneth. "Within Four Years, China To Consume More Oil Than U.S." *Forbes*, 25 August, 2014.

¹¹⁶ Rapier, Robert. "Prepare for the Chinese Energy Juggernaut." *The Energy Collective*, 5 September, 2014.

¹¹⁷ Eia.gov. "China – Analysis"

¹¹⁸ Tomsen, Jennifer and Marc Davies. "Shale Gas in Asia: Significant Reserves, Substantial Challenges." *Bloomberg Law*, 2014.

¹¹⁹ PIM LTD. "China's Shale Gas" 11

¹²⁰ Tollefson, Jeff. "China slow to tap shale-gas bonanza." *Karooshalegas*, 21 February, 2013.

¹²¹ Yang, Chi-Jen, Yipei Zhou and Robert B Jackson. "China's Fuel Gas Sector: Review and Prospects."

¹²² Blenda, Carol. "The Shale Revolution and Emerging Markets." *Harvard Law School Blog* 21 August, 2013. <http://blogs.law.harvard.edu/carolblenda/2013/08/> (accessed 21 Feb 2014).

¹²³ Breitling Energy Corporation. "China's shale gas supremacy | Pros and cons of hydraulic fracking| Energy hungry China." 2012. <http://www.breitlingenergy.com/energy-hungry-china-seeks-shale-gas-supremacy/> (accessed 21 Feb 2014).

¹²⁴ Lee, Edwin. "Shale Gas In China: How Far From Dream To Reality?." *Chadbourne&Parke LLP*, 2014. 3

[Resources]

China is estimated to hold the greatest amount of shale gas in the world at 1,100 trillion cubic feet, and the third largest reserve of shale oil, at 32 billion barrels.¹²⁵

China has seven major onshore basins with abundant shale resource potential, shown in **Figure 3**: Sichuan, Tarim, Junggar, Songliao, the Yangtze Platform, Jiangnan and Subei.¹²⁶ The Sichuan Basin is considered to have the most potential for commercial production, and is “by far China’s most active drilling area.”¹²⁷



Figure 3: Major Shale Basins in China (Source: EIA)

The southern region’s basins (the Sichuan, Jiangnan, Subei, and the Yangtze Platform) are considered to be the most promising as they have existing pipelines, a relatively large amount of surface water, and are near major cities.¹²⁸ The Yangtze Platform, Jiangnan Basin and Sebei Basin are less promising, as they are “structurally complex with poor data control.” However, they are near major cities and still considered prospective.¹²⁹

China’s northwest Tarim Basin, despite its relatively simple structure, is extremely deep and far away from significant water sources.¹³⁰ Potential remains in this region, and “horizontal

¹²⁵ “Technically Recoverable Shale Oil”

¹²⁶ EIA. *China*. Washington D.C.: EIA, 2013. (accessed 21 Feb 2014). 1

¹²⁷ *Ibid*, 28

¹²⁸ EIA. *China*. Washington D.C.: EIA, 2013. (accessed 21 Feb 2014). 6

¹²⁹ *Ibid*, 6

¹³⁰ *Ibid*, 7

wells already account for half of conventional oil production in the Tarim Basin...a good foundation for application in future shale development.”¹³¹

The Junggar Basin has a simple structural geology with thick and rich Permian source rocks.¹³² The Songliao Basin is China’s largest conventional oil-producing region; fracking studies are being conducted there.¹³³

[Current Policy]

There are six government bodies that regulate oil and gas in China: the National Development and Reform Commission (NDRC), Ministry of Land and Resources (MLR), Ministry of Finance (MOF), Ministry of Environmental Protection (MEP), Ministry of Science and Technology (MOST) and the State Administration of Taxation (SAT).¹³⁴ Each body’s responsibilities are as follows: the NDRC is responsible for shale industrial policies and planning (targets, transportation, consumption, pricing), the MLR manages public tenders of shale blocks and thresholds for entry, the MOF and SAT create fiscal incentives like tax policies, MOST runs a program meant to improve and invent technologies specifically for Chinese geology, and the MEP regulates underground and surface water protection for plants and animals.¹³⁵

There are very few formal fracking laws in China, and it has yet to establish any specific environmental regulations for shale.¹³⁶ For instance, no official regulations exist to protect groundwater from possible contamination.¹³⁷

Foreign participation, on the other hand, is heavily monitored. Regulations require that any foreigner work directly with a Chinese energy company. Only Chinese companies, public and private, are permitted to bid for state-owned shale blocks.¹³⁸ Foreign companies must work with a “Sino-foreign equity joint venture in which a Chinese party holds a majority of the shares.”¹³⁹ The foreign company must also have at least RMB300 million registered capital, and experience in oil or gas exploration. Many of the largest oil companies have entered into such agreements, including Statoil and BP.¹⁴⁰

Although the Chinese government highly regulates foreigners, it “appears to be moving away from a protectionist approach to a more open one” by loosening restrictions.¹⁴¹ During the first round of auctions in June 2011, for instance, bidding was only open to six, state-owned companies which bid on four blocks.¹⁴² Foreign and private companies were excluded from

¹³¹ Ibid, 7

¹³² Ibid, 7

¹³³ EIA, *China* 30

¹³⁴ Lee, "Shale Gas In China"

¹³⁵ Ibid.

¹³⁶ Wittmeyer, Hannah. "China, Fracking, and Environmental Leadership?." *Frackwire*, 13 September, 2013.

¹³⁷ Biello, David. "Can Fracking Clean China's Air and Slow Climate Change?" *Scientific American*, 27 January, 2014.

¹³⁸ Lee, "Shale Gas In China"

¹³⁹ Ibid.

¹⁴⁰ Ibid.

¹⁴¹ *PIM LTD* "China’s Shale" 24

¹⁴² Hart et al "Making Fracking Safe"

bidding. During the second round of auctions in 2012, the government lowered entry requirements to allow more Chinese companies to bid, including private companies.¹⁴³ 16 Chinese firms were awarded exploration rights in 19 blocs; two of these were private.¹⁴⁴

In December of 2011, revisions were made in the Foreign Investment Industry Guidance Catalogue which stated that “foreign investment in the exploration and development of shale gas and oil are encouraged. Foreign investors can set up joint ventures with their Chinese partners and enjoy administrative and tax benefits,”¹⁴⁵ which assured investors of the government’s support of their involvement.

[Incentives]

China’s principle incentives in fracking technology are to gain energy independence and to shift energy reliance away from coal to cleaner energy. The long-term goal is to export natural gas.¹⁴⁶

Imported energy supplies about 58% of China’s oil and 28% of its gas needs¹⁴⁷, which hinders strong economic growth.¹⁴⁸ China’s oil demand is almost certainly going to increase. By 2020 it will be using over 2.8 million pbd largely due to increase demand for road transport.¹⁴⁹ As a net importer, if China is unable to tap its own energy resources, it “could import more than 75% of its oil [by 2035]. At current price levels, this would substantially alter China’s trade balance and perhaps eliminate its current trade surplus.”¹⁵⁰

China also faces mounting domestic and international pressure to reduce smog and carbon emissions, which is largely caused by its use of coal.¹⁵¹ The National Development and Reform Commission (NDRC) has said that natural gas is the preferred source of clean energy, and aims to increase the percentage of natural gas to 7-8% by 2015 and 12% by 2020.¹⁵²

[Strengths]

There is a significant amount of political will to develop this technology. For instance, the government has recently taken steps to loosen regulations on the price of natural gas, which

¹⁴³ Cges.co.uk. "China's oil demand to 2020."

¹⁴⁴ Wittmeyer, Hannah. "China, Fracking, and Environmental"

¹⁴⁵ Wong, Jimmy and Toby Shek. *China shale gas – Not all it is fracked up to be. China shale gas – Not all it is fracked up to be.* Hong Kong: CIMB, 2014. http://pg.jrj.com.cn/acc/Res/CN_RES/INDUS/2013/11/29/9171cd91-c6dc-4ff3-a451-b5e36d8191d9.pdf. (accessed 23 Feb 2014).

¹⁴⁶ Richardson, John. "US Support For Big China Shale Gas Challenge." *Asia Chemical Connections*, 21 December, 2014.

¹⁴⁷ Jinzhou, Zhao, Yang Hai and Li Yongming. "China developing strategy for horizontal fracturing technology." *Oil&Gas Journal* (2013) Accessed 22 Feb 2014. <http://www.ogj.com/articles/print/volume-111/issue-7/drilling-production/china-developing-strategy-for-horizontal-fracturing.html>

¹⁴⁸ Daly, John. "It's Official - China Embraces Oil Shale and Fracking." *OilPrice*, 2 September, 2012.

¹⁴⁹ Cges.co.uk. "China's oil demand to 2020."

¹⁵⁰ Slideshare.net. "Oil Security 2025: U.S. National Security Policy in an Era of Domes...." 2014. <http://www.slideshare.net/IRSmarrt/oil-security-2025-us-national-security-policy-in-an-era-of-domestic-oil-abundance> (accessed 21 Feb 2014).

¹⁵¹ Hornby, Lucy and Ed Crooks. "Oil and gas: A new frontier - FT.com." *Financial Times*, 7 January, 2014.

¹⁵² Cges.co.uk. "China's oil demand to 2020."

will increase incentive to frack.¹⁵³ Unconventional gas prices, which had been held at artificially low prices by the NDRC, discouraged production in the past. The government loosened regulations in 2011, and gas prices were increased again in 2013. The Chinese government claims they will continue to take deregulatory steps in order to move toward international parity. In the long term these reforms will “lead to full deregulation of the natural gas market.”¹⁵⁴

The government has also worked to make gas development more competitive by officially labeling shale gas as an independent mining resource. Shale gas was previously considered a natural resource. This opened up shale gas to private and foreign investors in January of 2012 and “removed the big 3 state owned enterprises exclusively over shale gas”¹⁵⁵ to allow private companies into the industry.

The government has also pursued other measures to encourage shale gas exploration by deregulating pipelines to increase pipeline construction. It took the first steps toward deregulation in 2013.¹⁵⁶ All long-distance natural gas pipelines have been owned and operated by the three major national oil companies;¹⁵⁷ however there has been “more diversified investment as the government continues to encourage market competition.”¹⁵⁸

The Chinese government also offers fiscal incentives to those producing unconventional gas by offering production subsidies for shale gas, and a VAT rebate policy is expected to be announced once large-scale production starts.¹⁵⁹

Additionally, China’s shale industry has received international support; most notably from the US through the US-China shale gas initiative. This initiative is discussed in more detail in Chapter 11.

[Challenges]

Despite efforts, China currently faces several above- and below-ground challenges that hinder shale extraction. The most significant are China’s geology and water shortages.

China’s shales have proven to be challenging to frack, partially because of its particular geology.¹⁶⁰ Chinese shales tend to be found deeper underground: between 3,000 to 5,000 meters deep. US shales, by comparison, have average depths of 1,000 to 3,000 meters.¹⁶¹ Wells are thus more costly to drill and also require more water.¹⁶²

Additionally, Chinese shales tend to have higher clay content, making them less brittle and thus more difficult to frack.¹⁶³ Because China’s shales differ so greatly from American shale,

¹⁵³ Yang et al "China’s Fuel Gas Sector"

¹⁵⁴ Suttikulpanich, Duke, Ying Wang and Akash Gupta. "China Shale Gas." Standard Chartered, 2013. 31

¹⁵⁵ PIM LTD “China’s Shale” 21

¹⁵⁶ Suttikulpanich, et al. "China Shale Gas." 9

¹⁵⁷ Yang et al "China’s Fuel Gas Sector."

¹⁵⁸ Suttikulpanich, et al. "China Shale Gas." 45

¹⁵⁹ Ibid, 48

¹⁶⁰ Hornby et al "Oil and gas"

¹⁶¹ Shale Oil and Gas Resources. "IHS: Shale Oil Boom Could Go Global." 2013. <http://shalestuff.com/controversy-2/ihs-shale-oil-boom-global/article09282> (accessed 23 Feb 2014).

¹⁶² Aizhu, Chen. "China's ragtag shale army a long way from revolution." *Reuters*, March 11, 2013.

¹⁶³ Breitling Energy Corporation "China’s shale gas supremacy"

China cannot simply import methods and technologies that have been successful there. All of this makes fracking much more expensive; an estimated 10 times more expensive than in the US.¹⁶⁴

China's shale basins are also largely located in areas which are tectonically complex, some which are seismically active, thus more prone to earthquakes, which could possibly be exacerbated by fracking activity.¹⁶⁵ The Sichuan Basin, for instance, is one of the nation's most seismically active provinces.¹⁶⁶ In 2008 the Wenchuan earthquake killed 70,000 people, and some argue that fracking played a role in this.¹⁶⁷ In addition, most shale resource deposits are located in the southwest where the area is mountainous with little existing infrastructure necessary for the transport of gas and oil.¹⁶⁸

Water insecurity is a national challenge in China; as a result, one of companies' most pressing concerns is having enough fracking water.¹⁶⁹ Over two-thirds of cities in China suffer water shortages; it has only about 2,100 cubic meters of renewable water resources per person. By comparison the U.S. has 17,000 cubic meters per person.¹⁷⁰ The high level of pollution in Chinese rivers complicates this further as fracking requires clean water.¹⁷¹

China's fracking efforts have been further hindered by above-ground factors. Chinese state-owned companies (CNOOC, PetroChina, Sinopec) lack the technical experience and the know-how necessary to effectively pursue fracking. This "could prove to be the greatest hurdle to overcome."¹⁷²

[Future Prospects]

Overall, China's shale future looks promising. The government has set ambitious shale gas goals in their most recent five-year plan to produce 60-100 billion cubic meters of shale gas by 2020, and 6.5 billion cubic meters by 2015.¹⁷³ There is controversy over whether this goal is plausible or not; nevertheless it demonstrates the significant political drive that is pushing the industry forward.

The country's third shale block auction will take place some time in 2014 and it is not yet known whether the government will decide to allow foreign companies to take part in the

¹⁶⁴ Aizhu, "China's ragtag shale"

¹⁶⁵ EIA, *China* 14

¹⁶⁶ Haas, Benjamin. "China Fracking Quake-Prone Province Shows Zeal for Gas." *Bloomberg*, 1 August, 2013.

¹⁶⁷ Biello, "Can Fracking Clean"

¹⁶⁸ EIA, *China* 8

¹⁶⁹ Barbee, Darren "The Great Wall: China Struggles to Emulate US Shale Success." *Unconventional Oil and Gas Center*, 31 December, 2013.

¹⁷⁰ Breitling Energy Corporation "China's shale gas supremacy"

¹⁷¹ Bridges, Brianna. "Demand Chemical Plant Clean Up Pollution in China's Longest River." *Forcechange.com*, 2014.

¹⁷² Ogfj.com. "Global update on shale development." 2014. <http://www.ogfj.com/articles/print/volume-10/issue-9/features/global-update-on-shale-development.html> (accessed 26 Feb 2014).

¹⁷³ Jian-Chun, Guo and Zhao Zhi-Hong. "China vigorously promoting shale gas exploration, development." *Oil&Gas Journal* (2014) Accessed 22 Feb 2014. <http://www.ogj.com/articles/print/vol-110/issue-3/exploration-development/china-vigorously-promoting.html>.

bidding.¹⁷⁴ This would simplify the process and likely attract more investors. Whether or not this happens, however, “exploration of shale gas is picking up [speed]”¹⁷⁵ among companies that are already involved in China.

As discussed above, China faces many challenges. “From first identification through to significant commercial production of any gas resource normally takes ten years. China’s shale is likely to take more than ten years because of all these impediments.”¹⁷⁶ Thus, although the intention to move forward with shale fracking and progress is clear, it will likely take a decade or more before levels of shale gas extraction are high enough for commercial production.

Conclusion

Global potential for shale oil (and gas) has been assessed at over 300 billion bbls, and 8,000 trillion cubic feet of technically recoverable reserves. Given the rapid increases in well recoveries that have come from continued adjustments and innovations in fracking technology, these figures may well prove to be conservative. Thus, the feasibility for extracting shale resources is high, yet development is still in the beginning stages. It is almost certain that this technology will spread as economic incentive is high both for energy companies and countries. However further exploration and proper regulatory frameworks are needed in order to allow this to happen. In industry parlance, the main hurdles continue to exist above ground, not in the subsurface. The US’s success has also been a significant factor in the growing interest in global shale resources, putting the US in a unique position to act as a leader in shale oil and hydraulic fracturing development.

¹⁷⁴ Linklaters.com. "Linklaters - Year to Come – China Law in 2014." 2014. <http://www.linklaters.com/Publications/year-review-year-to-come/2013-2014/Pages/Year-Come-Chinese-Law-2014.aspx> (accessed 21 Feb 2014).

¹⁷⁵ Riaz, Saleha. "Future of shale gas in China is promising, according to new analysis." *Shale Energy Insider*, 14 January, 2014.

¹⁷⁶ Richardson, John. "US Support For Big”

PART III

Environmental Concerns and Responses

Part III focuses on the potential environmental and health risks that result from the fracking industry, contextualizing these issues within the analysis of anti-fracking groups and scientific biases. Chapter Six introduces the controversy surrounding the potential health and environmental impacts of fracking through the examination of water issues associated with acquisition, chemical mixing, well injections, flowback water and wastewater treatment and disposal. The chapter discusses air pollution from flaring and the increase in carbon dioxide emissions, referencing climate change. The health impacts on humans and animals are also examined. Chapter Seven introduces the economic, social, environmental, and health risks associated with the transportation of shale oil through the analysis of three primary transport methods: trucking, railway, and pipelines. The chapter touches on the debate over the proposed Keystone XL pipeline that will link Canadian tar sands and crude shale oil from the Bakken to refineries in the US. Chapter Eight addresses public opposition and government responses to the anti-fracking movement. The chapter examines the goals of the anti-fracking movement while showing how media has played an important role in influencing and mobilizing the movement. Chapter nine provides a detailed look at biases within the scientific community and how seemingly apolitical scientific experiments and results are frequently heavily influenced through monetary compensation or other means. The chapter not only examines scientific controversy within fracking, but also within other energy sources, such as nuclear and conventional oil drilling. The chapter concludes by examining the role that media plays in perpetuating and sustaining scientific through a news industry constructed around rhetoric and sound bites rather than in-depth, factual reporting.

Chapter Six

AIR AND WATER POLLUTION

Allison Ashmore

Abstract

Through the examination of studies and reports, this chapter focuses on the potential environmental impacts associated with air and water pollution resulting from fracking. First off, the informational void within this sector and how it comes to play when addressing environmental issues is discussed. While disagreement still remains over the potential environmental impacts, countless recent studies have proven that there is, in fact, great potential for environmental detriment as a result of fracking. This chapter first examines water issues within the five steps of fracking: water acquisition, chemical usage, well injection, flowback water, and wastewater treatment and disposal. The latter also focuses on deep well injection, treatment plants, recycling, and fracking-induced earthquakes. Next, this chapter will assess the potential for air pollution, covering CO₂, methane, VOCs, and diesel emissions, flaring, and climate change. Lastly, this chapter will cover the potential health effects from air and water pollution on humans, animals and crops.

Introduction

Controversy over the effects of fracking has risen in parallel with the rapid, large-scale development of shale oil in the US. Of particular concern are water and air impacts on the environment. Much of the debate surrounds the extent to which air and water quality has actually been affected. Those making claims that there have been serious impacts include landowners, local officials, environmental activists, and a selected number of university scientists who have performed recent water-quality studies of varying scale and type. Opposing many of these claims are scientists from the fracking industry, state and federal agencies, and academia as well.

Environmental concerns derived from fracking can be studied in a wide array, including analysis of existing data, scenario evaluations, laboratory studies, toxicity assessments, and case studies.¹ Not all information derived from these research techniques can be used to draw concrete conclusions regarding potential environmental impacts. However, despite opposition, especially from the fracking industry, concrete conclusions about environmental impacts from fracking strongly suggest that fracking does indeed pose numerous environmental concerns from water acquisition, wastewater treatment, water contamination, air pollution, and the potential health risks resulting from those.

¹ United States Environmental Protection Agency. "Study of the Potential Impacts of Hydraulic Fracturing on Drinking Water Resources Progress Report." Washington DC: 2012.

Section I: Difficulty With Findings and Agreements

Environmental issues associated with fracking are subjected to heated debates, mainly due to the lack of confirmed evidence. Although fracking technology itself is not relatively new, it has never before been done on such a massive scale and is constantly progressing, thus, “understanding the longer-term and cumulative effects of shale gas extraction on ecosystems landscape, terrestrial, and aquatic, water resources, and air quality is an area requiring more attention”² is important but poses difficulty in evaluating potential effects. Knowledge of the long-term and cumulative impacts will allow a deeper understanding of not only the key drivers of environmental impacts from fracking, but also what can be altered and improved within the industry as well. Due to non-disclosure agreements and proprietary secrecy over chemicals used for fracking fluids, it has remained difficult for scientists and researchers to conclusively link environmental issues with fracking.³

Besides non-disclosure agreements, there are many other factors that come into play making linkage between fracking and environmental impacts difficult. A lack of consistent research is also due to the limited number of years that intensive fracking has been in use, the difficulty in proving direct correlation between cases, and challenges in studying health impacts such as: lack of unidentified unique health indicators, latency of effects, limited baseline and monitoring data, and low population densities in many affected areas.⁴ Some say that it is not yet possible to assess data on long-term environmental and health impacts, however, an increasing number of case studies, agency documents, and environmental models suggest fracking does, in fact, pose environmental and health risks.⁵ While many anti-fracking oppositional groups are demanding change, scientists and researchers are steadily working on assessing and determining risks. The fracking industry, in response, is developing methods to minimize those risks, and regulatory agencies are developing guidelines and policies to ensure those risks are minimized.⁶

The production industry is countering the argument that there is a great potential for environmental risk, arguing that fracking has been conducted for decades, with more than a million wells and without any major environmental or health disaster.⁷ However, it is worth noting that the process has been significantly modified for multi-staged application in long-reach

² Rebecca Hammer and Jeanne VanBriesen, *In Fracking's Wake: New Rules are Needed to Protect Our Health and Environment from Contaminated Wastewater*. D:12-05-a. [report] Natural Resources Defense Council, 2012, 71.

³ Environment.yale.edu. 2014, *Fracking Outpaces Science on Its Impact* | *EnvY: The Journal of the Yale School of Forestry and Environmental Studies*, [online] Available at: <http://environment.yale.edu/envy/stories/fracking-outpaces-science-on-its-impact> [Accessed: 23 Jan2014].

⁴ American Public Health Association, “*The Environmental and Occupational Health Impacts of High-Volume Fracturing of Unconventional Gas Reserves*,” 2012.

⁵ Apha.org. “American Public Health Association: Policy Statement Database.” 2014. <http://www.apha.org/advocacy/policy/policyserach/default.htm?id=1439> (accessed 9 Feb 2014).

⁶ Mike Mitka, Rigorous evidence slim for determining health risks from natural gas fracking. *JAMA*, 307 (20), 2012, 2135-2136.

⁷ Ibid.

(>5,000 ft) horizontal wells. As used in tight oil and gas reservoirs, including shale, current fracking technology is using considerably more water, more proppant, a larger total volume of chemicals and components of fracking mixtures, and is therefore forced to deal with a larger amount of waste that must be appropriately treated and disposed.

This indicates that there is a demand, now more than ever, for conclusive, reliable scientific data to assess the key drivers and potential environmental impacts. Without this reliable data, industry personal cannot make statements that say that fracking is environmentally safe. Research is beginning to prove otherwise.

It is important to note that for our purposes, and because of the lack of confirmed evidence, potential impacts of fracking on the environment will be addressed in this report.

Section II: Water Issues

The vast array of potential effects arising from fracking-related water issues is possibly the greatest environmental concern of fracking. Once freshwater is obtained and used for the fracking operation, it becomes wastewater and must be taken care of in a variety of ways. For final disposal, well operators must recycle the wastewater, inject it into underground wells, discharge it to nearby surface water, or transport it to wastewater treatment facilities. This polluted wastewater can potentially threaten the health of drinking water supplies, ground and surface water, and ecosystem and human health.

Regarding environmental impacts, this report will discuss five main focuses of water usage in fracking, including:

- Water acquisition
- Chemical mixing
- Well injection
- Flowback and produced water
- Wastewater treatment and disposal

In response to public concerns and at the urgency of Congress, the EPA is currently conducting extensive research on drinking water resources based on these five stages in the fracking water cycle. This research project will help assess how freshwater may be adversely affected by fracking. The progress report describes 18 projects that are underway to help address questions raised by each stage in the fracking water cycle. The study was among the first by the government to directly link the possibility of fracking with groundwater pollution, yet the report explicitly states that conclusions from this report cannot be made at this time.⁸ Future progress of

⁸ United States Environmental Protection Agency. “*Study of the Potential Impacts of Hydraulic Fracturing on Drinking Water Resources Progress Report.*”

the study and a final draft of the report will set the stage for new regulations and policy regarding fracking, which will require the industry to focus a greater attention on environmental risk prevention.

[Freshwater Acquisition]

The energy boom is increasing demand for water supplies that are already under pressure from a growing population and increasing droughts. Concerns over water depletion and shortage are increasingly important when considering that there are many different factors that threaten water security, including climate change and thus shifting weather patterns. Water depletion and shortage is especially concerning because water can be diverted from other users such as farmers, households and manufacturing plants. Water can be acquired from numerous other places including: surface water, groundwater, municipal water supplies, treated wastewater from municipal and industrial treatment facilities, power plant cooling water, or recycled produced water and/or flowback water.⁹ A fracking operation's fluid is composed of around 90% of water.¹⁰ The operation can use anywhere from around three to eight million gallons of freshwater,¹¹ depending on the geographic shale formation. Wells in Texas's Eagle Ford shale can even use up to 13 million gallons,¹² though such volumes are becoming rare. Thus, the amount of freshwater used can lead to potential environmental impacts regarding water security such as water depletion, especially in arid and highly populated regions that are already facing water shortages issues.

Since 2011, fracking has consumed nearly 100 billion gallons of water to drill over 39,000 shale oil and gas wells. Around 36% of those 39,000 wells were in areas already experiencing groundwater depletion,¹³ meaning that current water issues were not of importance when the drilling process began. Since 2011, 55% of fracking wells have been in drought-stricken areas and close to half were in regions under high or extremely high water stress.¹⁴ For example, in Colorado, 97% of wells were drilled under high or extremely water stressed regions. In California, 96% of wells were also in water stressed regions.¹⁵ Texas has been facing a drought since 2010, and a study by the University of Texas found that the amount of water used for fracking has doubled between 2008 and 2011 and will likely increase.¹⁶ All of these examples indicate that there was already a great amount of pressure on water supplies in many fracking-

⁹ United States Environmental Protection Agency, "Study of the Potential Impacts of Hydraulic Fracturing on Drinking Water Resources Progress Report," 13.

¹⁰ United States Environmental Protection Agency, "Study of the Potential Impacts of Hydraulic Fracturing on Drinking Water Resources Progress Report," 14.

¹¹ Tamara Thompson, *Fracking* (Farmington Hills: Greenhaven Press, 2013), 86.

¹² Alex Prud'homme, *Hydrofracking* (Oxford: Oxford University Press, 2014), 73.

¹³ Julie Schmit, "Report: Fracking raising water supply worries," *USA Today*, 5th Feb, 2014.

¹⁴ *Ibid.*

¹⁵ *Ibid.*

¹⁶ Prud'homme, *Hydrofracking*, 74.

intensive regions before the amount of water used in fracking was taken into account, in addition to there being a lack of policy pertaining to water acquisition.

The industry, in response, says that this is not as alarming of an issue as it sounds. In 2011, all shale wells drilled and completed used 135 billion gallons of water, which is only 0.3% of the total freshwater consumption, according to an analysis by *TheEnergyCollective.com*. To put this into perspective, they compared it to the amount of freshwater golf courses used in 2011: 0.5% of US water supplies.¹⁷ Despite the fact that the amount of freshwater used for fracking may only be a minimal percentage of the total US water consumption, it is problematic that specific regions are not taken into consideration, like the regions that were already facing water insecurity. If the industry looks at the minimal usage as a whole, it does not focus on the specific local regions that are facing water shortages before, during, and after fracking. Freshwater, in this case, needs to be regarded as a local issue and not just a national figure.

[Chemical Mixing]

After the acquired water is delivered to the well site, chemical additives and proppant are mixed with the water to create the fluid used for fracking. Chemicals are essential because they are used to thicken or thin fluids, improve fluid flow, prevent corrosion of the piping, or kill bacteria.¹⁸ Once the fracking fluid is used, it becomes wastewater, which contains numerous agents that are of toxicological concern and may possibly pose many health risks if fluids are released to surface and groundwater. Two types of mixtures are of concern: mixture of fracking compounds and in the flowback fluids that not only contain fracking compounds, but hydrocarbons, dissolved minerals, brine constituents, and naturally occurring radioactive materials.¹⁹ Although chemicals used in fracking fluids usually make up less than 1% of the composition, they can add up to as much as 40,000 gallons.²⁰

In a study by the Committee on Energy and Commerce, fourteen leading oil and gas service companies were asked to disclose the types and volumes of the fracking products used in fluids and the chemical contents of those products between 2005 and 2009. The information released shows that over 2,500 fracking products contained 750 chemicals and other components and used over 780 million gallons of fracking products, excluding water. Some components are entirely harmless, like salt and citric acid, while others are extremely hazardous and include known toxins such as benzene and lead. The most widely used chemical in 2005-2009 was

¹⁷ Prud'homme, *Hydrofracking*, 64.

¹⁸ Fracfocus.org. "Chemical Use In Hydraulic Fracturing | FracFocus Chemical Disclosure Registry." 2014. <http://fracfocus.org/water-protection/drilling-usage> (accessed 2 Feb 2014).

¹⁹ Bernard Goldstein. "The Public Health Implications of Unconventional Gas Drilling." Speech, February 1, 2012, Committee on Science, Space, and Technology. <http://science.house.gov/sites/republicans.science.house.gov/files/documents/hearings/HHRG-112-SY20-WState-BGoldstein-20120201.pdf>

²⁰ Thompson, *Fracking*, 77.

methanol, which was used in 342 products, and is a hazardous air pollutant and a candidate for potential regulation under the Safe Drinking Water Act.²¹ Out of the chemicals used, 29 chemicals are used in over 650 products that are either known or possible human carcinogens, regulated under the Safe Drinking Water Act, for their risks to human health, or listed as hazardous air pollutants under the Clean Air Act.²² These figures demonstrate that, even without extensive research, the fracking industry handles countless chemicals and because of this, they need to be carefully monitored and handled in order to assess the potential health concerns.

The Energy Policy Act of 2005, which is popularly known as the “Halliburton Loophole” is important to keep in mind when assessing the use of chemicals in fracking fluids. Essentially, it allows trade secrets within the industry and has allowed Congress to grant the fracking industry special exemptions from the Clean Air Act, the Clean Water Act and the Safe Drinking Water Act, without appropriate investigation of the potential environmental and health consequences.²³ This loophole has exempted fracking companies from disclosing chemicals used²⁴ and has thus hindered substantial progress in assessing the chemicals used and their impacts with the current regulations that are in place.

[Well Injection]

In the third stage of fracking, the pressurized fluid is injected into the well, creating cracks in order for the shale oil to be released and sent back up through the casing. The potential impacts that arise from this process include:

- Release of the fracking fluid to groundwater due to inadequate well construction and/or operation
- Movement of fluids from the formation to drinking water aquifers through local man-made structures, including abandoned wells or existing faults
- Movement into drinking water aquifers of natural substances found underground, such as metals or radioactive materials, which are released during fracking²⁵

Well failures and malfunctions are a definite concern during the well injection process. When fluids are injected underground, the migration of the fluids is not entirely predictable. Insufficient cement casing can lead to the release of chemicals at shallower depths, to

²¹ Aarik Schultz, *Hydraulic fracturing and natural gas drilling* (New York: Nova Science Publishers, 2012), 50.

²² United States House of Representatives Committee on Energy and Commerce, “*Chemicals Used in Hydraulic Fracturing*,” 2011.

²³ Prud'homme, *Hydrofracking*, 70.

²⁴ Prud'homme, *Hydrofracking*, 84.

²⁵ United States Environmental Protection Agency. “*Study of the Potential Impacts of Hydraulic Fracturing on Drinking Water Resources Progress Report*,” 9.

groundwater supply and thus closer to drinking water supplies or even to escape to the surface.²⁶ In order to prevent accidents as such from occurring, strict regulations need to be created to improve well maintenance, such as cement casing.

[Flowback and Produced Water]

In the fourth stage, pressure in the well is released and fracking fluid, formation water and shale oil flow up the well. This combination is known as flowback water. Once production begins at the well, the wastewater emerging is known as produced water.²⁷ There is concern surrounding the release of flowback to surface and groundwater, leakage from onsite storage to drinking water, and improper pit construction, maintenance, or closure. This is of concern due to flowback containing harmful chemicals and also contaminants drawn from within the earth, such as heavy metals, VOCs, salty brine, and radioactive materials. In order to minimize environmental damage, wastewater must be properly managed to reduce risk of harming the environment and health.

For example, an elevated level of Naturally Occurring Radioactive material (NORM) is typically present in produced water from fracking. The most abundant types of NORM in produced water are radium-226 and radium 228, which are produced from radioactive decay of uranium and thorium present in shale formations. Data from Marcellus Shale-produced water indicates that sometimes NORM levels are detected at higher levels above background and drinking water standards. Long-term exposure to radiation can have adverse health effects, including cancerous tumors.²⁸ This signals that produced water has the potential to release material from within the earth, such as NORM, that could potentially contaminate drinking water resources.

[Open-Air Pits/Impoundments]

Open-air pits, used to store wastewater, are prone to accidental spills and poor management and can release waste into the environment that could potentially contaminate nearby water and soil.²⁹ Evaporation is also a technique utilized to reduce the volume of wastewater for disposal. It is a widely practiced technique in arid areas where evaporation is greater than precipitation. However, it can potentially contribute to air pollution if volatile

²⁶ United States House of Representatives Committee on Energy and Commerce, “*Chemicals Used in Hydraulic Fracturing*.”

²⁷ Hammer and VanBriesen, *In Fracking’s Wake: New Rules are Needed to Protect Our Health and Environment from Contaminated Wastewater*, 13.

²⁸ Hammer and VanBriesen, *In Fracking’s Wake: New Rules are Needed to Protect Our Health and Environment from Contaminated Wastewater*, 24.

²⁹ Hammer and VanBriesen, *In Fracking’s Wake: New Rules are Needed to Protect Our Health and Environment from Contaminated Wastewater*, 57.

chemicals, such as benzene, xylene and naphthalene, are present in the wastewater that will then evaporate.³⁰

[Wastewater Treatment and Disposal]

The last step in fracking is the treatment and disposal of the wastewater. Wastewater is either disposed by underground injection, treated and disposed to surface body waters, or recycled for use in future fracking operations. There are many concerns surrounding incomplete treatment of the wastewater and therefore wastewater discharge into drinking water sources.

Underground/Deep Well Injection

The most popular process of disposing wastewater is through deep well injections in order to isolate potentially toxic water from the ecosystem and human health. It is considered to be the safest, most efficient and economical way to deal with wastewater.³¹ However, it may not always be a viable option in some locations due to the geology of the land. Despite injection wells possibly being the safest, most efficient way to dispose wastewater, there are still potential risks associated with the process. There is concern that it is possible for wastewater to escape from a disposal well into surface or groundwater.

Different types of waste are disposed in different classes of injection wells. A risk analysis by the EPA determined that injection via strictly regulated Class I hazardous waste wells is a safe and effective technology that results in low risks to the environment and human health.³² However, wastewater is currently being injected into Class II disposal wells, which are subject to fewer safety requirements and pose a greater risk of contaminating groundwater and triggering earthquakes. Injection of wastewater for disposal is regulated as part of the Underground Injection Control (UIC) section of the Safe Drinking Water of 1974; UIC Class II wells are specific to injection of brines and other fluids associated with oil production.³³ Loopholes such as these have allowed the industry to practice unsafe methods without making further progress in the safety of wastewater disposal.

Treatment plants: Disposal to Surface Body Waters

Wastewater that is not disposed of underground is sent to treatment plants. These plants can discharge harmful levels of radiation and toxic substances into local waterways. This poses a

³⁰ Hammer and VanBriesen, *In Fracking's Wake: New Rules are Needed to Protect Our Health and Environment from Contaminated Wastewater*, 25.

³¹ Committee on Energy and Natural Resources, *Shale Gas and Water Impacts*, (S. Prt. 112), Washington: Government Printing Office, 2012, (YREN2:S.HRG. 112-247).

³² Hammer and VanBriesen, *In Fracking's Wake: New Rules are Needed to Protect Our Health and Environment from Contaminated Wastewater*, 6.

³³ Hammer and VanBriesen, *In Fracking's Wake: New Rules are Needed to Protect Our Health and Environment from Contaminated Wastewater*, 18.

threat to aquatic and human life because some plants, even specialized facilities, are not fully capable or equipped to handle fracking contaminants.³⁴

Pennsylvania, known as the heart of the US fracking boom, has had a numerous amount of drilling accidents and spills, demonstrating that, despite regulations, accidents commonly happen.³⁵ The following example will examine one study that was conducted in the heart of the boom.

At the Josephine Brine Treatment Facility in Indiana County, Pennsylvania, which processes flowback water from Marcellus Shale gas extraction operations, researchers from the Center for Healthy Environments and Communities found elevated levels of radioactivity in Blacklick Creek where treated fracking wastewater is released. Researchers collected sediment samples downstream from the facility, and found that radium levels were 200 times greater in the samples than those collected upstream from the plant. Other contaminants included barium, bromides, benzene, chlorides, magnesium, sulfate and pH.³⁶ Despite the treatment process, treated wastewater that is being released into waterways still contains a substantial amount of toxins. This indicates that plants are not facing strict regulations pertaining to the treatment process of fracking wastewater and events such as this will continue to happen without strict regulations in place.

From the samples gathered, it was noticed that barium had a concentration 14 times the EPA maximum concentration limit in drinking water. Strontium was over 43, 51.7 and 97.9 times the derived drinking water minimum risk level (MRL) for intermediate exposures to adult men, adult women and children, respectively.³⁷ Benzene, a known carcinogen, was 0.6, 1.2 and 1.5 times the derived drinking water MRL for chronic exposures to adult men, women and children. Barium is a metal that has been linked with increases in blood pressure³⁸ and strontium, also a metal, has been linked to bone cancer and leukemia.³⁹ Despite standards and despite the potential health risk in ingesting these chemicals, drinking water was still highly contaminated, indicating that proper treatment and regulations were not in place.

³⁴ Schultz, *Hydraulic fracturing and natural gas drilling*, 95.

³⁵ Natural Resources Defense Council, *Five Primary Disposal Methods for Fracking Wastewater All Fail to Protect Public Health and Environment*, [report] New York, 2014.

³⁶ Conrad D Volz, Kyle Ferrar, Drew Michanowicz, Charles Christen, Shannon Kearney, Matt Kelso, and Samantha Malone, *Effluent from Pennsylvania Brine Treatment Inc., Josephine Facility: Implications for Disposal of Oil and Gas Flowback Fluids from Brine Treatment Plants*, [report] University of Pittsburgh Graduate School of Public Health, 2011.

³⁷ Volz, Ferrar, Michanowicz, Christen, Kearney, Kelso, and Malone, *Effluent from Pennsylvania Brine Treatment Inc., Josephine Facility: Implications for Disposal of Oil and Gas Flowback Fluids from Brine Treatment Plants*.

³⁸ Water.epa.gov, "Basic Information about Barium in Drinking Water | Basic Information about Regulated Drinking Water Contaminants | US EPA," 2014. <http://water.epa.gov/drink/contaminants/basicinformation/barium.cfm> (accessed 08 Feb 2014).

³⁹ Epa.gov, "Strontium | Radiation Protection | US EPA," 2014. <http://ww.epa.gov/radiation/radionuclides/strontium.html> (accessed 08 Feb 2014).

The implication of having these concentrations beyond the maximum limit poses a greater risk to human health, through ingestion of drinking water resources, inhalation, and dermal exposure at the site. Blacklick Creek has also been classified as a trout stocking stream,⁴⁰ meaning that it has the potential to impact the ecosystem as well. Moreover, plants like Josephine Brine are not fully equipped and do not face strict regulations to make a change in the treatment process. This is just one example, where, although treatment removes a substantial amount of radioactivity, it does not necessarily remove all contaminants.

Recycling

Recycling wastewater to be used for future fracking jobs has the greatest potential for improvement in environmental conditions. Recycling avoids all other wastewater treatment methods that have potentially negative consequences while also conserving freshwater. Companies are beginning to pursue recycling innovations and new cutting-edge approaches and technology is being used to improve the efficiency of recycling fracking wastewater as discussed in Chapter 12. However, the process has proven difficult, as many oil companies have not yet felt the urge to undergo extensive recycling practices. A recent study in the Eagle Ford suggests that oil companies are not dedicating much attention to recycling, despite ongoing drought conditions because recycling is much more expensive than other practices, such as injecting wastewater in disposal wells.⁴¹ In another study, it was estimated that in the past few years, only 5-10% of water was recycled in the Barnett Shale and close to 0% in the Texas-Haynesville Shale.⁴² It was concluded that overall, recycling is still a small fraction of total water use in fracking,⁴³ and the low level of recycling may be based on economics relative to other options such as deep well injection.⁴⁴ In order for oil companies to increase recycling practices, technology will have to improve, cost will have to decrease, and incentives will have to be given to make recycling a more economical practice.

Fracking-Induced Earthquakes

Fracking-induced earthquakes are also potential environmental concerns. They can either be induced as stimulation for tight shale formations or by disposal of fracking wastewater in deep well injections. The disposal deep underground (built-up water pressure) weakens the surrounding rock and causes friction along fault lines that can trigger these earthquakes. As the

⁴⁰ Volz, Ferrar, Michanowicz, Christen, Kearney, Kelso, and Malone, *Effluent from Pennsylvania Brine Treatment Inc., Josephine Facility: Implications for Disposal of Oil and Gas Flowback Fluids from Brine Treatment Plants*.

⁴¹ Jim Forsyth, "Report: Fracking Fails to Recycle Huge Amounts of Water," *WOAI Local News*, 6th Feb, 2014.

⁴² Jean-Philippe Nicot and Bridget R. Scanlon, "Water Use for Shale-Gas Production in Texas, US," Bureau of Economic Geology, Jackson School of Geosciences, University of Texas, Austin, 2012, 11.

⁴³ Jean-Philippe Nicot, "Assessment of Industry Water-Use in the Barnett Shale Gas Play (Fort Worth Basin)," Bureau of Economic Geology, Jackson School of Geosciences, The University of Texas at Austin, 2014, 541.

⁴⁴ Nicot and Scanlon, *Water Use for Shale-Gas Production in Texas, US*, 11.

number of wastewater injection wells has risen since 2011, the number of earthquakes above 3.0 has surged from 50 in 2009 to 134 in 2011 according to a USGS report.⁴⁵ According to the USGS, however, only a small fraction of disposal wells have caused earthquakes large enough to be of concern. The cases that have been recorded are most notable for the amount of public concern they have raised, not necessarily the magnitude of the quake.⁴⁶ However, wastewater disposal by injection into deep wells holds a higher risk, because the practice can potentially induce larger earthquakes.

A USGS research team has linked fracking operations to a series of recent earthquakes from Alabama to the Northern Rockies.⁴⁷ According to the USGS study, published by the Seismological Society of America, the spikes in earthquakes since 2001 near fracking operations is “almost certainly man-made” and cites underground injection of drilling wastewater as a possible cause.⁴⁸

For example, central Oklahoma has experienced a massive increase in earthquakes in the past few years. The USGS found that from 1975 to 2008, central Oklahoma experienced only one to three 3.0 magnitude earthquakes per year. The number has increased to an average of 40 per year from 2009 to 2013. One specific earthquake in Oklahoma in 2011 was a magnitude 5.7 and was linked to well injection. It set off tremors felt in 17 states that destroyed 14 homes and almost 200 other buildings.⁴⁹ Scientific data signals that the drastic rise in earthquakes suggests that the fracking boom plays a major role in causing them, and although they may be relatively small, they still pose concern for possible future earthquakes as the industry expands.

Section III: Air Pollution

Along with water issues, air pollution is another key element within environmental concerns. There are concerns surrounding the increase of global temperatures and what anthropogenic causes society can minimize. Fracking increases the amount of methane emissions, VOCs, and CO₂. It adds not only to local and regional air quality concern, but also impacts climate change as well.

Diesel engines are the main source of power during a fracking process. They generate power for many different aspects of fracking including: well-pad equipment, storage tanks, drilling rigs, compressor stations, and extensive truck traffic during the operation and extraction process.⁵⁰ It is estimated that around 3,950 one-way truck trips would be necessary for just one

⁴⁵ Prud'homme, *Hydrofracking*, 89.

⁴⁶ William L. Ellsworth, Injection-induced earthquakes, *Science*, 2013, 341 (6142).

⁴⁷ Thompson, *Fracking*, 38.

⁴⁸ Ibid.

⁴⁹ Prud'homme, *Hydrofracking*, 90.

⁵⁰ Niladri Basu, Mark Bradley, Casey McFeely and Marie Perkins, “*Public Health Technical Report | Public Health and Hydraulic Fracturing in Michigan*,” University of Michigan, 2013, 16.

newly created well in New York.⁵¹ These engines emit diesel emissions that contribute to increased ozone levels and local smog, and also contain many toxins that can affect human health.

Once a well has undergone fracking, some gas, mostly methane, leaks into the atmosphere known as “fugitive emissions.” Methane can escape from broken pipes, valves or other production equipment such as drill rigs or pumps. However, fugitive emissions are hard to measure and researchers continually disagree on numbers.⁵² Methane is a concern because it is a potent greenhouse gas, 20-25 times more potent at trapping heat within the atmosphere than CO₂.⁵³

A study released in 2013 in Fort, Worth, Texas found air pollution levels above state limits at five sites, and reported visible emissions at 296 of 388 gas well sites.⁵⁴ In Colorado, hydrocarbon emissions from drilling have been high, where researchers found that twice the amount of methane was seeping into the atmosphere from oil and gas activity than originally expected.⁵⁵ Expected or unexpected, fracking sites potentially contribute to air pollution in a variety of ways, whether it be more localized pollution or greenhouse gas emissions that contribute to larger effects such as climate change.

Air pollution is also a well-site concern because it can potentially be an occupational hazard to extraction workers. The National Institute for Occupational Safety and Health (NIOSH) collected air samples at 11 fracking sites in five different states including: Arkansas, Colorado, North Dakota, Pennsylvania and Texas, to evaluate worker exposure to crystalline silica. Crystalline silica has been determined to be an occupational lung carcinogen. NIOSH found levels that exceeded the occupational health criteria at each of the 11 sites.⁵⁶ Based on the results, workers are potentially exposed to inhalation health hazards from dust containing silica, which can cause silicosis. This reinforces the fact that air pollution levels need to be further understood, not just on a local and global scale, but at the work site as well to ensure worker safety.

The EPA has expertise in the measurement and modeling of air pollutants from sources during all phases including: extraction, processing, storage and distribution. Currently, the EPA is using mobile and fixed air monitoring systems to estimate local, regional and national exposures to air pollutants, which shows that the government is taking steps to improve air

⁵¹ Basu, Bradley, McFeely and Perkins, *Public Health Technical Report | Public Health and Hydraulic Fracturing in Michigan* 16.

⁵² Prud'homme, *Hydrofracking*, 91.

⁵³ Epa.gov. “Methane Emissions | Climate Change | US EPA.” 2014.
<http://epa.gov/climatechange/ghgemissions/gases/ch4.html>. (accessed 8 Feb 2014).

⁵⁴ Thompson, *Fracking*, 36.

⁵⁵ American Public Health Association, “*The Environmental and Occupational Health Impacts of High-Volume Fracturing of Unconventional Gas Reserves*,” 2012.

⁵⁶ Osha.gov, “HAZARD ALERT – Worker Exposure to Silica during Hydraulic Fracturing,” 2014,
https://osha.gov/dts/hazardalerts/hydraulic_frac_hazard_alert.htm | (accessed 11 Feb 2014).

quality. The EPA plans to impose new regulations limiting air pollution caused by fracking in 2015.⁵⁷ With more studies and new regulations in the future, air pollution has the potential to be minimized.

[Flaring]

A very common practice in oil and gas exploration and operations is flaring, which is the controlled burning of natural gas and is possibly the greatest concern regarding air pollution resulting in fracking. Flaring is used for a number of reasons. One, after a shale oil or gas well is drilled and fracked, a temporary flare is used during the well production testing in order to determine the flow, pressure and composition of the gas or oil from the well. Second, it can be used as a safety device when the piping becomes over-pressured. Third, flaring is used to manage small volumes of waste gas that cannot be efficiently captured and returned to the system.⁵⁸

Large-scale flaring occurs frequently in the Bakken shale region due to the fact that the shale contains high amounts of oil. North Dakota lacks adequate gathering pipelines and processing plants to transport and process the gas from the wells, therefore companies frequently turn to flaring.⁵⁹

Flaring is environmentally concerning because pure natural gas is composed of mostly methane. Along with methane, there is also a concern about other VOC's and CO₂ from operations as well. Although flaring natural gas produces less greenhouse gas emissions than releasing it directly into the atmosphere, it is still environmentally damaging.⁶⁰ Gas flaring releases around six million tons of CO₂ into the atmosphere each year, which is equivalent to three medium-sized coal plants.⁶¹ Around 30% of gas flowing out of the wells has been burned due to lack of gas-gathering lines that connect oil wells to processing plants.⁶² The amount of gas flared from January-July was up nearly a quarter over the same period in 2012, averaging at 280 cubic feet per day. In North Dakota, producers have flared around 32% of natural gas produced this year.⁶³

Total flaring volumes will continue to rise above the set 2012 levels up until 2020 unless the percentage of flaring is reduced from its current level to below 21%.⁶⁴ However, a task force

⁵⁷ Yosemite.epa.gov, "EPA Issues Updated, Achievable Air Pollution Standards for Oil and Natural Gas," 2014, <http://yosemite.epa.gov/opa/admpress.nsf/bd4379a92ceceec8525735900400c27/c742df7944b37c50852579e400594f8f!OpenDocument> (accessed 10 Feb 2014).

⁵⁸ Environmental Protection Agency, *Understanding the Basics of Gas Flaring*, [report] Columbus, 2012.

⁵⁹ Ibid.

⁶⁰ Ryan Salmon and Andrew Logan, *Flaring Up: North Dakota Natural Gas Flaring More Than Doubles In Two Years*, [report] Boston: Ceres, 2013, 2.

⁶¹ Clifford Krauss, Industry in North Dakota to Cut Flared Natural Gas, *New York Times*, 29th Jan, 2014.

⁶² Ibid.

⁶³ Justin Jacobs, Gas Flaring Complicates Bakken Oil Boom, *Petroleum Economist*, 2013.

⁶⁴ Salmon and Logan, *Flaring Up: North Dakota Natural Gas Flaring More Than Doubles In Two Years*.

representing hundreds of companies in North Dakota have pledged to capture almost all natural gas by the end of the decade. In order to do so, they suggested stricter regulations that would require gas-capture plans before filing for a drilling permit as well as constructing gas-gathering pipelines and processing plants.⁶⁵

The EPA has established new “green completion” rules in 2012, in other words, reduced emission completion, in order to reduce air pollution. The rules require fracking companies to capture natural gas at the wellhead rather than flaring it or releasing it into the atmosphere. However, the EPA has allowed the industry to delay full implantation until 2015,⁶⁶ thus hindering substantial progress.

[Climate Change]

Within a broader outlook, fracking for shale oil has the capability to directly affect climate change. It is important to address how fracking and climate change may be directly correlated on a more globalized scale. The abundance of shale oil that is currently being produced is extending the use of fossil fuels that will inevitably impact climate change. All components of fracking such as the extraction process, refining, transportation, and the future consumption of shale oil are all factors in contributing to climate change because each one adds to the release of methane and CO₂ into the atmosphere.

A Cornell study suggested that there has been a significant increase in atmospheric methane, that fracking releases around 8% of methane into the atmosphere, and that all methane will contribute to 44% of global warming.⁶⁷ This provides another insight on how particularly difficult it is to assess the long-term impacts such as climate change. It shows how critical it is to conduct more research and collect more data to focus on the long-term impacts of fracking as well as short-term.

Experts have found that another 15 years of failure to limit CO₂ emissions could make the problem of climate change virtually impossible to significantly reduce the impact of, even with current technologies.⁶⁸ If the fracking industry and the fossil fuel industry as a whole do not practice methods to reduce these impacts and do not comply with regulations, the future impact on climate change will be significant.

⁶⁵ Krauss, Industry in North Dakota to Cut Flared Natural Gas.

⁶⁶ Prud'homme, *Hydrofracking*, 109.

⁶⁷ Stacey Shackford, “Natural gas from fracking could be ‘dirtier’ than coal, Cornell professors find,” *Chronicle Online*, 2011.

⁶⁸ Intergovernmental Panel on Climate Change, “*Climate Change 2013 The Physical Science Basis, Working Group I Contribution to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*,” New York: Cambridge University Press, 2013.

Section IV: Potential Health Impacts

Studies have begun to show that exposure to fracking operations are possibly linked to causing a wide array of health issues in humans. It is also possible that fracking can be linked to the death, illness and reproductive issues in many different types of animals including issues related to respiratory failure, circulatory collapse and exposure to contaminated water. Along with humans and animals, crops are also at risk. Despite the concern, there are many uncertainties about the specific types of exposures and resulting health impacts that are associated with fracking. The long-term health effects are not completely certain and cannot be entirely proven due to the difficulty of long-term assessment, non-disclosure of chemicals and other factors previously discussed. It is important to assess these risks as more than 15 million Americans live within a one-mile radius of a well.⁶⁹ Many studies near fracking sites have discovered water contaminated by methane, arsenic and other chemicals linked to infertility, birth defects and cancer.⁷⁰

For example, a study by the National Institute of Environmental Health Sciences in Colorado found that mothers living near fracking wells were around 30% more likely to give birth to newborns with congenital heart defects. It was noted, however, that correlation does not necessarily imply causation, and more testing in other areas is necessary before forming conclusions.⁷¹ This is a progressive step towards hypothesizing that there is a strong correlation between fracking and human health effects.

In a second example, in Garfield County, Colorado, VOC emissions increased 30% between 2004 and 2006 during the same time where there was an increase in health complaints from local residents.⁷² There are countless stories such as these that span from around the country, however, few, if any, epidemiological studies have been conducted and have been able to prove that fracking causes these specific health problems.

Some chemicals such as toluene, xylenes and benzene used in fracking are suspected of causing tumors and other mutations in humans. They are known to cross the placenta, raising the possibility of fetal exposure. A study conducted in Colorado shows that endocrine-disrupting chemicals are found in higher concentrations in the groundwater near fracking sites. Around 40% of chemicals added to the fracking mixture are known endocrine disruptors.⁷³ The endocrine

⁶⁹ Russell Gold and Tom McGinty. "Energy Boom Puts Wells in America's Backyards- Hydraulic Fracturing Largely Driving Transformation of the Nation's Landscape." *The Wall Street Journal*, 25th, Oct, 2013.

⁷⁰ Renee Lewis, New study links fracking to birth defects in heavily drilled Colorado, *Aljazeera America*, 30th Jan, 2014.

⁷¹ Lisa M. McKenzie, Ruixin Guo, Roxana Z. Witter, David A. Savitz, Lee S. Newman, and John L. Adgate, *Birth Outcomes and Maternal Residential Proximity to Natural Gas Development in Rural Colorado*, [report] National Institute of Environmental Health Sciences, 2014.

⁷² Prud'homme, *Hydrofracking*, 92.

⁷³ Catskillmountainkeeper.org, *Food Supply Dangers from Fracking*, [online] Available at: <http://www.catskillmountainkeeper.org/our-programs/fracking/whats-wrong-with-fracking-2/farming-and-fracking/> [Accessed: 23 Jan 2014], 2014.

system regulates all biological processes in the body and disrupters could cause problems with fertility, reproductive issues and gynecological disorders.⁷⁴

A Pennsylvania study looked at 14 products used in fracking operations and found that 73% of those products had between 6-14 different adverse health effects including skin, eye, and sensory organ damage; respiratory distress such as asthma; gastrointestinal tract and liver disease; brain and nervous system harms; cancers; and negative reproductive effects.⁷⁵

These studies provide evidence that chemicals used in fracking operations can possibly lead to great health implications and need to be carefully regulated to ensure public safety. It is not only important to understand the harmful effects of these chemicals, but also the extent to which they cause damage in order to be able to create strict regulations on the use and handling of chemicals. Without stricter regulations in place, the public may and will feel in danger, and if their health is directly impacted, public opposition will continue to remain.

[Animals]

Surface water contamination has been linked to animal illness and even death, as animals are attracted to the saltiness of the fracking fluids.⁷⁶ Many fracking sites are located either on farmland or in close proximity to farms. The proximity of fracking sites and farm animal illness incidents seem to be inextricably linked based on studies gathered thus far due to exposure to contaminated water.

A study by a team of researchers at Cornell's College of Veterinary Medicine in 2012 suggested that fracking has sickened and killed a wide array of animals. They looked at 24 case studies in six shale-rich states and found that hundreds of cows in Colorado, Louisiana, New York, Ohio, Pennsylvania, and Texas gave birth or stillborn babies after being exposed to fracking fluids. This has been the first and only peer-reviewed report to suggest a connection between fracking and animal deaths.⁷⁷ The study also noted that it was difficult to assess health impacts due to the Halliburton Loophole. They recommended that products from animals such as milk, cheese and eggs should be tested along with water soil and air monitoring.

In one of these case studies, a farmer separated cows into two different groups: 60 were placed in a pasture with a creek where fracking wastewater was allegedly dumped; 36 were placed without creek access. Of the 60 cows that were exposed to the creek water, 21 died, 16 failed to produce calves. The other 36 cows showed no health problems and only one failed to breed. Another farmer reported 140 of his cows were exposed to wastewater that was allegedly

⁷⁴ Epa.gov. "What are Endocrine Disruptors? Endocrine Disruptor Screening Program, US EPA," <http://www.epa.gov/endo/pubs/edspoverview/whatare.htm> (accessed 27 Jan 2014), 2014.

⁷⁵ Madelon L. Finkel, "The Rush to Drill for Natural Gas: A Public Health Cautionary Tale," *American Journal of Public Health* 101, no. 5 (2011).

⁷⁶ "Fracking and Farmland: What Farmers and Landowners Need to Know About the Risks to Air, Water, and Land." *The Ohio Ecological Food and Farm Association* (2011).

⁷⁷ Prud'homme, *Hydrofracking*, 94.

dumped and drained into a pond within the cow's access. Around 70 of his cows died and there were high incidences of stillborn and stunted calves. In Louisiana, 17 cows died within an hour of direct exposure to fracking fluid. A necropsy report showed respiratory failure with circulatory collapse as the most likely cause of death.⁷⁸ This indicates that there is a high potential that fracking wastewater not only affects drinking water for humans, but also endangers animals.

The study, however, concluded that finding a direct correlation between death and illness is not yet possible due to incomplete testing, proprietary secrecy from drilling companies regarding the use of chemicals and non-disclosure agreements.⁷⁹

[Crops]

Fracking has the potential to disrupt farming productivity, endanger livestock health and affect produce and livestock quality. For example, soil contamination impacts including soil acidity levels, methane, heavy metals, and saline water.⁸⁰ Soil acidity increases where flaring occurs, reducing the amount of usable essential nutrients such as carbon, nitrogen and phosphorus. A decrease of these nutrients makes it more difficult for plants to grow. When methane is leaked, it changes the oxygen and bacterial content of the soil. It reduces plant's ability to fix nitrogen and limits the plant's ability to remain hydrated. Heavy metals used in fracking including arsenic, barium, cadmium, chromium, lead, and mercury are released into the soil and can potentially enter into the food chain.⁸¹ Saline water can change the physical properties of soil and thus hinders plant growth.⁸² These all are important not only for the process of growing crops in fracking regions, but also more important in regards to thinking about how produce grown near these sites has the potential to be contaminated before human consumption.

Conclusion

Despite a lack of conclusive evidence in all realms of environmental impacts, it is clear that fracking has the potential to negatively affect local water and air at a serious level and in a variety of ways. The potential must also be viewed in terms of the extremely rapid expansion in shale oil development and the scale of such activity. Within the next decade, tens of thousands of wells will likely be drilled in the Bakken, Eagle Ford, and Permian plays, with thousands more in the Niobrara, Utica, and perhaps other formations. With more knowledge, conclusive studies,

⁷⁸ Krishna, Ramanujan, Study suggests hydrofracking is killing farm animals, pets, *Cornell Chronicle*, 7th March, 2012.

⁷⁹ Ibid.

⁸⁰ Catskillmountainkeeper.org, *Food Supply Dangers from Fracking*, [online] Available at: <http://www.catskillmountainkeeper.org/our-programs/fracking/whats-wrong-with-fracking-2/farming-and-fracking/> [Accessed: 23 Jan 2014], 2014.

⁸¹ Catskillmountainkeeper.org, *Food Supply Dangers from Fracking*.

⁸² Peduzzi and Harding Rohr Reis, Gas fracking: Can we Safely Squeeze the Rocks, 95.

innovative technology and stricter regulations in the near future, environmental risks will have a great potential to be minimized.

Chapter Seven

TRANSPORTATION OF SHALE OIL

Mengqin Ouyang

Abstract

This chapter addresses urgent issues on the transportation of shale oil. In order to present a comprehensive evaluation of the current US oil delivery system, environmental concerns and public reactions will be discussed through studies of trucks, railways and pipelines. First off, three main issues in trucking delivery will be discussed: carbon emissions, mobility, and public opposition. Next, recent railway accidents will be closely examined to address two major issues today: the explosiveness of Bakken crude and current railroads in populated areas. Lastly, the chapter will conduct a detailed evaluation of Keystone XL pipeline through the assessment of oil spills and emissions. This comparative study among these three oil major transportation means shows the advantages of oil delivery by pipeline.

Introduction

Development of shale oil in the US has expanded rapidly, resulting in pipeline infrastructure that has been unable to keep pace. Oil coming out of North Dakota and Texas, is therefore expanding to other transportation networks, such as trucks and railways. Associated with the growing demand in railways, transportation of oil by trucks has also increased significantly in recent years. Along with the fast growing number of trucks on the road, some crucial drawbacks of truck delivery regarding both environmental and economic aspects have shown up. As production surged after the “boom” in 2008, large amounts of oil have had to be transported by rail, increasing the potential for spills and related fires, as well as air and water pollution. Many rail lines where oil is transported pass through populated areas, including towns and cities. Such transport is capable of posing serious risk to public safety. A recent series of railways accidents has drawn public attentions to the already controversial topic of shale oil and fracking. Another pressing topic is the Keystone XL Pipeline project as a means of transporting shale oil. As more and more arguments are being brought into this fierce debate, there is a growing need for a comprehensive study of the current shale oil delivery system in the US. In order to better understand current issues faced by the transportation sector, this chapter will evaluate the environmental impact, economic efficiency, and public opposition of the three main transportation means— trucks, railways, and pipelines – and their implications on the future development of US shale oil transportation.

Section I: Trucks

As the production shale oil has accelerated, the number of trucks on American roads has been increasing too, especially in producing states like North Dakota. In 2012, North Dakota, alone, produced 10% of the total US crude oil, with an average speed of 770,000 barrels per day; trucks transported about 75% of this production to nearby railways.¹ Currently, in the US, trucks are an important link between extraction sites and larger transportation systems. However, along with the fast-growing volume on the road, more issues and drawbacks have been found regarding this transit means. The three main issues of truck transportation in the US oil industry are carbon emissions, mobility, and community opposition.

[Carbon Emissions]

The first concern regarding the large volume of trucks is the rising level of carbon emissions. Although technologies, such as reducing sulfur content in diesel, have helped to lower emissions over the past decade, the trucking industry in the US still consumes a large amount of fuel: around 37.2 billion gallons of diesel and 14.8 billion gallons of gasoline in 2011 alone.² The trucking industry has been one of the targets of the Obama administration's environmental policies. The federal government's announcement on February 18, 2014 promised further regulations on fuel efficiency of medium- and heavy-duty trucks, which account for large portions of the nation's carbon emissions in the transportation sector.³ Moreover, the soaring price of diesel in recent years has significantly driven the industry towards natural gas. Nonetheless, high demand, especially after the "boom" in 2008, makes it difficult to achieve the overall emission goal in the trucking industry, at least for a while. **Figure 1** below shows the amount of freight carried by commercial transportation in US. The number rose by 1.2% in November 2013 from October, reaching its record high.⁴ According to the analysis of the Bureau of Transportation Statistics, the production of oil and gas, in particular, contributed greatly to the growing truck tonnage in 2013. Why does fracking utilize so many trucks then? First off, fracking requires a large volume of water – up to six million gallons of water per well.⁵ Jose Ofornio, a truck driver in Greeley, Colorado,

¹ "North Dakota oil production reaches new high in 2012, transported by trucks and railroads," *U.S. Energy Information Administration*, <http://www.eia.gov/todayinenergy/detail.cfm?id=10411> (accessed Feb. 15, 2014).

² "Reports, Trends & Statistic," *American Trucking Association*, http://www.truckline.com/_layouts/ATARedesign/News_and_Information_Reports_Energy.aspx? (accessed Feb 11, 2014).

³ Juliet Eilperin, "Obama to tighten fuel efficiency standards for big trucks," *The Washington Post*, Feb. 18, 2014. <http://www.washingtonpost.com/blogs/post-politics/wp/2014/02/18/obama-to-tighten-fuel-efficiency-standards-for-big-trucks/>.

⁴ "BTS Releases Freight Transportation Services Index (TSI); Freight Shipments Rose 1.2% in November from October," *U.S. Department of Transportation*, http://www.rita.dot.gov/bts/sites/rita.dot.gov.bts/files/bts02_14.pdf (accessed Feb. 10, 2014).

⁵ Bryan Walsh, "Fracking for Natural Gas May Help Us Save Water," *Time*, Dec. 23, 2013. <http://science.time.com/2013/12/23/fracking-for-natural-gas-isnt-so-water-wasteful/> (accessed Feb. 17, 2014).

described an everyday scene, "... trucks often have to wait in line for their turn". This was his third trip of the day. In less than 15 minutes, thousands of gallons of water gushed into his tank and was shuttled 50 miles away to a drilling site.⁶ While a few places are working on pipelines for water, currently, most of the water is still transported by trucks from water wells to fracking wells. Secondly, as mentioned before, crude oil extracted from fracking wells is mainly moved to other transportation systems by means of truck. Consequently, under the current delivery system, the growing production of shale oil in the US has inevitably led to a growing number of trucks and higher carbon emissions. Remedial actions can be taken to control the overall emission level, improving diesel efficiency by redesigning trucks' engines, braking systems, and tires,⁷ reducing sulfur oxide emissions by using biodiesel, and shifting primary fuel to natural gas, which is highly practical considering fast rising domestic production. Nonetheless, all of these strategies would only help control rather than reduce the carbon emissions created by huge truck traffic so long as there is no profound change in current oil delivery system.

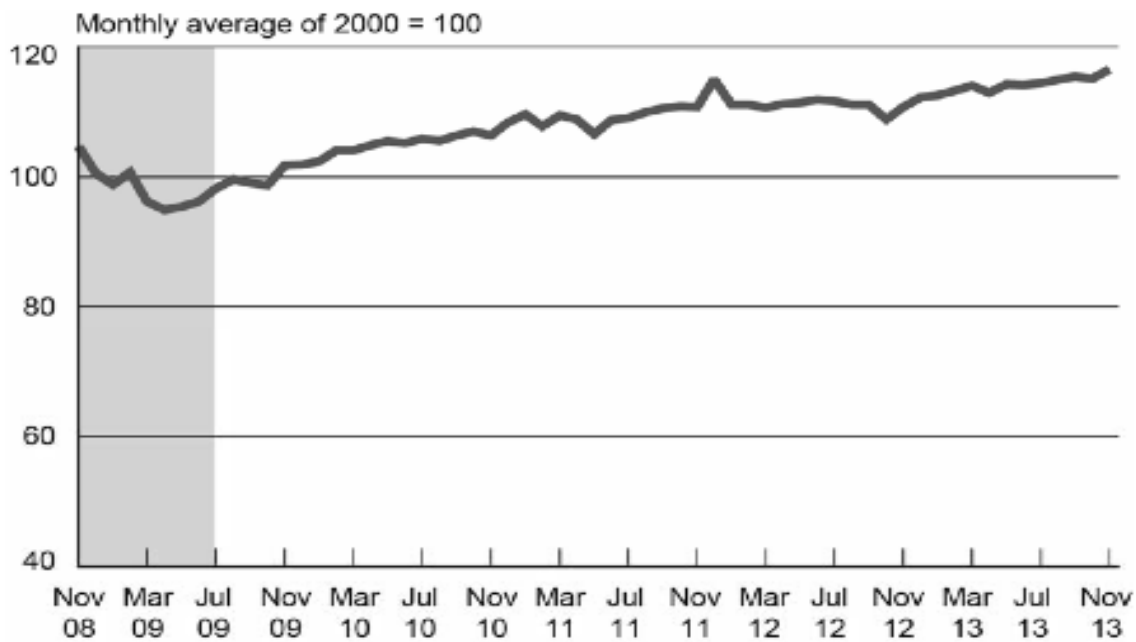


Figure 1: Five Years: Freight Transportation Service Index, November 2008 – November 2013. (Source: United States Department of Transportation)

[Mobility]

Mobility refers to the ability of people or subjects to move rapidly from one location to another.⁸ Here, the mobility of trucks will be evaluated by capacity, flexibility, and

⁶ Jenny Deam, "In parched states, fracking's thirst grows," *Los Angeles Times*, Feb. 19, 2014. <http://www.latimes.com/nation/la-na-colorado-fracking-20140220,0,3689568.story#axzz2uPFvqIJZJ>.

⁷ "Secondary Energy Infobook," *National Energy Education Development Project*, <http://www.switchenergyproject.com/education/CurriculaPDFs/SwitchCurricula-Secondary-Introduction/SwitchCurricula-Secondary-EnergyInfobook.pdf>. (accessed 26 Feb 2014).

⁸ "Mobilities." *Encyclopedia of Identity*, Ed. Ronald L. Jackson, Vol. 1 (2010): 464-467. http://go.galegroup.com/ps/i.do?id=GALE%7CCX1700600165&v=2.1&u=wash_main&it=r&p=GVRL&sw=w&asid=6120334758b2218cabf5364c1589b471.

infrastructure needs, and how they affect trucks' ability to move shale oil efficiently from extraction sites to railways. One for this large volume of traffic is trucks' weak capacity. In fact, among the three transportation means discussed in this chapter, truck is the least efficient in terms of delivering oil. For instance, in April 2012, the delivery capability of oil in North Dakota was "450 thousand bbl/day by pipeline, 150 thousand bbl/day by rail, and only small volumes by truck."⁹ Nevertheless, producing states still rely heavily on trucks for most of their oil deliveries, which leads us to another crucial issue. In 2012, a rare heavy snowstorm hit North Dakota, resulting in the significant decline of shale oil production in November.¹⁰ The primary reason for this sudden decline was trucks' low flexibility in extreme weather. Most drilling sites had to stop production, because trucks were unable to operate and the on-site storages were full. Their low flexibility in extreme weather conditions fundamentally affects oil production.

Well Pad Activity	Early Well Pad Development (all water transported by truck)		Peak Well Pad Development (pipelines may be used for some water transport)	
	Heavy Truck	Light Truck	Heavy Truck	Light Truck
Drill pad construction	45	90	45	90
Rig mobilization ²	95	140	95	140
Drilling fluids	45		45	
Non-rig drilling equipment	45		45	
Drilling (rig crew, etc.)	50	140	50	140
Completion chemicals	20	326	20	326
Completion equipment	5		5	
Hydraulic fracturing equipment (trucks and tanks)	175		175	
Hydraulic fracturing water hauling ³	500		60	
Hydraulic fracturing sand	23		23	
Produced water disposal	100		17	
Final pad prep	45		50	
Miscellaneous	-	85	-	85
Total One-Way, Loaded Trips Per Well	1,148	831	625	795

Table 1: Estimated Number of One-Way (Loaded) Trips Per Well: Horizontal Well. (Source: New York State Department of Environmental Conservation)

In addition to inefficiency and unreliability, investing in necessary infrastructure, such as roads, can also add to the cost of trucking delivery for US shale oil production. **Table 1** above shows that one horizontal well, which is the most common type in today's fracking wells, usually requires up to 3,399 one-way truck trips by heavy and light trucks.¹¹ Many of

⁹ "Williston Basin crude oil production and takeaway capacity are increasing," *U.S. Energy Information Administration*, <http://www.eia.gov/todayinenergy/detail.cfm?id=5870> (accessed Feb. 26, 2014).

¹⁰ "North Dakota," *EIA*.

¹¹ "Final Supplemental Environmental Impact Statement on Keystone XL Project," *U.S. Department of State*, <http://keystonepipeline-xl.state.gov/documents/organization/221190.pdf> (accessed Feb. 12, 2014).

the roads linking the drilling sites to wider transit systems are in rural areas and not built to handle the weight and volume of truck traffic. The Texas Department of Transportation estimates that up to one billion per year will be needed to upgrade the state-maintained rural roads to support the drilling activities in Texas.¹² The New York Department of Transportation, on the other hand, estimates the cost per lane mile for local roads to be from \$70,000 to \$530,000, depending on the level of maintenance needed, not including state roads, bridges and other infrastructure needs.¹³ Overall, the weak capacity and low flexibility of trucks, as well as the high costs of infrastructure, result in trucks' limited mobility in the US oil delivery system.

[Public Opposition]

Aside from the environmental concerns on carbon emissions and economic concerns on mobility, public opposition is another important issue that needs to be addressed. Health is a pressing topic in the public discourse surrounding fracking. While recent studies haven't found enough evidence to directly link water contamination to fracking, rising air and noise pollution from substantial truck traffic is obvious to many people in local towns. Additionally, the prosperity brought by the "boom" has also created issues for local communities. Once a quiet town of 5,600, Carrizo Springs, Texas, now has a population of over 40,000, with rising social issues, like sexual assaults, thefts, and crashes.¹⁴ On-site job opportunities and in trucking are the leading factors of rapid population growth. With workers rushing into towns, the demand for housing is skyrocketing as well. Rent in Williston, New York is higher than the average rent price in metropolises like New York City and Los Angeles.¹⁵ The high volume of trucks is increasing air and noise pollution on local roads, while the high demand for workers is raising the cost of living in these communities. Another public concern over fast growing trucking delivery is drivers' safety. According to the National Institution for Occupational Safety and Health, vehicle accidents are one of the top causes of death among oil and gas workers; accidents like truck-train collisions in producing states are substantially higher than the national average rate.¹⁶ Additionally, the March 3, 2011 report from the National Transportation Safety Board points out the frequent violation by some oil companies regarding the legal limit of 14 working hours per shift for truckers, which is

¹² Ana Campoy, "Drilling Strains Rural Roads," *The Wall Street Journal*, Jul. 26, 2012. <http://online.wsj.com/news/articles/SB10000872396390444840104577551223860569402> (accessed Feb. 16, 2014).

¹³ "Revised Draft SGEIS on the Oil, Gas and Solution Mining Regulatory Program – Potential Environmental Impact Part B," *New York State Department of Environmental Conservation*, http://www.dec.ny.gov/docs/materials_minerals_pdf/rdsgeisch6b0911.pdf (accessed Feb. 25, 2014).

¹⁴ Molly Hennessy-Fiske, "Fracking brings oil boom to south Texas town, for a price," *Los Angeles Times*, Feb. 15, 2014. <http://articles.latimes.com/2014/feb/15/nation/la-na-texas-oil-boom-20140216> (accessed Feb. 18, 2014).

¹⁵ The Associated Press, "Rent in Williston, N.D. tops averages in New York City and Los Angeles," *NY Daily News*, Feb. 17, 2014. <http://www.nydailynews.com/life-style/real-estate/average-rent-williston-n-tops-costs-nyc-article-1.1617187> (accessed Feb 19, 2014).

¹⁶ Tim McDonnell and James West, "It's the Wild F*ing West Out There," *Mother Jones* 37, no. 6 (November 2012): 58-59. *Academic Search Complete*, EBSCOhost (accessed Feb. 28, 2014).

another major cause for the high rate of truck accidents in these areas.¹⁷ Health and social issues caused by the high trucking volume will continue to be part of the public debate over fracking, unless further regulations and changes are made.

Section II: Railways

In producing states like North Dakota, where refinery facilities are limited, fast growing production has surpassed the capacity of the local pipeline system. Therefore the current typical pattern for shale oil transportation in the US is a combination of trucks and trains. After the “boom,” the traffic volume on railways has increased more than four times from 9,500 carloads of crude oil in 2008 to 400,000 carloads in 2013.¹⁸ According to Association of American Railroads (AAR), transportation of crude oil by rail provides several significant advantages including geographical flexibility, responsiveness, efficiency, underlying infrastructure, and product purity.¹⁹ However, a recent series of explosions on railways has raised wide concerns over such a high volume of traffic on railways carrying crude oil, especially crude from North Dakota’s Bakken Shale formation. The two main issues faced by railway transportation in the US right now are the explosiveness of Bakken crude and current railway routing through populated areas.

[Bakken Crude]

On July 6th, 2013, a train with 72 tank cars of Bakken crude derailed and caused multiple explosions near the center of Lac- Mégantic, Quebec, Canada.²⁰ This accident, one of the worst involving Bakken crude, led to 47 deaths in this town of 6000²¹, raising questions about the safety of shipping shale oil by rail. A series of similar accidents occurred again in both US and Canada: one derailment in Alabama in November 2013, another in North Dakota in December 2013, and the most recent one in New Brunswick, Canada in 2014.²² Railway transportation in the US and Canada have maintained a good record of the recent shipping of shale oil, both with a stable decline in the number of accidents over the past few decades. In spite of this, recent events cannot be ignored. Along with the oil boom, railway shipping currently bears the vast majority of shale oil transportation in the US and is facing new

¹⁷ "Documents on the Oil Field Exemptions From Highway Safety Rules, Explored and Annotated by the Times," *New York Times*, May 14, 2012. <http://www.nytimes.com/interactive/2012/05/15/us/exemptions-documents.html#document/p34/a49973> (accessed Feb. 12, 2014).

¹⁸ "Moving Crude Oil by Rail," *Association of American Railroads*, <https://www.aar.org/keyissues/Documents/Background-Papers/Crude-oil-by-rail.pdf> (accessed Feb. 10, 2014).

¹⁹ "Moving," AAR, 5-6.

²⁰ Tadros A. Wendy, "Rail Safety and Public Confidence," *The Globe and Mail*, Oct. 16, 2013. <http://www.tsb.gc.ca/eng/medias-media/articles/rail/2013/GlobeMail-OpEd-WT-20131016.asp> (accessed Feb. 28, 2014).

²¹ Ian Austen, "In Quebec Town, Fires Are Out, but Recovery Is Distant," *New York Times*, Jul. 6, 2013. <http://www.nytimes.com/2013/07/25/world/americas/in-quebec-town-fires-are-out-but-recovery-is-distant.html> (accessed Feb. 27, 2014).

²² Ben Winkley, "Bakken Shale Really Is Explosive," *The Wall Street Journal*, Feb. 24, 2014, <http://blogs.wsj.com/moneybeat/2014/02/24/bakken-shale-really-is-explosive/> (accessed Feb. 20, 2014).

challenges in future operations. All of the trains in these accidents were carrying crude oil produced from the Bakken shale formation, which leads to the question: how explosive is Bakken crude? A safety alert issued by the Pipeline and Hazardous Materials Safety Administration (PHMSA) on January 2nd, 2014 states that, “emergency responders and shippers and carriers that recent derailments and resulting fires indicate that the type of crude oil being transported from the Bakken region maybe be more flammable than traditional heavy crude oil.”²³ Aside from the higher flammability compared to conventional oil, other characteristics of Bakken crude, such as corrosivity, gas content, and toxicity, may also be reasons for the recent series of railway accidents, which are still under examination by PHMSA. Bakken crude tends to be light sweet crude oil, which has a higher value due to lower density and sulfur content.²⁴ Yet, Katie Haarsager, spokeswoman for the Canadian energy delivery company, Enbridge, stated in an interview that, “we did discover that some of the crude coming into the system had much higher levels of hydrogen sulfide.”²⁵ Fracking chemicals have once again taken the spotlight in investigations and studies regarding the potential impact of Bakken crude on the environment and public safety. According to a firefighter who fought in the Lac-Mégantic accident, the fire that resulted from explosions of Bakken crude on those oil tankers took 30 hours and special foam to be extinguished.²⁶ In any case, the recent series of railway accidents indicate the urgent need for regulation intervention. On January 23rd, 2014, the US National Transportation Safety Board (NTSB) and the Transportation Safety Board of Canada (TSB) both issued recommendations in regards to safe crude oil shipping by rail. These include raising standards of all Class 111 tank cars, which tend to have corrosion issues, strategic planning on safer rail routes, and developing emergency response assistance plans (ERAPs) along the routes.²⁷ This news release from TSB also suggests the need for cooperation between the US and Canada under current situations.

²³ "Safety Alert: Preliminary Guidance from Operation Classification," *Pipeline and Hazardous Materials Safety Administration*,

<http://www.phmsa.dot.gov/portal/site/PHMSA/menuitem.ebdc7a8a7e39f2e55cf2031050248a0c/?vgnextoid=c6efec1c60f23410VgnVCM100000d2c97898RCRD&vgnnextchannel=d248724dd7d6c010VgnVCM10000080e8a8c0RCRD&vgnnextfmt=print> (accessed Feb. 27, 2014).

²⁴ "Crude oils have different quality characteristics," *U.S. Energy Information Administration*, <http://www.eia.gov/todayinenergy/detail.cfm?id=7110> (accessed Feb. 20, 2014).

²⁵ Jim Efstathiou Jr. and Angela Greiling Keane, "North Dakota Oil Boom Seen Adding Costs for Rail Safety," *Bloomberg*, Jan. 14, 2014. <http://www.bloomberg.com/news/2013-08-13/north-dakota-oil-boom-seen-adding-costs-for-rail-safety.html> (accessed 28 Feb 2014).

²⁶ Russell Gold and Lynn Cook, "U.S. News: Cities Grapple With Oil-Train Safety," *The Wall Street Journal Europe*, Jan. 16, 2014. <http://search.proquest.com.offcampus.lib.washington.edu/docview/1477654432?accountid=14784> (accessed Feb. 10, 2014).

²⁷ "TSB and NTSB call on Canadian and U.S. regulators to improve the safe transportation of crude oil by rail," *Transportation Safety Board of Canada*, <http://www.tsb.gc.ca/eng/medias-media/communiqués/rail/2014/r13d0054-20140123.asp> (accessed Feb. 15, 2014).

[Railway Routing]

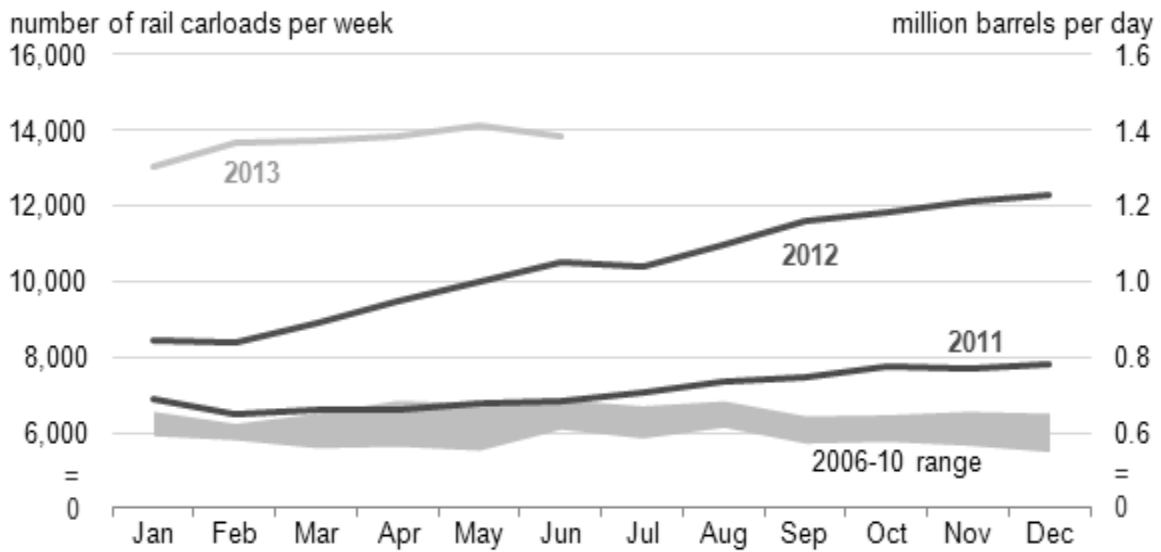


Figure 2: Average weekly US rail carloads of crude oil and petroleum products (Source: EIA)

Based on ARR data, **Figure 2** above shows a 48% increase in the number of crude oil and petroleum products transported by rail in the first half of 2013, compared to same period in 2012.²⁸ During the first six months of 2013, the average number of US weekly carloads of crude oil and petroleum products was around 13,700 rail tankers, which makes the total amount of crude oil and petroleum products shipped via railway at that period close to 1.37 million barrels per day.²⁹ According to EIA analysis, crude oil produced from the Bakken formation in North Dakota, now the second largest producing state after Texas, accounts for a large part of this increase in railway shipping traffic. Due to the lack of pipeline infrastructure in North Dakota, most crude oil from the area are being transported by rail, which is about 750,000 barrels a day.³⁰ Like the NTSB and TSB recommendations mentioned, strategic planning for rail routes for Bakken crude shipping is particularly important, considering the high volume of rail traffic everyday and the populated areas along rail routes. One of the primary reasons that the explosions in Lac-Mégantic caused so many deaths is because the train route went through the highly populated downtown area. Although later accidents did not lead to injuries or deaths, many still worry that similar accidents may cause catastrophe on the current US freight railroads network if no urgent action is taken.

²⁸ Eia.gov. "Rail delivery of U.S. oil and petroleum products continues to increase, but pace slows - Today in Energy - U.S. Energy Information Administration (EIA)." 2013.

²⁹ "Rail delivery of U.S. oil and petroleum products continues to increase, but pace," *U.S. Energy Information Administration*, <http://www.eia.gov/todayinenergy/detail.cfm?id=12031> (accessed Feb. 14, 2014).

³⁰ Gold and Cook, "U.S. News," *WSJ*.

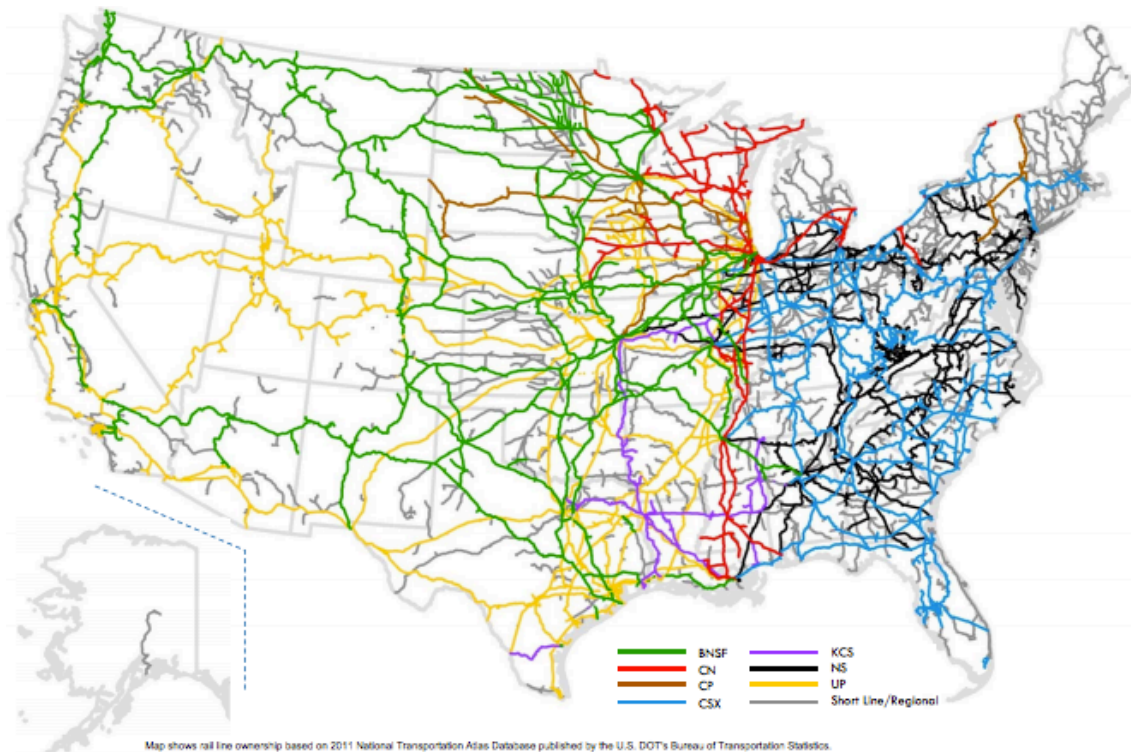


Figure 3: Freight Railroads in United States (Source: AAR)

The AAR views the current freight railroads system, as indicated in **Figure 3** above, an important advantage in rail shipping, “whereas most Bakken crude shipped by pipeline goes to Cushing, Oklahoma, and eventually the refineries in the Gulf region, railroads deliver crude to terminals not only in Louisiana and other places in the Gulf region, but also to locations on the East Coast, the West Coast, and elsewhere.”³¹ However, this seeming advantage of railroads can also be problematic when it comes to frequent shipment of more explosive oil like Bakken crude. Trunk lines in current railroad networks usually go through highly populated areas, such as Boston, New York, and Chicago. This is because the original purpose for such an interlaced network was to connect raw material producing areas with energy consumption intensive areas. Naturally, the shipment of Bakken crude through these highly populated areas can be extra alarming to the public, especially after the Lac-Mégantic accident. Responding to the growing concern over this issue, DOT and AAR announced new safety practices on Feb 21st, 2014, including speed limits of 40 miles-per-hour for trains “with 20 or more tank cars carrying crude oil that include at least one older DOT-111 car” in the federally designated 46 high-threat-urban areas (HTUA)³². This new emergency rule also requires crude oil to be tested before and during the railway shipping, in hopes of getting a more comprehensive idea of the explosiveness of Bakken crude, in particular.

³¹ "Moving," AAR, 6.

³² "Freight Railroads Join U.S. Transportation Secretary Foxx in Announcing Industry Crude By Rail Safety Initiative," *Association of American Railroads*, <https://www.aar.org/newsandevents/Press-Releases/Pages/Freight-Railroads-Join-U-S-Transportation-Secretary-Foxx-in-Announcing-Industry-Crude-By-Rail-Safety-Initiative.aspx#.UxDp5vRdWDo> (accessed Feb. 10, 2014).

Additionally, as previously discussed, the current oil delivery system relies on the combination of trucks and trains. Therefore, the increasing volume of railway transportation requires more trucks on both the oil output and input ends. This means not only more emissions for oil delivery but also higher risks to public health, such as noise pollution and drivers' safety. The recent series of train accidents reminds us of the urgent need for government regulations and system monitoring in the booming transportation sector; moreover, it shows the even more urgent need for comprehensive, long-term planning to contribute to a more environmental friendly and economically efficient means for the future US shale oil delivery.

Section III: Pipelines

Pipeline is another major means of shale oil transportation that consistently stands out in recent news reports for both its existing strengths and potential impacts. Supporters stress the benefits of oil transportation by pipeline, such as higher efficiency and safety levels; opponents, on the other hand, focus on its potential damages to the environment and local communities, especially the Keystone XL Pipeline Project. In any case, it is important to realize that three phases of the Keystone Pipeline in **Figure 4** above exist. Despite all the current controversies, pipeline transport is still the cheapest domestic transportation means for oil in the US. A comprehensive look at pipelines' current status and outlook is necessary for the future development of the US oil transportation system. This section will focus on the case studies of the Keystone XL pipeline from two aspects: oil spills and routing, and emissions from oil sands.

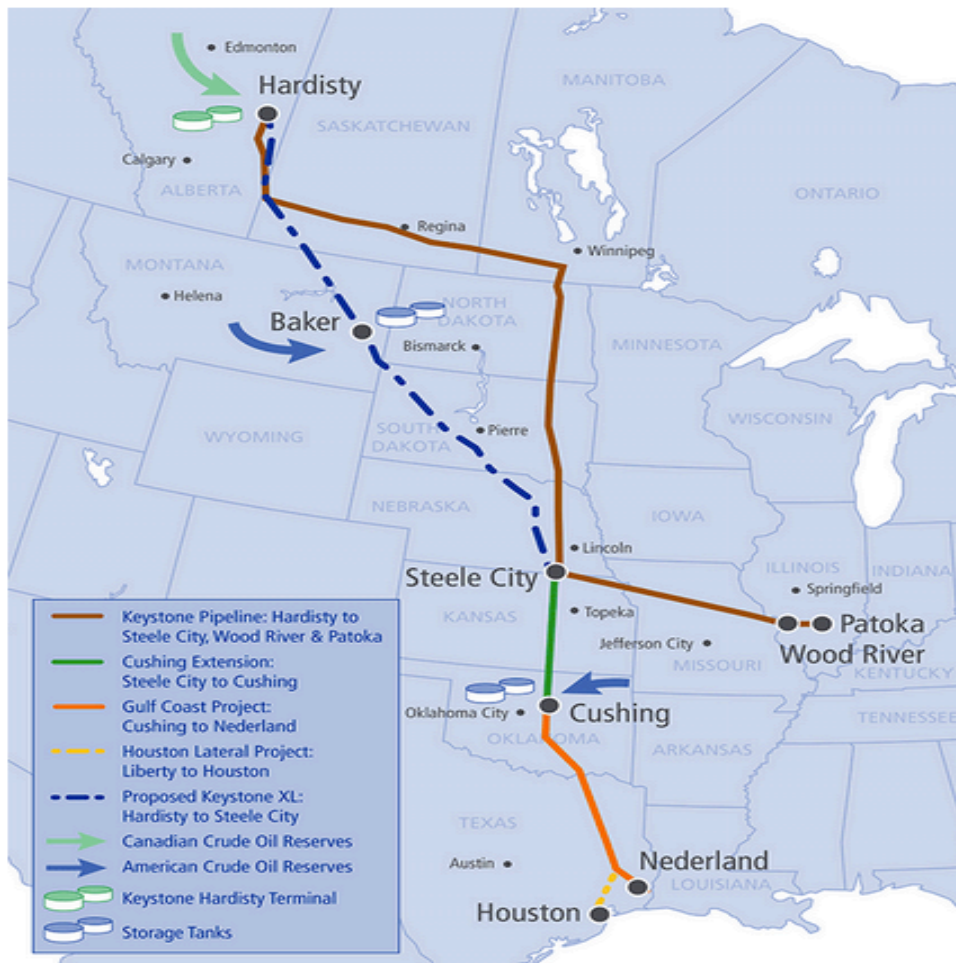


Figure 4: Keystone XL Pipeline – Overall route map. (Source: keystone-xl.com)

[Oil Spills and Routing]

One example often brought up in the opposition against Keystone is the devastating oil spill related the Trans-Alaska pipeline. On March 24th, 1989, the oil tanker Exxon Valdez struck reef in Prince William Sound, Alaska, resulting in more than 11 million gallons of crude oil leaking into the ocean. The EPA describes this accident as the “largest in U.S. history and tested the abilities of local, national, and industrial organizations to prepare for, and respond to, a disaster of such magnitude.”³³ Many believe that the impact of this incident continues even to this day, especially when considering the fragile ecosystem in the Arctic area. Similar hypothesis on Keystone from many environmentalists is understandable. However, in order to objectively evaluate such a possibility, further examination of spills by pipeline is necessary. Causes for pipeline spills vary. In the case of Komi Republic of Russia, the destructive oil spill that happened in October 1994 was a combination of ruptured pipelines and weather conditions: leakage started as early as February along pipelines at the south of the Arctic, long before the spills, then, the dike that had been holding the leaked oil

³³ "Exxon Valdez Spill Profile," *United States Environmental Protection Agency*, <http://www2.epa.gov/emergency-response/exxon-valdez-spill-profile> (accessed Feb. 25, 2014).

collapsed due cold and snow.³⁴ This spill widely impacted nearby areas, where a large portion of the land consists of forest and wetlands.³⁵ A similar case occurred in the Trans-Alaska Pipeline; corrosion of pipelines led to a spill of 6,000 barrels of crude oil in March 2006.³⁶ Although current technology and innovative construction can help reduce cases like these, there are some incidents that are beyond control. In June 1981, as a result of vandalism, the Trans-Alaska Pipeline spilled some 5,000 barrels of oil into the land.³⁷ Another notable fact is that both spills in Komi and Alaska had a particularly negative impact in nearby areas, due to the fragility of the local ecosystem. Considering previous cases, rerouting the Keystone XL pipeline to avoid the Sand Hills regions, a sensitive area with a high concentration of wetlands and a large reserve of drinking water,³⁸ will greatly help reduce the potential impact of a spill on the natural environment. To date, TransCanada has submitted its third application for the Keystone XL pipeline to the State Department with a new routing plan.

[Emissions from Oil Sands]

The Keystone XL pipeline, if approved, would carry production from oil sands in Canada and shale oil production, especially from Bakken, to US refineries, which leads to another pressing topic: potential emissions from oil sands. Oil sands in Alberta contribute to the vast majority of Canada's proven oil reserves, ranking third in the world, but also lead to higher greenhouse gas emissions³⁹. In an interview with the Washington Post published in March 2013, Jennifer Grant, the Director of the Oil Sands Program from Pembina Institute (a Canadian non-profit think tank on energy), pointed out a general environmental concern of oil sands, "oil sands are about 2.5 to 3.4 times more greenhouse gas intensive than conventional production basis; and when you look at the whole life-cycle of emission... about 23% more greenhouse gas intensive than, say, conventional oil."⁴⁰ Because of its unconventional production process and unique formation, oil produced from oil sands normally has higher greenhouse gas emissions than conventional oil. Environmentalists have

³⁴ "Russia Oil Spill," *American University*, <http://www1.american.edu/ted/KOMI.HTM> (accessed Feb. 26, 2014).

³⁵ Edward H. Owens, "Komi Pipeline Crude Oil Spill," *United States Environmental Protection Agency*. <http://www.epa.gov/osweroe1/docs/oil/fss/fss00/komi.pdf> (accessed Feb. 23, 2014).

³⁶ Robert S. Carmichael, "Trans-Alaska Pipeline," *Encyclopedia of Environmental Issues*, Rev. ed. Ed. Craig W. Allin. Vol. 4. (2011): 1231-1233. *Gale Virtual Reference Library* (accessed Feb. 27, 2014). http://go.galegroup.com/ps/i.do?id=GALE%7CCX1946300711&v=2.1&u=wash_main&it=r&p=GVRL&sw=w&asid=e3c55ccaa3ef23c1c565650c8e96a97c (accessed Feb. 27, 2014).

³⁷ Carmichael, "Trans-Alaska," *EEL*.

³⁸ John Broder and Dan Frosch, "U.S. Delays Decision on Pipeline Until After Election," *New York Times*, Nov. 10, 2013. <http://www.nytimes.com/2011/11/11/us/politics/administration-to-delay-pipeline-decision-past-12-election.html?action=click&module=Search®ion=searchResults%230&version=&url=http%3A%2F%2Fquery.nytimes.com%2Fsearch%2Fsite%2F%3Faction%3Dclick%26contentCollection%3DArt%2520%2526%2520Design%26region%3DTopBar%26module%3DSearchSubmit%26pgtype%3Darticle%23%2Fsandhills+keystone> (accessed Feb. 28, 2014).

³⁹ "Canada," *U.S. Energy Information Administration*, <http://www.eia.gov/countries/cab.cfm?fips=CA> (accessed Feb. 14, 2014).

⁴⁰ "Extracting oil sands for the Keystone XL pipeline," *The Washington Post*, <https://www.youtube.com/watch?v=Dh6far2zbWc> (accessed Feb. 28, 2014).

often referred to this emission difference in the argument of sand oil being “one of the most destructive, dirty, and costly fossil fuels”⁴¹ and will significantly raise US greenhouse gas emissions. Yet, scholars have also raised argument against such claim by pointing out that majority of the well-to-wheel emissions, which is the extraction and production process, won’t move to the US just because of the approval of Keystone XL pipeline project. The State Department, in its Final Supplemental Environmental Impact Statement on Keystone XL Project, noted that there will be increased emissions once the project is running: about 1.44 MMTCO₂e (million metric tons of carbon dioxide equivalent) per year for operation and 27 MMTCO₂e per year mostly resulting from use of the oil. However, the report also stresses that, regardless of whether the Keystone XL pipeline is approved or not, Canada will unlikely stop production and instead export to other countries in the market.⁴² An alternative pipeline plan for TransCanada, if the Keystone XL pipeline does not work out, is to build another major pipeline to the west coast and export its production to Asia, which is already a big energy consumption market.

Conclusion

Judging by the overall trend in global energy market, oil will remain the most important fuel for a long time. Current debate over the possible environmental impact of the Keystone XL pipeline is very important. Based on recent studies and discussions, there are practical strategies to reduce the possibility of oil spills in the future, including careful planning of the pipeline route, a better monitoring system, and fast emergency response program. It is also important to objectively assess the domestic energy needs and global energy reality. Disapproval of Keystone XL Pipeline project will not stop Canada from developing its oil industry and exporting sand oils to other countries. On the other hand, approval of the project will not only ensure US energy security but also ease the transportation issues faced by shale oil producing states profoundly, while strengthening the US’s economic and political partnership with Canada. Pipelines show clear advantages from both an economic and environmental perspectives.

⁴¹ "Keystone XL Tar Sand Pipeline," *National Wildlife Federation*, http://www.nwf.org/pdf/Policy-Solutions/Keystone%20XL%20Fact%20Sheet_2.pdf (accessed Feb. 27, 2014).

⁴² "Final," *State Department*.

Chapter Eight

OPPOSITION TO FRACKING AND RESPONSES

Emily Vyhnanek

Abstract

*After gaining momentum in 2010 with the popular documentary *Gasland*, opposition to fracking has played a key role in regulations, moratoriums, and bans all over the world. A complex anti-fracking opposition movement has subsequently developed with global economic and political implications. This chapter provides context for fracking opposition by presenting its goals, and analyzing the responses to public concerns. Fracking opposition will be examined through the scope of four distinct goals including information transparency from oil and gas companies, increased regulation of fracking, moratoriums, and bans. Next, the government, the oil and gas industry, and neutral third party actors will be analyzed in their responses to these public fracking concerns. Because of the political leverage of environmental and anti-fracking groups, serious consideration of both fracking opposition concerns and fracking perceptions will be necessary for the advancement of US leadership in shale oil and gas production.*

Introduction

With fracking gaining momentum globally, public opposition to this unconventional oil and gas extraction technique has become a critical factor in its success. Politicians as well as the oil and gas industry, emphasize the potential economic and political gains from fracking, including billions of dollars in revenue, increases in domestic job opportunities, and increased energy security. However, the environmental impacts, known and unpredicted, local and potentially worldwide, are the source of controversy and a rapidly developing anti-fracking movement.

Although fracking has been a standard practice in the oil industry for over 40 years, public opposition only began within the past four years, with the commencement of large scale drilling in the Marcellus Shale in the eastern US. Most observers cite the release of the 2010 documentary *Gasland* as a critical developing point. National and global anti-fracking movements precipitated both in response to the documentary as well as in response to the rapid increase in drilling for natural gas, and later shale oil wells. Opposition to fracking now takes the form of hundreds of different environmental groups and activists across the nation and targets all forms unconventional resource extraction.

Responses to opposition have come from local, state, and federal governments, the oil and gas industry, and neutral third party actors. These responses range from heavily funded public relations campaigns by way of the oil and gas industry, to statements of economic and political benefits from politicians. Additionally, a critical part of the government response has

been through the research of the environmental and health effects of fracking via the EPA, USGS, and other state departments. However, most studies are still being conducted and while the impacts of fracking remain unknown, the boom continues, with regulation struggling to keep up. Without comprehensive results from these studies, anti-fracking concerns cannot be entirely addressed and insecurity surrounding unconventional oil and gas drilling will remain high. Perceptions of fracking will, therefore, continue to be determined by competing information sources until accurate information can be gathered. Similarly, regulation of oil and gas companies will remain difficult, if not impossible until these studies are complete.

In order for the US to become a leader in shale oil production, serious consideration of public perception, in regards to fracking, will be necessary for effective policy development. Without understanding what the public wants or how their perceptions of fracking are formed, anti-fracking campaigns will continue to create barriers to efficiency in national and global shale oil development. This chapter will provide key analysis of the development of fracking opposition by providing context through which to understand and respond to public opposition.

Section I: Opposition

While public opposition to fracking varies depending on the social and economic backdrop of any given state, the origins of the anti-fracking movement can be seen as largely centered in Pennsylvania. This opposition is a result of the dynamic between the traditional coal mining industry and the newer role of the oil and gas drilling industry. Pennsylvania has an extensive history of oil production, with Titusville as the site of the first known oil well and the state itself as the location of the first oil boom beginning in the 1860s.¹ This boom was short lived and other regions of the nation and world soon began to surpass Pennsylvania's oil production by the end of the 19th century.² At the same time, the steel industry also had a major presence in western Pennsylvania, which added greatly to industrial activity, but declined considerably due to overseas competition in the 1970s and 80s. Coal, by contrast, remained a steady industry in the Pennsylvanian landscape, it has even experienced an upswing in underground production since 1993.³

¹ Pennsylvania Department of Environmental Protection. *Oil and Gas Well Drilling and Production in Pennsylvania. Oil and Gas Well Drilling and Production in Pennsylvania.* Department of Environmental Protection, 2011.

<https://thompson.house.gov/sites/thompson.house.gov/files/PA%20DEP%20Oil%20and%20Gas%20Well%20Drilling%20and%20Production.pdf>. (accessed 4 Feb 2014).

² Pennsylvania Historical & Museum Commission. "Barbara T. Zolli on "A Drop of Oil"." 2009.

http://www.portal.state.pa.us/portal/server.pt/community/history/4569/drake_well__oil150/471308 (accessed 22 Feb 2014).

³ Pennsylvania Department of Environmental Protection. "Pennsylvania Mining History." 2014.

<http://www.dep.state.pa.us/msi/mininghistory.html> (accessed 13 Feb 2014).

Controversy began with the recent introduction of drilling and fracking to the Pennsylvania landscape. With successful gas production established, the states of New York, Pennsylvania, West Virginia, and Ohio experienced a spike in deep horizontal drilling. Unconventional drilling began in Pennsylvania when the first horizontally fracked well was drilled in 2003.⁴ The introduction of fracking has provided economic opportunities not only for job seekers and the oil industry, but has also been important for local landowners who are able to lease their land for compensation in the form of signing bonuses and royalties. Landowner Karen Foertsch, who lives in Butler County Pennsylvania was one of the first to lease to natural gas companies. While Foertsch receives a land royalty of only 12.5%, she says that, currently, some nearby landowners receive up to 20%.⁵ As the boom began to take off in 2008, environmental concerns from local communities, specifically in regards to water source and aquifer contamination began to take shape in public perception vis-a-vis the economic upswing experienced by local landowners.

Contributing to the environmental issues in Pennsylvania are the often-overlooked impacts stemming from coal mining. The coal industry has an extensive history of abandoned mine drainage (AMD), which has been a source of water contamination in several northeastern states, including Pennsylvania.⁶ Its steady place as a fixture in Pennsylvanian livelihood, however, has made the population accustomed to the extreme health and environmental consequences known and associated with it.⁷ Information and knowledge of the effects of fracking, by contrast, are largely unknown and completely foreign to a population that has not experienced such an expansive drilling boom in over a century.⁸ Now local populations, including some landowners and their neighbors, have attributed the increase in water contamination, in the form of tainted aquifers, rivers, streams, and ponds, to fracking. Dimock, Pennsylvania is the source of some of the original claims of water contamination by way of fracking, with claims that fracking has contaminated local aquifers with methane and other chemicals with various levels of toxicity.⁹

Riding off of claims made in Dimock and other areas experiencing increased natural gas exploration, public opposition gained momentum in 2010 with the release of independent filmmaker Josh Fox's documentary, *Gasland*. The documentary garnered social and later

⁴ PennFuture. "Drilling and Mining: History of Drilling in Pennsylvania." 2014.

<http://www.pennfuture.org/content.aspx?SectionID=218&MenuID> (accessed 04 Feb 2014).

⁵ "Gas Rush Stories: A Landowner." Kirsi Jansa. 2013. video.

⁶ United States Environmental Protection Agency. "Abandoned Mine Drainage." 2014.

http://water.epa.gov/polwaste/nps/acid_mine.cfm (accessed 04 Feb 2014).

⁷ Hudgins, Anastasia. "Fracking's Future in a Coal Mining Past: Subjectivity Undermined." *Culture, Agriculture, Food and Environment* 35, no. 1 (2013), 55.

⁸ Hudgins, "Fracking's Future in a Coal Mining Past," 55.

⁹ Lustgarten, Abrahm. "So, Is Dimock's Water Really Safe to Drink?." 20th March, 2012, <http://www.propublica.org/article/so-is-s-water-really-safe-to-drink> (accessed 25 Jan 2014).

political influence stemming from a widely viewed trailer and an Academy Award nomination.¹⁰ Fox uses grassroots journalism, visiting local landowners across the US, to reveal the story behind fracking. Through the use of eye-catching imagery such as flammable tap water and gas masks, *Gasland* and Fox's follow-up *Gasland Part II* have largely been used as ubiquitous sources of information and motivation for the anti-fracking movement. The films themselves have been discredited and heavily criticized for exaggerations and misinformation.¹¹ The influence of the film on both public awareness and public perception of fracking, however, cannot be discounted by government officials or the oil and gas industry. By looking at Google statistics in the months and years following the release of the movie in 2010, one can see that there is a dramatic spike in searches for the terms "Gasland," "fracking," and "shale gas."

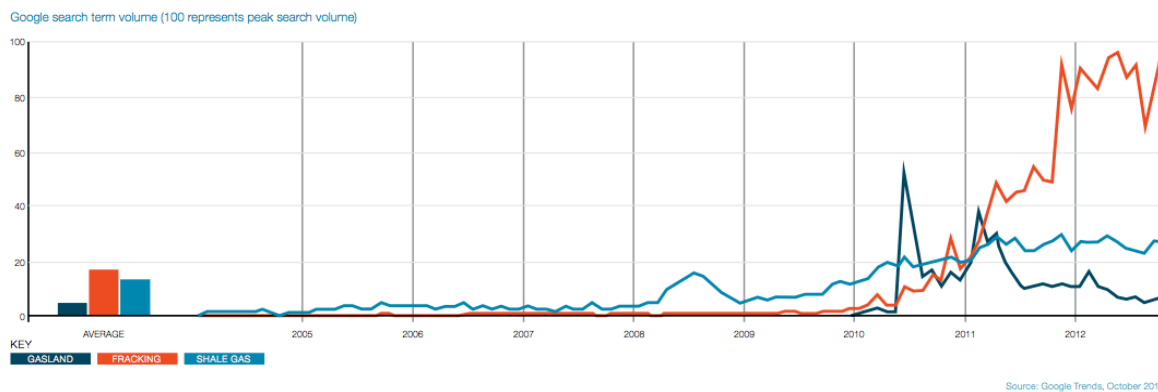


Figure 1 Google search term volume for “Gasland” (dark blue), “fracking” (orange), and “shale gas” (light blue) with 100 representing peak search volume¹²

This spike in public interests in mid-to-late 2010 and extending through 2011, as shown in **Figure 1**, represents both the success and the influence that the documentary had on shifting the issue from a local to a national level. Moreover, this spike in public interest moved beyond the US and was critical in shaping public opposition abroad in countries like France and Bulgaria, where fracking bans were implemented in 2011 and 2012 respectively.¹³ In France, *collectifs*, or community meetings, of 150 to 400 people would begin by showing *Gasland* to spread information in the months leading up to a national ban on the extraction technique.¹⁴ The use of

¹⁰ Soroghan, Mike. "Groundtruthing Academy Award Nominee 'Gasland'." 24th Feb, 2011, <http://www.nytimes.com/gwire/2011/02/24/greenwire-groundtruthing-academy-award-nominee-gasland-33228.html?pagewanted=all> (accessed 20 Jan 2014).

¹¹ Soroghan, "Groundtruthing Academy Award Nominee 'Gasland'."

¹² Wood, Jonathan. "The Global Anti-Fracking Movement: What It Wants, How It Operates And What's Next." *Control Risks* (2012) Accessed 20th Jan 2014. ControlRisks.com, 2.

¹³ Wood, "The Global Anti-Fracking Movement," 15.

¹⁴ Mansfield, Michael. "The villages of southern France take on Sarkozy over shale gas." 20th April, 2011, <http://www.theguardian.com/environment/2011/apr/20/southern-france-sarkozy-shale-gas> (accessed 21st Jan 2014).

the documentary, in such a high volume settings, allowed the anti-fracking movement to quickly and easily mobilize itself in order to influence legislation.

Other documentaries that followed in *Gasland's* footsteps aimed to reveal the human stories of the stakeholders in the natural gas and shale oil extraction process. The *Marcellus Shale Documentary Project* was developed as a way for local photographers in the Marcellus Shale Region to document “how the lives of Pennsylvanians are affected by the Marcellus Shale Gas Industry”.¹⁵ Similarly, the mini documentary series *Gas Rush Stories* by Kirsi Jansa aims to present human stories from many different viewpoints that are “often ignored by the mainstream media”.¹⁶ These human stories have been popular and successful tools for presenting the environmental and social concerns of the fracking opposition in a more tangible and accessible way via the Internet.

As the anti-fracking movement spreads, even high-ranking industry officials like chief executive of Total Energy, Christophe de Margarie, are taking note, stating that, “our business is not sustainable if we are not responsible operators, accepted by all stakeholders, including civil society”.¹⁷ With an opposition movement that has helped pass over 400 local anti-fracking measures, anti-fracking and environmental groups are able to play off of this political leverage with major implications both within the US and abroad.¹⁸ These organizations use mass media as an effective tool to both gain momentum and bring fracking to the attention of the general public. Fracking opposition achieves this mobilization specifically through heavy Internet presence, with organization websites and YouTube videos as well as influential celebrity support.

By drawing on several different forms of mass media, celebrity influence has been one of the biggest factors in the quick dissemination of the anti-fracking position. Capitalizing on their own social influence, celebrities and musicians now exercise their power in the fracking debate by utilizing YouTube videos, PSAs, and songs, as well as highly popular talk show interviews. Over 100 celebrities have taken an anti-fracking stance and several have been influential in developing public discourse on fracking. In response to New York Governor Andrew Cuomo’s original plan to allow fracking to occur in New York, Yoko Ono and son Sean Lennon created *Artists Against Fracking*, an organization that is now comprised of nearly 200 artists.¹⁹ In his

¹⁵ Marcellus Shale Documentary Project. "About." 2014. <http://www.the-msdp.us/about> (accessed 1 Feb 2014).

¹⁶ Gas Rush Stories. "About Gas Rush Stories." 2013. <http://www.gasrushstories.com/grs/About.html> (accessed 1 Feb 2014).

¹⁷ WGC, News. "View From The Top." *WGC News*, 8th June, 2012, 11.

¹⁸ Food and Water Watch. "Local Resolutions Against Fracking." 2014. <http://www.foodandwaterwatch.org/water/fracking/fracking-action-center/local-action-documents/> (accessed 21 Feb 2014).

¹⁹ Artists Against Fracking. "About." 2012. <https://artistsagainstfracking.com/about/> (accessed 15 Feb 2014).

2012 film, *The Promised Land*, Matt Damon promoted his own anti-fracking stance through the fictional story of a small town facing natural gas development.²⁰

The biggest celebrity player in the anti-fracking debate, however, is actor and resident of Upstate New York, Mark Ruffalo. Ruffalo recently became an outspoken advocate as well as a major influence in the anti-fracking movement through his co-founded environmental group, Water Defense, in 2010.²¹ Ruffalo furthered his influence in the development of the anti-fracking campaign by publishing a popular *CNN* editorial,²² and lobbying on the New York State Capitol in Albany in favor of the moratorium on fracking.²³ His appearances on talk shows like Comedy Network's *Colbert Report*²⁴ and MSNBC's *The Rachel Maddow Show*,²⁵ have arguably been most influential to the general public. During his appearance on the *Colbert Report*, Ruffalo argued that the US was lagging behind in the development of alternative energy sources, stating that 30% of Germany's energy is produced from solar energy. In actuality, Germany only produces 3% of its alternative energy from solar energy.²⁶ While Ruffalo went on to post a tweet noting the discrepancy, the event is an example of how anti-fracking actors can often rely on exaggerated or false data to quickly and easily generate support.

It is important to understand the influence that events like these, as well as the use of mass media, have on the formation of public opinion, specifically in the development and spread of fracking opposition. In general, "mass media, and television, in particular, serve as primary sources of information" for most people in the US.²⁷ Moreover, videos play a key role in "how human and environmental values and identity principles are constructed as being threatened by the practice of fracking" and in turn of a threatened identity.²⁸ In the context of the solar energy example above, Ruffalo was able to quickly gain support for the fracking opposition by framing fracking as a threat to the development and implementation of alternative energy sources in the

²⁰ Scott, A. O. "Deep Down, He Wants to Help." 27th Dec, 2012, http://www.nytimes.com/2012/12/28/movies/promised-land-with-matt-damon-directed-by-gus-van-sant.html?_r=0 (accessed 13 Feb 2014).

²¹ Water Defense. "About Us." 2014. <http://waterdefense.org/content/about-us> (accessed 14 Jan 2014).

²² Ruffalo, Mark and Phil Radford. "Don't let America get 'fracked'." 25th April, 2013, <http://www.cnn.com/2013/04/25/opinion/radford-ruffalo-natural-gas-fracking/> (accessed 22 Feb 2014).

²³ Navarro, Mireya. "Ruffalo Embraces a Role Closer to Home." 2nd Dec, 2014, <http://www.nytimes.com/2011/12/04/fashion/mark-ruffalo-actor-embraces-anti-fracking-role.html?pagewanted=all> (accessed 14 Jan 2014).

²⁴ Colbert Nation. "Colbert Report: Mark Ruffalo." 2012. <http://www.colbertnation.com/the-colbert-report-videos/411275/march-28-2012/mark-ruffalo> (accessed 14 Jan 2014).

²⁵ Levy, Alison. "Mark Ruffalo and Rachel Maddow on the Frack Threat to Our Water." 5th Oct, 2010, http://www.huffingtonpost.com/alison-rose-levy/mark-ruffalo-and-rachel-_b_750508.html (accessed 14 Jan 2014).

²⁶ Gerken, James. "Mark Ruffalo Addresses Fracking On 'Colbert Report' Interview." 30 March, 2012, http://www.huffingtonpost.com/2012/03/30/mark-ruffalo-fracking-colbert-report_n_1392584.html (accessed 03 Feb 2014).

²⁷ Hansen, Anders. "The media and the social construction of the environment." *Media, Culture and Society* 13, no. 4 (1991), 445.

²⁸ Jaspal, Rusi, Andrew Turner and Brigitte Nerlich. "Fracking on YouTube: Exploring Risks, Benefits and Human Values.." *White Horse Press* (2014), 18.

US. Even though the figures he stated were extremely out of proportion, the influence he had on viewers who will not perform any further research on the matter is high. The ease and access of the Internet, YouTube videos, and celebrity statements therefore makes the fracking opposition a highly influential and easily mobilized actor in the fracking debate.

[Aims and Claims]

Based on social and environmental claims, there are four guiding goals behind fracking opposition and anti-fracking organizations, which they hope to achieve in the face of the fast paced development of shale plays in the US. While many other goals and demands have been made by fracking opposition groups, these four goals are found throughout popular anti-fracking discourse:

- Information transparency from the oil and gas industry
- Stricter regulation of oil and gas industries by state and federal government
- Moratoriums on fracking until health and environmental impacts are understood
- Fracking bans

Information Transparency

Information transparency, specifically in regards to fracking chemicals, has been a demand of environmental and anti-fracking organizations since the beginning of the fracking opposition movement. In 2011, a poll of Pennsylvanians found that 84% strongly agreed that drilling companies should have to disclose the chemicals used in drilling.²⁹ In addition, the lack of information on such chemicals and the lack of regulation made Pennsylvanians unsure about where to access credible information regarding fracking.³⁰ While chemical disclosure is linked to state regulation and company practice, the issue of information transparency is also deeply connected to anti-fracking's distrust of the influence of oil and gas industries on government processes government officials who have stakes in the industry.

The industry has a history of influence over government officials, especially those who accept campaign donations and work, or have closely worked, with oil and gas companies. It is no surprise, then, that in the 2013-2014 election cycle, the top three recipients of the largest campaign donations from oil and gas companies come from some of the top oil and gas producing states in the nation. Senator John Cornyn (R-TX) received the highest amount of donations with \$448,359, followed by Speaker of the House John Boehner (R-OH) who came in

²⁹ Rabe, Barry G and Christopher P Borick. "Fracking for natural gas: public opinion on state policy options." *Center for Local, State, and Urban Policy (CLOSUP), Survey Report: Fracking* (2011), 7.

³⁰ Rabe and Borick, "Fracking for natural gas," 8.

second, receiving \$310,339, and finally Senator Mary Landrieu (D-LA), who came in third with \$177,250.³¹

Exemplifying this issue for fracking opposition is a small section of the 2005 Energy Act known by anti-fracking groups as the “Halliburton Loophole.” With the help of former Vice President and former chief executive of Halliburton, Dick Cheney, the Halliburton Loophole allows oil and gas companies to label chemicals used in the frack fluid as proprietary secrets thereby exempting them from full chemical disclosure.³² Although 18 states now require various levels of chemical disclosure, many still allow for companies to maintain trade secrets for competitive advantages. For a growing opposition movement, alongside issues of industry influence in congress, chemical disclosure has become an important step in establishing and maintaining public confidence in and support of the technique. Without knowledge of the chemicals used in nearby wells, local communities are unable to understand the health risks that they may face. Information transparency must not only come by means of breaking down existing policy loopholes, but also by promoting accessible and credible information to the public.

Stricter Regulation

Increased regulation of the natural gas and shale oil industry is the goal with the broadest support base within the fracking opposition movement and has the ability to eradicate some existing public concerns. In their Revised Fracking Policy statement, *Sierra Club’s* Board of Directors are quoted as saying that fracking “should be governed by a robust and effective regulatory structure; all natural gas and oil should be produced according to rigorous standards to minimize environmental damage.”³³ This statement reveals the importance of stricter environmental regulations within the anti-fracking context. For instance, in the North Dakota Bakken Shale Play, “[s]tate officials say they rely on companies to clean up spills voluntarily,” thus leaving companies to set the standards for environmental protection.³⁴ Because standards vary from company to company, increased federal regulation can mitigate environmental impacts.

Water use and contamination presents perhaps the biggest example of how state and federal policy can increase regulation and, in turn, support for fracking. In a 2012 poll, 80% of

³¹ Open Secrets. "Oil & Gas: Money to Congress." 2014.

<http://www.opensecrets.org/industries/summary.php?ind=E01&cycle=2014&recipdetail=M&sortorder=U> (accessed 20 Feb 2014).

³² The New York Times. "Editorial: The Halliburton Loophole." 2nd Nov, 2009, http://www.nytimes.com/2009/11/03/opinion/03tue3.html?_r=2& (accessed 4 Feb 2014).

³³ Sierra Club Board of Directors. "Revised Fracking Policy." 22 Feb, 2013, 1.

³⁴ Kusnetz, Nicholas. "North Dakota’s Oil Boom Brings Damage Along With Prosperity." 7th June 2012, <http://www.propublica.org/article/the-other-fracking-north-dakotas-oil-boom-brings-damage-along-with-prosperity> (accessed 20 Feb 2014).

respondents indicated that they are “somewhat” to “very concerned” about the impacts of fracking on water quality.³⁵ Without regulations in place, oil and gas companies will continue to be left to set their own standards, which can vary from company to company. There are three areas through which fracking opposition sees the need for industry regulation: aquifer or water source contamination, water usage, and wastewater disposal.

Following *Gasland*'s provocative imagery of flammable tap water in Dimock and some areas in Colorado, water source and aquifer contamination became the source of increasing controversy for fracking opposition. Although most of these concerns are based on inaccurate information, the fast paced boom of natural gas and shale oil drilling resulted in inadequately built cement casings providing truth to these claims. One study found regions experiencing groundwater or aquifer contamination are experiencing cement casings that are “essentially disbonding, in the rock-cement and /or the cement-casing interface.”³⁶ Although instances of poor cement jobs are declining, further regulation, including inspection and higher quality standards for the industry drilling practices can help act as preventative measures against further environmental degradation.

Total water usage in the fracking process is also a source of controversy and possible regulation, as freshwater scarcity continues to become a bigger issue in the coming years. Because fracking requires several million gallons of water per frack-job, areas experiencing rapid increases in drilling are now feeling the pressure. In Texas, where droughts have historically been an issue, the dramatic increase in horizontally fracked wells has led local communities to associate extreme drought conditions with the oil and gas industry. Fracking in the scope of the entire state of Texas uses only roughly 1% of the Texan water supply.³⁷ However, 20% of fresh water in some counties in the Eagle Ford Shale goes towards fracking.³⁸ While statewide water consumption may not be impacted by fracking, it is clear that some counties experience exacerbated drought conditions as a direct result of fracking freshwater usage. The need for further regulation on total freshwater consumption, as well as the use of recycled wastewater, will be necessary as the fracking boom spreads into other communities, like California, which face similar freshwater constraints.

³⁵ Wolske, Kim and Andrew Hoffman. "Hydraulic Fracturing in the State of Michigan-Public Perceptions Technical Report." (2013), 5.

³⁶ Physicians Scientists & Engineers for Healthy Energy. "*Fluid Migration Mechanisms Due To Faulty Well Design and/or Construction: An Overview and Recent Experiences in the Pennsylvania Marcellus Play.*" Damascus Citizens for Sustainability, 2012, 1.

³⁷ Blackmon, David. "Shale, Fracking Are Not The Main Cause Of Texas Water Shortages." 21st August, 2013, <http://www.forbes.com/sites/davidblackmon/2013/08/21/shale-fracking-are-not-the-main-cause-of-texas-water-shortages/> (accessed 9 Jan 2014).

³⁸ Malewitz, Jim and Neena Satija. "In Oil and Gas Country, Water Recycling Can Be an Extremely Hard Sell." 21st Nov, 2013, http://www.nytimes.com/2013/11/22/us/in-oil-and-gas-country-water-recycling-can-be-an-extremely-hard-sell.html?pagewanted=1&_r=1 (accessed 9 Jan 2014).

Further complicating the issue of water quality is an important clause in the Clean Water Act, which exempts “the underground injection of fluids or propping agents (other than diesel fuels) pursuant to hydraulic fracturing operations related to oil, gas, or geothermal production activities.”³⁹ Because this water is not regulated, water disposal has become a source of major contention with anti-frackers. Specifically, disposing of chemically altered fracking fluid has now been found to be the cause of hundreds of small earthquakes in Ohio, including a 4.0 in 2011.⁴⁰ Communities in Oklahoma and Texas have also experienced a spike in earthquakes within the past three to four years, some of which have exceeded 5.0 in magnitude. Wastewater disposal wells are injected with large amounts of leftover fracking fluids deep beneath the surface where earthquakes may result from the “weakening [of] a preexisting fault by elevating the fluid pressure...typically those [wells] that dispose of very large volumes of water and/or communicate pressure perturbations directly into basement faults.”⁴¹ The fact that these earthquakes have been linked to post-fracking procedures highlights the need for regulations on industry standards of disposal.

Overall, increased regulation allows for a dramatic decrease in environmental and health impacts related to fracking. With the decrease in these impacts, environmental and anti-fracking concerns can begin to be addressed.

Moratoriums

Moratoriums are a goal of the fracking opposition that serve to offer a balance between the implementation of stricter state and federal regulations and more extreme fracking bans. They allow for data from studies to be collected and interpreted over a period of time, without simultaneously and negatively impacting local communities or the environment by continued fracking. *Sierra Club* President, Allison Chin said that “[i]f drillers can’t extract natural gas without destroying landscapes and endangering the health of families, then we should not drill for natural gas.”⁴² Chin’s statement shows how the development of safe, environmentally oriented drilling practices has the ability generate support and trust from the general public as well as certain anti-fracking groups. By placing moratoriums to slow the shale oil and gas boom, government institutions like the EPA, the USGS, and other state level departments are given time

³⁹ United States Environmental Protection Agency. "Regulation of Hydraulic Fracturing Under the Safe Drinking Water Act." 2014. http://water.epa.gov/type/groundwater/uic/class2/hydraulicfracturing/wells_hydroreg.cfm (accessed 04 Feb 2014).

⁴⁰ Choi, Charles. "Confirmed: Fracking practices to blame for Ohio earthquakes." 4th Sept, 2013, <http://www.nbcnews.com/science/science-news/confirmed-fracking-practices-blame-ohio-earthquakes-f8C11073601> (accessed 16 Feb 2014).

⁴¹ Ellsworth, William L. "Injection-induced earthquakes." *Science* 341, no. 6142 (2013), 142.

⁴² Sierra Club. "Beyond Natural Gas: Dirty, Dangerous, and Run Amok." 2012. <http://content.sierraclub.org/naturalgas/> (accessed 16 Feb 2014).

to collect baseline data, with which environmental impacts of fracking can be analyzed, to take bigger steps towards safety.

Moratoriums have been implemented across the nation, most notably in New York. With the help of environmental activists, specifically the celebrities mentioned prior, the halt on fracking in the state of New York was a legislative success for the anti-fracking movement, thus aiding in the development of the campaign. Now, with proposed moratoriums as well as the successful implementation of moratoriums across the US, anti-fracking sentiments clearly have far reaching effects. Moratoriums can function as a way to restore public confidence in drilling. However, it remains to be seen whether moratoriums will be successful in providing ample time to gather and interpret data.

Bans

For some opposition actors, fracking is seen as inherently dangerous to the community and environment, thus necessitating extreme policy measures.⁴³ Subsequently, environmental and anti-fracking groups have played an influential role in the implementation of fracking bans around the world. Fracking bans can be found across the US from Pittsburg, Pennsylvania to Mora County, New Mexico, as well as internationally in countries like Bulgaria and France. Along with many other small areas, fracking bans are the most extreme goals of fracking opposition, with the aim to act preemptively in the face of perceived imminent health, environmental, and social risks.

Mora County of New Mexico offers an example of how fracking opposition can be influential in extreme policy measures such as fracking bans. With a population of 4,700, dozens of local landowners were the targets of oil and gas lease deals in 2009 and 2010 with KHL Inc.⁴⁴ For county citizens, however, the threat of water well contamination was enough to create a large support base against fracking. Mora County citizens overwhelmingly support the ban with a 95% approval rate.⁴⁵ While the advantages of a booming industry in one of the poorest counties in the US are clear, County Commission Chairman John Olivas emphasized that the county is, by contrast, rich in other assets, saying, ““We've got land, we've got agriculture, we've got our heritage and we've got our culture.”⁴⁶ The Mora County example shows how broad based community opposition, on terms that go beyond environmental or health concerns and into cultural values, can also have significant impacts on the success of fracking.

⁴³ Food and Water Watch. "Why Ban Fracking?." 2014. <https://www.foodandwaterwatch.org/water/fracking/> (accessed 21 Feb 2014).

⁴⁴ Matlock, Staci. "World is watching Mora County battle vs. fracking." 23rd Nov, 2013, http://www.santafenewmexican.com/news/local_news/world-is-watching-mora-county-battle-against-fracking/article_edc8353d-3c1e-5ce1-ba74-d8c12d682fab.html (accessed 20 Feb 2014).

⁴⁵ Cart, Julie. "New Mexico county first in nation to ban fracking to safeguard water." 28th May, 2013, <http://articles.latimes.com/2013/may/28/local/la-me-fracking-ban-20130529> (accessed 20 Feb 2014).

⁴⁶ Cart, "New Mexico county first in nation to ban fracking to safeguard water."

Section II: Response

Responses to public concern stem from three different areas:

- Local, state, and federal government
- The oil and gas industry
- Third-party organizations seeking to be a source of information transparency

Responses to public opposition have varying levels of success in addressing concerns. However, some of these responses have failed to address the complex and deeply entrenched interests of anti-fracking actors.

[Local, State and Federal Government]

The response from the US government can be found on federal, state, and local levels, as well as through departmental research studies aiming to provide environmental impact analysis. In both his 2012 and 2014 State of the Union Addresses, President Obama spoke positively of the role of natural gas and shale oil drilling through fracking, regarding it as an economic tool with the ability to create some 600,000 jobs within the next decade.⁴⁷ Further, as factories begin to switch to the use of natural gas, he stated that he would “cut red tape to help states get those factories built and put folks to work.”⁴⁸ For environmentalists, this response neglects the importance of climate change in today’s society by the deferment of alternative energy source development and by maintaining a reliance on fossil fuels.

President Obama and other government officials have responded to this concern by reiterating that fracking will be promoted not only because of its economic and political potential but also because of natural gas’ ability to be a “bridge fuel that can power our economy with less of the carbon pollution that causes climate change.”⁴⁹ US Secretary of Energy Ernest Moniz further argues that because natural gas emits less than half of the carbon dioxide of coal, natural gas is a way through which humans can bide time for the switchover to alternative energy sources, while reducing the US carbon footprint.⁵⁰ While shale oil, by contrast, does not lead to the reduction of fossil fuels, domestic production provides environmental impact reductions in

⁴⁷ The White House. "Remarks by the President in State of the Union Address." 2012.

<http://www.whitehouse.gov/the-press-office/2012/01/24/remarks-president-state-union-address> (accessed 1 Feb 2014).

⁴⁸ The White House. "President Barack Obama's State of the Union Address." 2014. <http://www.whitehouse.gov/the-press-office/2014/01/28/president-barack-obamas-state-union-address> (accessed Jan 30 2014).

⁴⁹ The White House, "President Barack Obama's State of the Union Address."

⁵⁰ Plumer, Brad. "Is fracking a ‘bridge’ to a clean-energy future? Ernest Moniz thinks so.." 4th March, 2013, <http://www.washingtonpost.com/blogs/wonkblog/wp/2013/03/04/is-fracking-a-bridge-to-a-clean-energy-future-ernest-moniz-thinks-so/> (accessed 16 Feb 2014).

the form of reduced oil imports, which works to reduce transport emissions. Most environmental groups are not satisfied with a continued reliance on fossil fuels via shale oil and natural gas production. Fracking will, however, continue to be pursued with the backing of local, state, and federal governments.

For most politicians, whether local, state, or federal, the economic benefits of fracking greatly outweigh the currently unknown social and environmental costs. For instance, in Pennsylvania, politicians cite increased revenue and job creation in response to anti-fracking campaigns. The state struggles with unemployment rates hovering around 7%.⁵¹ With the proposal of piece of legislation named the “Marcellus Moratorium,” local politicians, like Vice Chair of Pennsylvania Democrats Penny Gerber, stood in opposition, citing that “[b]ecause no set period of time is provided it truly is a ban on fracking, and this is a thriving industry.”⁵² Without the full knowledge of environmental and social impacts, politicians often make their decisions based on the information that is clear and easily interpreted, weighing economic benefits over unknown environmental and health impacts.

The political response to fracking opposition also extends in the form of recent studies hoping to respond to health and environmental concerns. These studies aim to analyze current impacts, which have been associated by local communities regarding the fracking technique. For example, with the concern of aquifer contamination by nearby wells, a recent USGS report addressed public concerns that natural gas was entering water sources and showed that “naturally occurring methane can be found in drinking water wells in areas where no natural gas development is occurring.”⁵³ Moreover, methane is an odorless, colorless, and tasteless gas that is not known to be toxic in low concentrations.⁵⁴ The results of this research imply that fracking may not be the only source of natural gas contamination and may not be as great of health concern as previously thought. Results like these generate mixed feelings with fracking stakeholders, with many in the fracking opposition unsatisfied. Local landowner and Dimock resident, Scott Ely’s concerns were not diminished with the knowledge that his water contains methane at “three times the state limit, as well as lithium, a substance that can cause kidney and thyroid disorders.”⁵⁵ Arsenic was also found in two samples collected from a different EPA study.⁵⁶ Indeed without far reaching, comprehensive studies that interpret these findings against baseline data before drilling began, it is almost impossible to trace the true source of these chemicals. Studies must be continued and preformed in areas prior to the start of natural gas or

⁵¹ Politics PA. "Democratic State Committee Roundup." 2013. <http://www.politicspa.com/democratic-state-committee-roundup/48796/> (accessed 20 Feb 2014).

⁵² Politics PA, "Democratic State Committee Roundup."

⁵³ Campbell, James and Diane Noserale. "Naturally Occurring Methane Found in Some Sullivan County Water." 18th June, 2013, <http://www.usgs.gov/newsroom/article.asp?ID=3619#.UwhD7PSzDBG> (accessed 29 Jan 2014).

⁵⁴ Campbell and Noserale 2013

⁵⁵ Lustgarten, "So, Is Dimock’s Water Really Safe to Drink?."

⁵⁶ Lustgarten, "So, Is Dimock’s Water Really Safe to Drink?."

shale oil drilling so to effectively respond to public concerns of water contamination and other impacts.

Some state studies have also responded specifically to the public concerns raised by the documentary *Gasland*. During the most poignant scene in the film, a Colorado resident shows Fox that he can light his tap water on fire. In a subsequent report released by the Colorado Oil and Gas Conservation Commission (COGCC) the commission addressed this tap water issue, citing that “investigations determined that the wells in question contained biogenic methane that is not attributable to such [oil and gas] development.”⁵⁷ These responses show that naturally occurring methane was present in water sources before the start of unconventional drilling. With the success of the film, this information has largely been overlooked in the face of provocative and eye catching imagery. However, reports like these are important because they reveal credible information in what is a highly controversial debate.

[The Oil and Gas Industry]

The oil and gas industry have been quick to respond to anti-fracking campaigns through the use of heavily funded public relations campaigns. In 2010, American Natural Gas Alliance (ANGA) spent a total of \$3,360,000 towards promoting their cause.⁵⁸

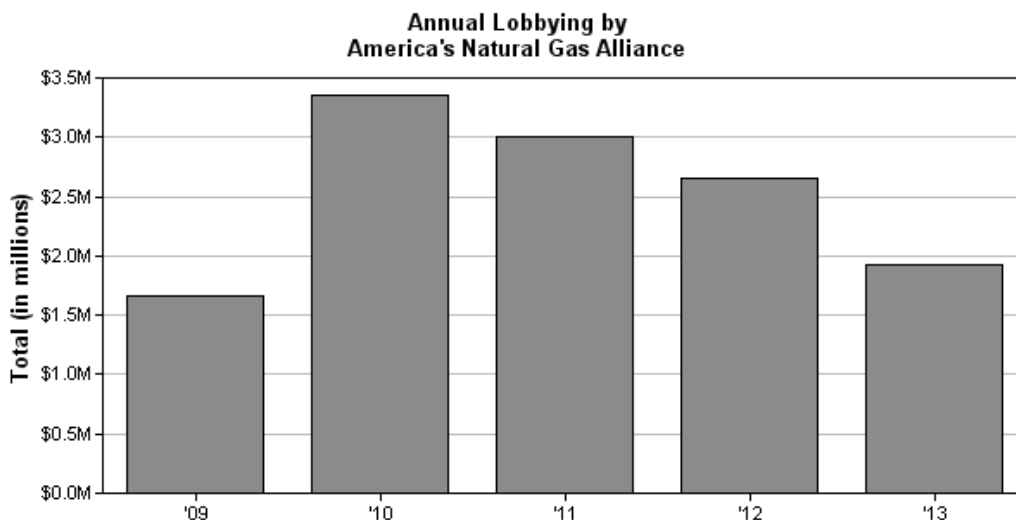


Figure 2: Lobbying spending by ANGA (in millions) during the years 2009 – 2013⁵⁹

⁵⁷ Ritter, Bill. *COGCC Gasland Correction Document*. Denver, CO: Department of Natural Resources, 2010. <http://cogcc.state.co.us/library/GASLAND%20DOC.pdf>. (accessed 4 Feb 2014).

⁵⁸ Open Secrets. "Oil & Gas: Money to Congress." 2014. <http://www.opensecrets.org/industries/summary.php?ind=E01&cycle=2014&recipdetail=M&sortorder=U> (accessed 20 Feb 2014).

⁵⁹ Open Secrets, "Oil & Gas: Money to Congress."

The marked spike in lobbying expenses, as shown in **Figure 2**, coincides directly with the release date of *Gasland* and the subsequent increase in fracking opposition. This lobbying movement has come in the form of public relations campaigns; Specifically, ANGA has attempted to garner support through the use of PSAs. The ANGA PSA campaign commercials frame natural gas in a similar way that politicians do, with one ad from Georgia Power Company stating their goal is “generating electricity that’s cleaner, reliable, and has fewer emissions.”⁶⁰ That particular ad has 1,719 national airings and has recently played on popular news channels like CNN.⁶¹ Campaigns like these focus on positive environmental factors rather than on the economic benefits of shale development. These ads can, therefore, be influential to the average person who may be concerned about climate change, but not directly affected by fracking. However, to anti-fracking groups and local communities experiencing fracking, these campaigns all too often gloss over serious environmental and health impacts associated with unconventional drilling.

PR campaigns from oil and gas companies have been met with predominately negative responses from the fracking opposition. Recently, Chevron has come under fire for its PR campaigns in the face of a blowout in the Marcellus Shale Play, only 50 miles outside of Pittsburg, which left one Chevron contractor missing and another injured.⁶² Following the blowout a fire, which continued to burn for four to five days, Chevron sent out letters to the community in apology, containing a voucher for a pizza special at a local pizzeria. Most view the response as lacking professionalism and understanding of the hardships that the community faces. Gloria Forouzan, a leader with Pittsburgh-based anti-fracking group Marcellus Protest asked, “How arrogant and stupid do they think people are?”⁶³ Ron Smith, a professor of public relations at SUNY Buffalo, went on to release a statement saying that, “With one person missing, that’s a major crisis. You don’t respond in such a meaningless way.”⁶⁴ PR responses like these only perpetuate an ever-increasing distrust of oil and gas companies. Anti-fracking discourse has recently taken hold in the Colorado region, forming suspicion of the once trusted oil and gas companies and leading to the proposal of a statewide ban on fracking.⁶⁵ Accidents like those at the Chevron drilling site occur often, but, in order to restore public confidence in the industry, PR campaigns must react in more socially appropriate ways to show understanding of public concerns.

⁶⁰ iSpot.tv. "America's Natural Gas Alliance TV Commercial, 'Georgia Power, Think About It'." 2014. <http://www.ispot.tv/ad/721t/americas-natural-gas-alliance-georgia-power-think-about-it> (accessed 20 Feb 2014).

⁶¹ iSpot.tv, "America's Natural Gas Alliance TV Commercial, 'Georgia Power, Think About It'."

⁶² Moskowitz, Peter. "After fracking blast, Chevron offers pizza." 18th Feb, 2014, <http://america.aljazeera.com/articles/2014/2/18/after-fracking-blastchevronofferspizza.html> (accessed 22 Feb 2014).

⁶³ Moskowitz, "After fracking blast, Chevron offers pizza."

⁶⁴ Moskowitz, "After fracking blast, Chevron offers pizza."

⁶⁵ Biederman, David. "Colorado Has Been Fracking For 40 Years; Why All The Fuss?." 27th Feb, 2014, <http://www.forbes.com/sites/realspin/2014/02/27/colorado-has-been-fracking-for-40-years-why-all-the-fuss/> (accessed 1 Mar 2014).

[Third Party Actors]

Third party actors in the fracking debate attempt to mediate between proponents and opponents of fracking by presenting information in as neutral space as possible. There have been a few third party sources, such as *FracTracker*, an online site that generates detailed maps of fracked wells around the nation.⁶⁶ A second, and possibly the most influential third party actor, is the chemical disclosure website *FracFocus*. While this third party method has the ability to directly address public concerns, it has been shown to do so ineffectively.

FracFocus was created in April of 2011 in response to information transparency concerns.⁶⁷ The site showed promise by providing oil and gas companies the public space to disclose the chemicals used in the fracking process.⁶⁸ 18 states now require the disclosure of fracking chemicals, 11 of which are required to disclose that information to *FracFocus*.⁶⁹ However, due to the third party nature of *FracFocus*, states give up the right to oversee the disclosure process.⁷⁰ In tandem with regulation differences between states and *FracFocus*, some companies are able to withhold some chemical information by finding discrepancies between *FracFocus* policy and local, state, and federal regulation. These competing levels of regulations make chemical disclosure a logistical nightmare, which ultimately leads fracking opposition to question the validity of the site. It is clear that third party actors provide the potential for increased support for fracking technologies, but are inadequate in providing governments and the general public with accurate and reliable information.

Section III: Reshaping Public Opinion

The fact that responses to fracking opposition, specifically from oil and gas industries, are inadequate is a result of an overall misunderstanding of the perceptions and concerns the general public has about fracking. The Chevron example above highlights how oil and gas companies both misunderstand and downplay the extent of public knowledge on the technique. Industry and government officials all too often discount these public opinions on the basis of a perceived actuality in the face of scientific data.

⁶⁶ FracTracker. "FracTracker." 2014. <http://www.fractracker.org/> (accessed 01 Feb 2014).

⁶⁷ Polson, Jim. "FracFocus Fails as Fracking Disclosure Tool, Study Finds." 23rd April, 2013, <http://www.bloomberg.com/news/2013-04-23/fracfoc-fails-as-fracking-disclosure-tool-study-finds.html> (accessed 20 Feb 2014).

⁶⁸ Polson, Jim. "FracFocus Fails as Fracking Disclosure Tool, Study Finds." 23rd April, 2013, <http://www.bloomberg.com/news/2013-04-23/fracfoc-fails-as-fracking-disclosure-tool-study-finds.html> (accessed 20 Feb 2014).

⁶⁹ Konschnik, Kate, Margaret Holden and Alexa Shasteen. "Legal Fractures in Chemical Disclosure Laws: Why the Voluntary Chemical Disclosure Registry FracFocus Fails as a Regulatory Compliance Tool." *Harvard Law School: Environmental Law* (2013), 3

⁷⁰ Konschnik and Holden et al., "Legal Fractures in Chemical Disclosure Laws," 4.

A problem arises when industry and government equate anti-fracking concerns with NIMBYism (Not In My Back Yard). NIMBYism is defined as “protectionist attitudes...and oppositional tactics adopted by community groups facing an unwelcome development in their neighborhoods,” and while these communities may feel as though these technologies are important and often necessary, NIMBYs would rather development be made elsewhere. Defining these concerns in terms of NIMBYism is inadequate, as the anti-fracking movement goes beyond the classic definition of NIMBYism. In actuality, anti-fracking opposition functions as “a diverse coalition of ideological and vested interests unlikely to be swayed by industry-funded studies or glossy public relations campaigns.”⁷¹ By regarding fracking opposition as NIMBYism, industry and government officials underestimate the political leverage that anti-fracking sentiments have had and will continue to have over the success of horizontal drilling.

In order to reshape public opinion on fracking and promote US leadership in the shale oil and gas industry, industry and government must understand how communities experiencing unconventional drilling perceive and adapt to notions of risk over time, and in turn respond to fracking concerns accordingly. Ultimately, “perceived risks and benefits are consistently strong predictors of opposition or support – on both the individual and community level.”⁷² This chapter has shown the incredible influence that fracking opposition can have on the success of natural gas and shale oil endeavors. In many ways, anti-fracking opposition is based in the struggle between perceived and actual risks. Regardless of tangibility, however, the anti-fracking movement has been shown to have the largest influence on the global spread of this movement. The US can effectively develop, or, in some areas, redevelop trust from local communities by working with the goals of this opposition movement

Conclusion

Public and anti-fracking opposition has proven to have important political influence in the spread of fracking both in the US and abroad. As the US develops its position as a leader in shale oil and gas development, understanding the goals and perceptions on which this movement is based on will be critical in effectively responding to public concerns and gaining support for fracking.

⁷¹ Wood, "The Global Anti-Fracking Movement," 2.

⁷² Boudet, H., Clarke, C., Bugden, D., Maibach, E., Roser-Renouf, C. and Leiserowitz, A. 2014. “Fracking” controversy and communication: Using national survey data to understand public perceptions of hydraulic fracturing. *Energy Policy*, 65 pp., 59.

Chapter Nine

SCIENCE CONTROVERSIES

Zoe Barker-Aderem

Abstract

There is debate among scientists regarding weighing the hazards and benefits of fracking. While objectivity remains a goal in scientific pursuits, bias continues to be a factor. This remains true in fracking as well as with other sources of energy, such as oil drilling in general and nuclear power. This chapter examines the creation of scientific controversies by looking at the way bias is created and perpetuated while considering science's role as a political tool. Then, the chapter addresses these issues in the context of the major controversies surround fracking. Since no source of energy is harmless and each option must be examined in its real world context, the chapter goes on to describe controversies in other sources of energy, including generalized oil drilling and nuclear power. Finally, this chapter explores the role of the media in creating and perpetuating scientific controversies.

Introduction

The claim that science is objective allows for it to be a useful tool in politics, especially because many lay people are unable to interpret the raw data from studies on their own. The issue is further complicated in the controversy surrounding fracking because of the lack of information on environmental conditions before large-scale fracking began. This increases the risk that unrecognized bias might skew results from fracking-related studies towards a particular viewpoint, such that an oil industry scientist and a scientist working for an environmental anti-fracking campaign may uncover different results from the same data. This creates confusion for the public, the media, and those in government charged with making decisions about possible regulations.

There are numerous controversies surrounding oil drilling in general and even more concerns and differing opinions about alternative energy sources, including nuclear power, thus this scientific debate is not only restricted to fracking. Throughout the field, unexamined biases as well as personal and financial motivations make objectivity a difficult pursuit.

Section I: Objectivity and Bias in Science

Because scientists value rational thought and objectivity, a primary goal in any scientific effort is to operate with as little bias and personal influence as possible. Ideally, a scientist would step outside of their personal and cultural beliefs in order to perform a study, even one that concerns a politically and emotional charged topic such as fracking. Contemporary societies take these beliefs seriously. They presume that science can resolve disputes over factual issues, such as whether fracking poses safety concerns. Such disputes are, however, not purely “scientific.” They are formed around and structured by complex ethical and political interests.¹ Unrecognized bias can blind scientists from recognizing how variations in their own personal experiences might cause them to see particular patterns in data, to emphasize certain results over others, or to

¹ Tristram H. Engelhardt and Arthur L. Caplan, *Scientific controversies*. (Cambridge: Cambridge University Press, 1987), vii.

design a study or an experiment that is more likely to create a desired outcome. It is worth noting that financial gain can influence results in multiple ways, from an unconscious desire to find data that benefits an employer to deliberately tampering results. Moreover, one of the structures within the scientific community – the process of peer review – can actually introduce bias when peer reviewers allow their own personal beliefs to guide the editing process. For example, Weston Wilson, an EPA whistle-blower, explained how “possible evidence” of contamination in an aquifer was excluded from the EPA’s final report. Wilson believed that this was because five of the seven members of the study’s peer review panel were current or former employees of the oil and gas industry.² The presumption that a scientist connected to the oil and gas industry will be corrupted by such association is easily matched by the accusation that all researchers in environmental fields will be biased in the other direction. Thus, such presumptions may lead to a dead-end, with the result that science itself is impugned.

The dynamic between supposed neutrality and the reality of personal bias is even more complex when considered within the context of government regulatory institutions like the EPA. These institutions are bound to the ideals of scientific neutrality in the name of public health, yet, realistically, they can be subjected to certain pressures, overt or otherwise, brought about by the administration in power and the existing political climate in Congress. As an example, Carla Greathouse, the author of a 1980s study on drilling waste, says she was told her findings were altered because of pressure from the Office of Legal Counsel of the White House under Ronald Reagan. While the report found some of the drillers’ waste was hazardous and should be tightly controlled, some of the associated recommendations were eliminated from the report given to lawmakers in 1987.³ Similarly, according to internal documents, the EPA had planned to call for a moratorium on fracking in a New York City watershed, but the advice was removed from the letter sent to New York. When asked why the reversal had occurred, an agency scientist simply said, “politics.”⁴ When science enters the political arena, scientists must play by the political rules.⁵ In other words, scientific information becomes just one of a number of factors contributing to a decision. Recognizing this reality is key to creating policy in the midst of scientific controversies. By looking both at data and the context in which it exists, it is possible to see the “artificial separation of scientific and technical knowledge from its political contexts, from the social distribution of power.”⁶

One of the great difficulties in the fracking debate is that the scientists and engineers with the most thorough understanding of fracking itself are also the most incentivized to say fracking is a safe process. Scientists employed by the energy industry have clear reasons for bias; not only do they work everyday with people who evaluate fracking positively, but their careers may also depend on continued use of the technology. Similarly, researchers that are part of the anti-fracking movement are often outside the industry and therefore may have a less complex understanding of the technical process and the everyday realities of fracking. These scientists are sometimes motivated to study and evaluate fracking due to their concern about the potential

² Ian Urbina, "Pressure Limits Efforts to Police Drilling for Gas" *The New York Times*, Mar. 3, 2011.

³ Urbina

⁴ Urbina

⁵ Robert Rich, "Politics, public policy-making, and the process of reaching closure," in *Scientific controversies*, by Tristram Engelhardt and Arthur Caplan. (Cambridge: Cambridge University Press, 1987), 163.

⁶ Brian Martin and Evelleen Richards, "Scientific knowledge, controversy, and public decision making," *Handbook of science and technology studies* (1995): 506 - 526.

damage fracking could cause – another bias that may end up in the way that they frame an experiment or analyze data. If a scientist begins a study or an experiment convinced that a particular result is more likely than another, he is more likely to see evidence of that result in the data collected. Within the context of policy, scientists are not only involved as “consultants or providers of expertise, but as overt and committed defenders or opponents of one side or the other, as active participants in the debate.”⁷ Scientists are citizens and should be allowed and encouraged to engage in these public debates. However, when bias is not accounted for the scientist or the society in which he lives, this involvement can be misleading to the general public.

Further complicating the issue is the use of the Internet by both sides in the controversy. This has meant the spread of video, audio, pictorial, and textual material that is employed as evidence for the validity of one side or the other. Much of this material is non-scientific or selectively scientific, further adding to the confusion and making it more difficult for the layperson to become informed. Yet, the Internet also allows for a more democratic debate, in which public opinion is a testing ground for new technologies. “Controversies provide societies with an informal means of technology assessment that is often superior to any of the institutionalized methods of assessing the risks and benefits of new technologies.”⁸ As fracking continues to be subjected to these controversies, the process of controversial debate itself will provide a useful assessment to be examined alongside scientific studies.

Section II: Science Controversies in Fracking

[The Numbers Game]

An illustrative example of the challenge that a layperson that researches fracking has is finding accurate data on groundwater contamination caused by fracking. A preliminary search reveals a wide variety of statistics. While some of these numbers are extreme outliers and ostensibly more obviously unreliable, reputable scientists will sometimes report different rates of groundwater contamination based on the same data. These numbers may appear to have only small differences – one scientist may report a 1-2% rate for cement casing failures while another reports 3-4%. Yet such differences become very significant when thousands of gas and oil wells are involved and when regulatory options must be considered. Some cite a 1-2% rate of cement or casing construction in wells based on estimates from engineers in the field.⁹ The Pennsylvania Department of Environmental Protection calculated a casing/cement problem rate of about 3% between 2008 and March 2013.¹⁰ Others cite faulty cement and/or casing rate of six to 8.9% a year using Pennsylvania regulators’ reports.¹¹ Even more drastic are statistics that say up to 15% of cement jobs are bad.¹² These rates are dramatically different, and highlight both the difficulty scientists face while attempting to accurately interpret results from raw data as well as the difficulty average citizens experience as they try to decipher the accuracy of varying results. However, variation in studies is not uncommon when data is limited. As fracking continues, continued scientific assessment will give policy makers and industry officials more information

⁷ Martin and Richards, 506 – 526.

⁸ Martin and Richards, 506 – 526.

⁹ Paul Roberts, Susan Brantley and Anna Meyendorff, "Revisiting the Facts on Fracking," *The New York Times*, Apr. 9, 2013.

¹⁰ Roberts et al.

¹¹ Roberts et al.

¹² James Conca, "The Fracking Solution Is A Good Cement Job," *Forbes*, Sep. 10, 2012.

to weigh political and economic costs against environmental concerns. While the “time scale appropriate to developments in science and technology is much longer than the typical time scale of social and political procedures,” it is still possible to make policy decisions based on current evidence and reevaluate as new results become available.¹³

[Water Contamination]

While anti-fracking groups have aggressively opposed this extraction technology in their communities, most reports seem to indicate that fracking is not significantly more harmful than other more accepted drilling methods. One clear area for concern, however, is groundwater contamination. While there are some confirmed sources of groundwater contamination, these are from improperly constructed oil and gas wells and the contamination is unrelated to the fracking process itself.¹⁴

Cement casings surrounding the well appear to be a key area for examination. It is faulty cement jobs, not fracking itself, which should be blamed in cases of groundwater contamination.¹⁵ Poorly cemented casing allows gas to possibly rise within the annulus (space between casing pipe and the rock) and into underground aquifers.

A primary difficulty in assessing the responsibility of fracking for any water contamination is the lack of pre-frack data. Lack of such baseline data often makes it challenging to determine whether poor water quality is due to fracking or some other source. This is particularly the case in areas that have been subjected to coal mining, steel manufacturing, and older oil and gas drilling. As summarized by the Geological Society of America:

“One challenge is to distinguish natural contaminants that seep into groundwater unrelated to oil and gas development, from contamination due to aspects of drilling unrelated to hydraulic fracturing, and from contamination directly caused by hydraulic fracturing. There often are no water quality samples prior to hydraulic fracturing to provide a baseline comparison...Local baseline testing of groundwater quality prior to hydraulic fracturing operations can provide valuable data for assessing the contamination risks”¹⁶

It is known that in many of the areas in the US where fracking is being held responsible for water contamination, the water quality has been very poor for decades due to factors ranging from naturally-occurring compounds to pesticide and agricultural runoff to poorly maintained oil wells from the late 1800s to contaminants from coal mining.

In some instances, there is documentation of this poor water quality. The US Geological Survey has documented poor water quality in the Wind River Formation, over which Pavillion sits, since at least the 1960s. Reports from the years 1969, 1989, 1991, and 1992 all indicate that the groundwater in the area may have been contaminated prior to the start of fracking near Pavillion.¹⁷ In another example, a recent study in Sullivan County, Pennsylvania found naturally

¹³ Ronald Giere, "Controversies involving science and technology," in *Scientific controversies*, by Tristram Engelhardt and Arthur Caplan. (Cambridge: Cambridge University Press, 1987), 150.

¹⁴ "Critical Issue: Hydraulic Fracturing," *Geological Society of America*, <http://www.geosociety.org/criticalissues/hydraulicFracturing/index.asp> (accessed Feb. 9, 2014).

¹⁵ Conca

¹⁶ Geological Society of America

¹⁷ Steve Everley, "Debunking Gasland, Part II," *Energy in Depth*, Apr. 25, 2013.

occurring dissolved methane in two of 20 randomly selected and tested household wells used for drinking water. The methane in one well was high enough to lead to explosive conditions.¹⁸ The issue with these studies is that the sample size was very small and more testing is necessary to draw broad conclusions.

While lack of baseline data can make assessing the source of poor water quality difficult, another issue is the secrecy surrounding fracking fluid. While fracking fluid is usually primarily composed of water and sand, other chemicals make up a small portion of the fluid injected to fracture the shale. Many companies do not release the composition of this fluid. As a result, it can be problematic to test groundwater for contamination because it isn't clear which chemicals should be tested for in the groundwater. Moreover, lack of communication between oil companies, scientists outside the industry, and the general public leads to a sense of suspicion of the whole process. This suspicion can naturally lead scientists and lay people to develop bias against oil and gas companies that can influence their thoughts and methodologies. However, "open communication – including full and honest disclosure about the potentially positive aspects and negative consequences of energy development – is likely to reduce the changes of rumors and inaccuracies about current activities and proposed developments."¹⁹ It is the responsibility of the oil companies to respond to this desire for transparency. The combination of these two factors – the lack of data from before fracking began and the ambiguity surrounding the chemicals used in fracking – create an almost impossible environment for reliable results.

[Earthquakes]

Underground disposal of wastewater from fracking and other drilling operations has been linked to induced earthquakes at some locations as an increase in seismic activity coincides with the injection of wastewater in deep disposal wells.²⁰ However, while these Class II wells are associated with oil and natural gas production, many other deep disposal wells such as Class I wells are used by various other industries including those associated metal, chemical, pharmaceutical, commercial and food production as well as municipal wastewater treatment.²¹ The number of earthquakes has increased dramatically in the last few years in the central and eastern US from an average rate of 20 earthquakes with a magnitude of 3.0 and larger per year from 1970-2000 to over 100 earthquakes per year on average from 2010 - 2013.

For the last three decades, Oklahoma has averaged approximately 50 earthquakes per year. However, the past year has been the most seismically active year in history with almost 3,000 earthquakes.²² Some scientists suggest there is evidence linking these earthquakes to Oklahoma's oil and gas industry – though they don't agree on the specific cause. One hypothesis is that the fluid injected deep into the earth as part of fracking can change pressure near faults, thus triggering the recent surge in earthquakes. Others disagree; studies done by USGS suggest that the actual fracking process is "only very rarely the direct cause of felt earthquakes."²³ The increase in earthquakes could be triggered by the oil and gas industry – but it is just as possible

¹⁸ U.S. Department of the Interior, U.S. Geological Survey, *Naturally Occurring Methane Found in Some Sullivan County Water*, USGS, 2013.

¹⁹ Gene Theodori, "The paradox of public opinion on the energy industry." *Energy Report*, (2009).

²⁰ William Ellsworth, Jessica Robertson and Christopher Hook. "Man-Made Earthquakes Update," USGS, Jan. 17, 2014.

²¹ "Industrial & Municipal Waste Disposal Wells," EPA, http://water.epa.gov/type/groundwater/uic/wells_class1.cfm (accessed Feb. 25, 2014).

²² Wertz

²³ Ellsworth, Robertson, and Hook

that the changes are simply a natural increase.²⁴ Yet another source states that while it is not an exaggeration to say fracking creates a “mini-earthquake”, it would be “too small to be felt by people.”²⁵ However, she does believe the deep underground injection of drilling waste causes more seismic activity. Much like in Oklahoma, some are attributing the recent “swarm” of minor earthquakes in Arkansas to the process of multistage hydraulic fracturing.²⁶

[Explosions]

Another concern associated with fracking is the explosive nature of natural gases that may be released from wells. In 2007, a house exploded in Ohio when natural gas seeped up from a fracking well. However, upon further examination, it was clear that the gas leaked as a result of a poor cement job rather than the specific mechanism of multistage hydraulic fracturing.²⁷ This kind of inadequate well construction is not limited to fracking, but is found in conventional drilling in general. Blaming fracking for destructive incidents related more to the general processes of oil drilling is a major theme in critiques of fracking. For example, industry groups, such as the Independent Petroleum Association of America, have accused Fox, the director of *Gasland*, of confusing fracking with drilling in general.²⁸ Without a clear understanding of fracking vs. standard oil drilling, misperceptions about the dangers of fracking will undoubtedly continue.

Section III: Science Controversies in Other Sources of Energy

Fracking is often presented as more dangerous than more conventional oil drilling methods, but this is not necessarily accurate. One of the cases sometimes cited against fracking is the 2004 case of the Harpers, a family killed in Pennsylvania when natural gas migrated into their basement from some nearby wells drilled by the Snyder Brothers. The family of the victims received court-ordered restitution from the Snyder Brothers because a negligent cement job was responsible for the leak. These wells, however, were actually conventional gas wells – no fracking was involved.²⁹ It is clear that one of the main concerns with fracking – negligent cement jobs – is a problem with conventional oil drilling as well. A primary concern surrounding oil drilling is the potential for oil spills. Many years later, Exxon Valdez remains a triggering phrase and the environmental consequences of the 2010 Deepwater Horizon spill in the gulf continue. The potential for spills from tankers can be mitigated through transportation by pipeline, but these have their own controversies. The Keystone XL pipeline represents one of the most substantial controversies in oil drilling in the US. For the last two years, environmentalists have demonstrated against the project while many Republicans and oil industry executives have supported the pipeline. In January 2014, the State Department released a report concluding that the Keystone XL pipeline would not substantially worsen carbon pollution, a significant concern voiced by the opposition to the pipeline. Environmentalists have disputed the objectivity of the report.³⁰ Currently, there is no real alternative to oil in the context of transportation. As a result, oil drilling will continue regardless of whether the fracking boom continues.

²⁴ Joe Wertz, "A Sharp Rise In Earthquakes Puts Oklahomans On Edge," *NPR*, Jan. 2, 2014.

²⁵ Mike Soraghan, "Groundtruthing Academy Award Nominee 'Gasland'," *The New York Times*, Feb. 24, 2011.

²⁶ Soraghan

²⁷ Ronald Bailey, "The Top 5 Lies About Fracking," *Reason*, Jul. 5, 2013.

²⁸ Soraghan

²⁹ Bailey

³⁰ Coral Davenport, "Report Opens Way to Approval for Keystone Pipeline," *The New York Times*, Jan. 31, 2014.

Outside of the field of transportation, nuclear power is a major player in the energy market. For many years, nuclear power was considered a cleaner alternative to oil. However, various nuclear disasters, including the most recent meltdown at Fukushima, highlight the drawbacks of nuclear energy. Additionally, nuclear energy provides a powerful example of dueling beliefs held by competent scientists. Nuclear power has huge potential in creating energy, but it also has the potential for extreme consequences, including radiation poisoning, loss of life, and environmental damage. While the consequences for nuclear energy are real, they are also often heightened by a generalized fear of nuclear explosions. “Nuclear power evokes greater feelings of dread among people than do any other activities, except terrorism and warfare.”³¹ Additionally, concerns about nuclear disasters are influenced by a multitude of factors, including geopolitical relations. A prime example is the Chernobyl incident. Following the explosion at the Chernobyl nuclear power plant, the United Post International (UPI) claimed that 2,000 people were killed in the accident while the Soviets reported two deaths. 34 days after the accident, UPI retracted its claim of 2,000 dead.³² The UPI exaggerated the damage done in Chernobyl within the Cold War context.

When challenging fracking, it is important to do so within the existing context. Currently, it is unrealistic to think that the US will be independent of all the potentially harmful effects of various sources of energy – from nuclear, oil, and beyond – anytime soon. Thus, any discussion of ending fracking must be considered in terms of the consequences of the alternative. The alternative to fracking is to drill more wells in an area.³³ However, most shale oil is in fact not accessible through conventional drilling technologies. This argument does however illustrate a key reality – more traditional wells will be drilled somewhere instead of utilizing fracking. Each well drilled has its own environmental implications, geopolitical realities, and potential for crises such as spills.

Section IV: The Role of the Media

Most adults learn about advances in technology and science through the media.³⁴ In a 2012 survey, “most of the British people surveyed cited television news (and other audiovisual sources) as primary sources of information concerning fracking (and therefore as a way to ‘make up their minds’).”³⁵ Ostensibly, the role of the media is to relay information to the general public. This information serves to warn citizens about hazards, opportunities, and changes from the norm. However, within our economic structure, media must sell to sustain a newspaper or a cable channel. This drive to make the news more enticing to the average viewer creates a tendency towards exaggeration. In a 24-hour news cycle, there is often an emphasis on speed rather than accuracy. In this regard, the media itself plays a role in creating and sustaining controversies. These trends towards the dramatic within a field that values quickly cycling stories above accurate reporting are especially detrimental when considered in the context of scientific studies.

³¹ Sharon Friedman, "Risk Management: The Public versus the Technical Experts," in *Risky Business*, ed. Lee Wilkins and Philip Patterson. (New York: Greenwood Press, 1991), 32.

³² Everett Rogers and Soon Bum Chang, "Media Coverage of Technology Issues," in *Risky Business*, ed. Lee Wilkins and Philip Patterson. (New York: Greenwood Press, 1991), 80.

³³ Robert Jackson et al, "Research and policy recommendations for hydraulic fracturing and shale-gas extraction," *Center on Global Change*, 2011.

³⁴ Dorothy Nelkin, *Selling Science* (New York: W.H. Freeman, 1987), Preface.

³⁵ Rusi Jaspal et al, "Fracking on YouTube: Exploring Risks, Benefits and Human Values," *White Horse Press* (2014).

In this brief time frame, reporters must write news stories that are both accurate and simple enough to be understood by those without expertise in the subject. Yet, readability in the eyes of the journalist may be oversimplification to the scientist.³⁶

Many reporters have limited training in science, taking years or decades to become competent in understanding the news that they report. The relevance of this detriment is magnified by one of the new roles of the media: studies indicate that mass media also performs an agenda-setting function, selecting and elevating certain issues to public awareness.³⁷ While this agenda setting may not be intentional, the result is the economics of a 24-hour news cycle, which drive controversies to become part of the public agenda.

Another difficulty for the media, as they cover science and technology, is the reality of inconclusive results. Two 2011 reports frequently cited by the anti-fracking movement, include a US EPA finding of water contamination from a well in Pavilion, Wyoming, and the UK DECC's determination that fracking induced minor earthquakes near Blackpool, were inconclusive on some points.³⁸ While this is a simple fact of scientific investigation, it creates conflict for a media encouraged to provide concrete information to the public. Moreover, facts are not the only factors operating in public risk assessment. Values, beliefs and attitudes also play a major role in influencing public actions, and they often override whatever the facts present.³⁹ To understand science and technology, readers need to know their context: the social, political, and economic implications of scientific activities, the nature of evidence underlying decisions, and the limits as well as the power of science as applied to human affairs.⁴⁰ Very few of these components are addressed in most news stories covering science and technology. The result is a gap between the knowledge possessed by experts and by laypeople.

This gap is increased by the tendency towards the dramatic in the media, which creates a dynamic where reports on science and technology are constructed more around rhetoric and sound bites rather than the facts surrounding the story. "Metaphors are an active and strategic tool that guide the analysis of science journalism. This sort of illustrative language positions the press in a significantly judgmental role rather than simply a conveyor of information."⁴¹ Finally, with the development of social media, an individual without journalistic or scientific training can have a huge influence on the national and international conversation surrounding fracking. An examination of YouTube videos on fracking revealed a focus on intrinsic rather than extrinsic environmental values. This allows an emotional attachment to nature to develop opposition to fracking based on sentiment rather than fact-based concern.⁴² Social media can also quickly spread false information, leaving an impression in the minds of regular consumers of social media. Once a person has read or seen something they believe to be true, it is hard to convince them otherwise.

Conclusion

³⁶ Nelkin, 173.

³⁷ Lee Wilkins and Philip Patterson, *Risky Business* (New York: Greenwood Press, 1991), 159.

³⁸ Jonathan Wood, "The Global Anti-Fracking Movement: What it Wants, How it Operates and What's Next," *Control Risks* (2012).

³⁹ Friedman, 32.

⁴⁰ Nelkin, 182.

⁴¹ Nelkin, 9.

⁴² Jaspal et al

When science is considered a neutral tool, it becomes useful in politics and is used by both the oil and gas industry and environmental activists to make a point. The media further polarizes the situation by pushing extremes at both ends. Like all sources of energy, fracking has its hazards. More concrete data must be gathered to determine whether the dangers of fracking truly outweigh the economic and geopolitical benefits. Further, evidence must be considered within the economic, political, and social contexts that influence interpretation of data. Public debate for scientific controversies acts as a testing ground, weighing potential benefits and risks with both positive and negative consequences.

PART IV

Security and Energy Diplomacy

Part IV examines the shale oil boom in the context of US and global energy security, as well as the potential implications of shale oil to change the geopolitical landscape and customary energy relations. Chapter Ten will analyze how current and projected US shale oil production will affect the US trade relations and military strength, while also analyzing the potential impacts abroad. The chapter will also examine possible shifts in the energy security of US allies based on shifts in traditional centers of production and consumption. Chapter Eleven will examine the affect of shifting oil production on US diplomatic relations with its allies and with other oil producing countries, in particular the Middle East, China, and Russia. Due to the global nature of the oil market, production of US shale oil has the potential to change the international playing field in favorable terms for the US and improve North American energy security.

Chapter 10

Energy Security Issues

Syailendra Kamdani

Abstract

By comparing EIA data, reports, and articles, this chapter will analyze how the US shale oil boom will affect energy security. The first section of the chapter looks at how projected US shale oil production and its effects on domestic supply and imports. The second section examines how oil supply impacts the strength of the military and its effects on domestic population. The third section examines the current energy situation of several US allies in different regions, and how the influx of US shale oil will affect their energy security and relations with the US. The evidence provided in this chapter will suggest that the benefits of US shale oil to energy security are worth the risks.

Introduction

Energy security is the ability of a country to obtain sufficient affordable energy for development and other needs in both the present and future. It entails not only the supply of energy but also factors including price, demand, effect on the environment, number of suppliers, impacts on equally important resources (e.g. water), and effect on the relationship between nations.¹ Energy security in the United States is an important issue to examine because of its wide-ranging implications for the nation and, in this case, the world.

The recent increase in US oil production as a result of fracking technology and the subsequent shale oil boom has the potential to play a major role in strengthening US energy security. The US is expected to utilize more of its domestic oil as well as find uses for its surplus. This will allow the US to rely less on imports for day-to-day domestic consumption, while possibly raising GDP through the increase of oil exports

An increase in energy security for the US also strengthens national security. Increased domestic oil supply ensures better protection from compromises in the availability of international oil imports that can be detrimental to security. It better protects the daily societal needs for oil. It will also improve national security by strengthening the energy security of the US' allies. This would mean stronger and more secure allies for the US that could better assist them in any matters of national security. This chapter will discuss specifically the effects of shale oil obtained from fracking on US public and military, and on its relationship with its allies, specifically in East Asia (Japan and South Korea), in Europe (UK and France), and its neighbors in the Americas (Canada, Mexico, and Brazil).

¹ (Montgomery 2010)

²Harvey, Christine and Loder, Asjlynn. "Fracking Boom Pushes U.S. Oil Output to 25-Year High." 11th, Dec 2013.

Section I: Increase in Domestic Supply, Decrease in Imports

The use of fracking in the US has raised domestic oil production to a level not seen in decades. By December of 2013 the US was producing over eight million barrels a day; a high last observed in October of 1988.² According to statistics from the Energy Information Administration (EIA) this number is only projected to rise. There is a projected peak in 2020 where oil production is predicted to reach nearly 15 million barrels a day. By 2040 production of oil is expected to fall slightly, to around 12.5 million barrels a day. Such a major rise in production would bring imports near a historic low in the post-World War II era, thus bolstering national energy security considerably. Graphs from the EIA depicts all this, and expects a fall in imports from 2012 to 2040; showing that net imports will fall from 40% all the way to 32% (See **Figure 1**).

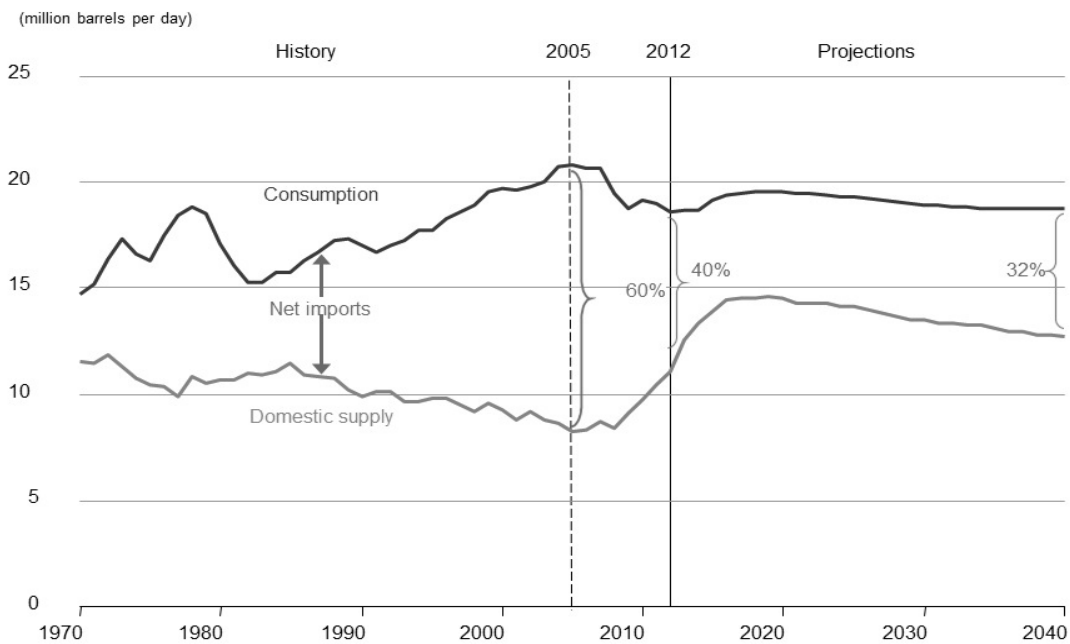


Figure 1: US petroleum and other liquid fuels supply (Source: www.eia.gov/)

While oil production increases, oil consumption is expected to remain somewhat stable, at a little under 20 million barrels per day. In 2012, the US was reported to have only imported around 40% of oil used for domestic consumption.³ This number was a low not seen since 1991, and it is expected to continue to decrease. In the first half of 2013 oil imports for domestic consumption decreased further to 36%, exceeding previous expectations. The EIA predicted in

²Harvey, Christine and Loder, Asjlyln. "Fracking Boom Pushes U.S. Oil Output to 25-Year High." 11th, Dec 2013.

³EIA. "How dependent is the United States on foreign oil? - FAQ - U.S. Energy Information Administration (EIA)." 2013.

2005 that oil imports would rise from 60% to 68% in 2025. 2005 turned out to be the peak of US oil dependency and trends now suggest the opposite.⁴

The US today is still very much reliant on imports, but the rising production from shale oil is causing major shifts in the US' oil landscape. In October 2013, the US production of oil surpassed its imports for the first time since February of 1995. In this month production was at 7.7 million barrels a day, while imports were at 7.6 million barrels per day.⁵ The statistic shows that the total crude oil imports actually went down the next month, and total production went up as can be seen in the numbers from December (8.075 million barrels a day).

The increase in US oil production brings into question its current policies on exports. Energy Secretary, Ernest Moniz, has suggested that, "it may be time for the Obama administration to reconsider the nation's ban on exporting domestically produced crude oil". Some theorize that the increasing oil production would make it more beneficial for the US to start increasing exports of its crude oil, one reason being that it could potentially benefit the domestic public by decreasing global oil prices. The US is already starting to do this by exporting 95,000 barrels a day to neighboring Canada. This number is expected to increase to 200,000 barrels a day in the near future.⁶ This suggests that the US is already planning to increase crude oil exports significantly in the future if the oil boom continues. From the increase in oil production, there is a potential for the US become a major oil exporter rather than an importer. This illustrates that the projected increase in oil production for the US could significantly alter its oil policies. The future of the US in terms of oil is looking more secure which also indicates that overall energy security will improve for the country.

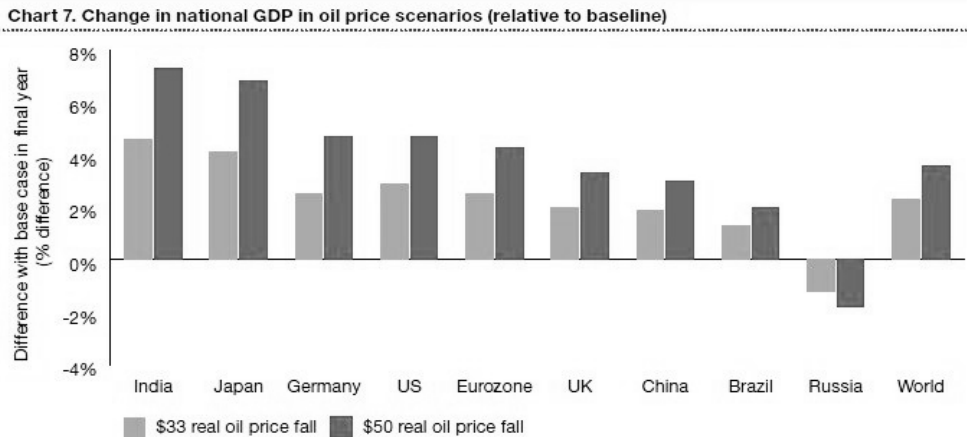
One benefit of growing oil independence for the US public is increased price stability. This prevents the public from having to suffer from "circumstances that cause uncertainty, such as the embargo on oil from Iran or loss of production due to drought or disaster."⁷ It also ensures that domestic uses of oil can be better protected from any changes in foreign supply. It allows the US to be increasingly functional on its own and less dependent on other countries to continue domestic operations.

⁴ The Economist Intelligence Unit. "Diminishing Dependence: Shrinking US Oil Imports." The Economist, 2013, 4-5

⁵ Harvey, Christine and Loder, Asjylyn. "Fracking Boom Pushes U.S. Oil Output to 25-Year High." 11th, Dec 2013.

⁶ Krauss, Clifford. "Energy Secretary Calls Oil Export Ban Dated." 14th Dec, 2013.

⁷ Faulkner, Chris. "Energy Independence Day is Just Around the Corner." USA Today, 2013.



Source: PwC analysis using NiGEM

Figure 2: Change in national GDP in oil price scenarios (Source: Shale oil: The Next Energy Revolution)

Other economic benefits are considerable. It is estimated that the production of oil and gas from fracking can cut down the US deficit by as much as one-third in ten years. It brought in around \$74 billion of federal and state government revenue in 2012, and is expected to rise to \$138 billion by 2025.⁸

The increase in oil production is also expected to significantly increase the current income coming from related industries. In 2012 income from “unconventional energy and chemicals activity” amounted to around \$150 billion, It is expected to rise to around \$269 billion by 2025.⁹ As seen from these numbers, an increase in fracking to obtain shale oil can not only increase household income for parties involved, but also create many new job opportunities.

Section II: The Strengthening of the Military

The total amount of energy consumed by the US military during 2012 was 827 trillion Btu, 80% of total federal government consumption. The Pentagon is “the largest single consumer of energy in the world,” and 80% of this consumption is from oil. The military in 2012 consumed a little less than 350,000 barrels a day, down from 400,000 barrels in 2009.¹⁰ This reflects the objectives outlined in the different branches of the military to decrease the military’s reliance on oil.

⁸ Robertson, Helen. "Petroleum Economist - Shale Boom to US Economy." 2013.

⁹ Robertson. "Petroleum Economist - Shale Boom to US Economy."

¹⁰ Karbuz, Sohbet. "How Much Energy Does the U.S. Military Consume? – An Update." 5th, August 2013.

The Army Energy Security Implementation Strategy, published in 2009, outlines the Army's objectives to reduce energy consumption, increase energy efficiency, use more renewable energy sources, and reduce negative environmental impacts. The document outlines specific goals to meet their objectives, including having five facilities with "net-zero" energy goals, and increasing the number of these facilities to 25 by 2030. It also emphasizes creating over 500 hybrid vehicles and 4000 low speed electric vehicles to reduce oil use in "non-tactical" vehicles.¹¹

The Marines and the Navy have similar goals. The Navy plans to increase the presence of vessels using alternative energy (e.g. biofuels and nuclear power). They also plan to make 50% of their shore-based energy from sources other than oil by 2020. The objective is to make 50% of all installations net-zero and to have 50% of total energy come from alternative sources. The Marines also plan to make 50% of their installations net-zero by 2020, and to reduce the need for liquid fuel by 50% by 2025.¹²

The Air Force plans to make their Forward Operating Bases capable of running on renewable energy, and their engines cleaner and more efficient by 2030. They also plan to use alternative fuel blends for 50% of domestic aviation fuel by 2016.¹³

If the military meets their goals, they will cut their oil expenditure by around 50%. By 2035 the level of military oil use could be as low as 200,000 barrels a day, while it is projected that the US will be producing over 13 million barrels a day (Figure 1). Even if only 1% of that is allocated to the military it would be 130,000 barrels; more than 50% of the total needed for the entire military.

Though these are only projections for the future, the likelihood of success is heightened by the constant improvement of technology, such as engine efficiency, and the availability of alternate sources of renewable energy. Being energy secure will strengthen the military, which in turn strengthens energy and national security in the US. The excess fuel will eliminate many potential weaknesses to the military and will make them more efficient in their operations. An example of this would be how 70% of military convoys in Afghanistan and Iraq are being used purely for the transport of fuel and water.¹⁴ Being less reliant on oil would mean that they could use the extra convoy space for something else, or at the very least lessen transport costs for the military. A more energy secure military allows them to better focus on their objectives without focusing on access to fuel.

¹¹ Environmental and Energy Study Institute. "Fact Sheet: DoD's Energy Efficiency and Renewable Energy Initiatives." Washington, DC: Environmental and Energy Study Institute, 2011.

¹² Environmental and Energy Study Institute. "Fact Sheet: DoD's Energy Efficiency and Renewable Energy Initiatives."

¹³ Environmental and Energy Study Institute. "Fact Sheet: DoD's Energy Efficiency and Renewable Energy Initiatives."

¹⁴ Think Progress. "The U.S. Military Leads the Charge on Renewables, Efficiency and Energy Security." 2011.

Section II: Influence of Oil in the International Community

Another benefit of oil is its ability to improve a country's relationships and leverage in the international community. This can be seen in the way multiple oil embargoes, during the late 20th century significantly affected the world. Many of these embargoes were politically charged.

	Production		Change	
	September	November	Rate	%
	1,000 b/d			
ARAB OPEC				
Saudi Arabia	8,570	6,268	-2,302	-27
Kuwait	3,526	2,470	-1,056	-30
Libya	2,286	1,766	-520	-23
Iraq	2,112	2,148	+36	+2
UAE	1,671	1,308	-363	-22
Algeria	1,100	900	-200	-18
Qatar	609	474	-135	-22
Subtotal	19,874	15,333	-4,541	-23
REST OF OPEC				
Iran	5,828	6,046	+218	+4
Venezuela	3,387	3,380	-7	-
Nigeria	2,138	2,238	+100	+5
Indonesia	1,420	1,450	+30	+1
Subtotal	12,773	13,114	+341	+3
Total OPEC	32,647	28,447	-4,200	-13

Figure 3: OPEC Crude Production (Source: <http://www.ogj.com/>)

One example of an oil embargo that managed to significantly affect the global oil industry is the embargo of 1973-1974. In this embargo, countries from the Middle East, which included all Arab OPEC countries excluding Iraq, cut oil production considerably as a protest to Israel's invasion of Egypt (**Figure 3**). These countries hoped that significantly cutting off the oil supply to Western countries would persuade allies of Israel to intervene in the situation in favor of Egypt. The Arab countries used their abundance of oil as a tool to achieve political goals. The countries accepted the loss in income knowing how dependent the West was on this oil, and that this would eventually lead to compromise. The embargo led to a 400% increase in oil prices. This happened for numerous reasons, including,

“Production cuts, a sharp decline in available stocks, the timing of the embargo just before winter, lack of excess production capacity, concentration of excess capacity in a few OPEC members, increased government control in the oil-producing countries, decreased US oil production, increased US dependence on oil imports from the Middle East, shortages of oil tankers and a decline in transportation excess capacity, US wellhead

price controls, expansionary monetary policy, inflation, speculation, hoarding, and stockpiling.”¹⁵

This led the US and European countries to alter their policy on Israel and Egypt to stop the embargo and satisfy the protesting OAPEC countries.¹⁶ At this time US reliance on oil imports forced them to compromise in matters of foreign policy, and the perceived depletion of reserves caused the prices to rise and the people to panic. The OAPEC countries also benefited from the embargo economically because the Western countries were forced to buy oil at a higher price afterwards.¹⁷

The US’ influx of shale oil obtained from fracking will effectively prevent these things from happening. It will give the US more security from being as badly affected by embargoes, it will allow them to maintain composure if another crisis occurs, and it will give them more pull in political matters that often come with oil.

[East Asia]

Increased US oil production will not only improve its own energy security but also that of its allies. This section will take an in-depth look at the effects of the oil boom on its East Asian allies. Both South Korea and Japan serve as examples that US’ allies in East Asia will most likely benefit from the oil boom.

South Korea

The US has had close relations with South Korea since allying during the Cold War and assisting them in fighting back the invasion of North Korea. Today it is one of the biggest importers of oil in the world, coming in at number six in 2011. That year, it imported over 2.2 million barrels of crude oil per day. As seen from Figure 4, 85% of these imports came from Middle Eastern countries; 33% from Saudi Arabia, 14% from Kuwait, 10% from Iran, 9% from Iraq, 9% from the United Arab Emirates, and 9% from Qatar. South Korea has virtually no proven oil reserves. Domestic production in the Donghae-1 section amounts to only 1000 barrels a day. The national oil company, Korea National Oil Corporation (KNOC), is part of some overseas production but this only amounts to 219,000 barrels a day for the country’s supply.¹⁸

¹⁵ OGJ. "The Oil Weapon: Past, Present, and Future." 2005.

¹⁶ OGJ. "The 1973 Oil Embargo: Its History, Motives, and Consequences." 2005.

¹⁷ OGJ. "The Oil Weapon: Past, Present, and Future."

¹⁸ EIA. "Korea, South - Analysis - U.S. Energy Information Administration (EIA)." 2013.

South Korea oil imports by source, 2011

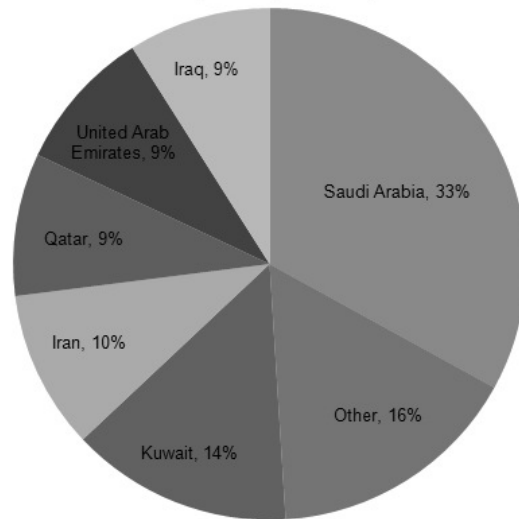


Figure 4: South Korea oil imports (Source: www.eia.gov/)

South Korea's heavy reliance on other countries for oil can put it in a precarious position if political problems arise. For example, in 2012 it was forced to briefly cut off ties with Iran despite getting 10% of its oil from them due to a US imposed sanction. It did not experience any severe adverse effects since the sanctions only lasted for two months. However, if it lasted significantly longer and the US did not choose to waive the sanctions for South Korea, then it would have put them in a difficult position to replace the oil that was coming from Iran. As can be seen here, its current energy security still needs to be vastly improved as South Korea's energy supply can be easily compromised.¹⁹

South Korea is currently trying to increase its use of alternative energies including wind, solar, and hydropower, to decrease the need for oil. The EIA does not have any projections for the far future, but in 2012 the need for oil decreased to 40% from 42% in 2011. In terms of renewable energy, its capacity has increased by 88% from 2005 to 2010, with monetary investment in 2010 amounting up to \$356 million with a focus on wind and solar power.²⁰ There is a noticeable increase in the production of renewable energy in South Korea; in 2010 it comprised 2.4% of the total energy produced, by 2015 there are plans to increase this to 4.3%, by 2020 to 6.1% and by 2030, 11%.²¹ This will result in a slight decrease in reliance on oil for energy, but South Korea will continue to be a major oil importer in the foreseeable future.

The influx of oil from fracking in the US will decrease South Korea's heavy reliance on Middle Eastern oil. The extra oil would allow the US to essentially move in as a new major exporter if it chose to do so. South Korea would be more likely to work with the US rather than

¹⁹ EIA. "Korea, South - Analysis - U.S. Energy Information Administration (EIA)."

²⁰ Meisen, Peter and Chanal, Margaux. "How is 100% Renewable Energy Possible in South Korea by 2020." Global Energy Network Institute, 2012, 13.

²¹ Meisen, Peter and Chanal, Margaux. "How is 100% Renewable Energy Possible in South Korea by 2020", 21

the Middle Eastern countries because of their history as strong allies, as demonstrated by South Korea's willingness to abide by the desires of the US by agreeing to stop importing from Iran, even if it might be detrimental to the country.

The status of the US as one of the biggest world powers would also ensure a higher stability of oil imports to Korea, if the US chooses to become an exporter. This is because of the US' stature in the international community; it is unlikely to be as vulnerable to sanctions as still developing countries. This lessens the possibility of a political situation similar to what happened in Iran from bothering the oil needs of South Korea.

The US even has Army and Air Force personnel stationed in South Korea to help them "defend itself against external aggression."²² This already close relationship between the two countries would make the start of an oil agreement easier. Not only could this connection lead to another source of oil for South Korea from the US, but it could also possibly lead to more business for them through the refinement of oil. Though South Korea does not produce much crude oil, it is known for refining oils for other countries. Three of the biggest refineries in the world are located in South Korea. The country exported about 1.1 million of refined barrels a day in 2011.²³ All this would lead to the energy security of South Korea and economic benefits for the US, as South Korea would gain a source of oil and the US would have another place to export any excess oil.

South Korea would have all the benefits associated with easy access to oil. It would be able to focus on the development of alternative energy without needing to worry about the short term; there would be less worry about getting oil from more unstable countries. An improvement in the energy security of South Korea is also beneficial for the international security of the US because it would have more developed allies to back them up should any problems arise. However, as the prominence of alternative fuels increase in South Korea, its oil consumption will decrease and it thus cannot be relied on as a long-term customer.

Japan

Japan, like South Korea, is known for lacking domestic oil reserves. Yet in 2011, 43% of its total energy consumption was attributed to oil (Figure 5). This is a significant decrease from 80% in the 1970's (EIA). Oil demand has fallen by about 15% since 2000 due to a declining population, and efforts to pursue alternative energies. It also maintains a large amount of strategic crude oil stocks, amounting to 590 million barrels in 2012, to ensure that it can counter any disruption in imports.²⁴

²² U.S. Department of State. "South Korea." 2014.

²³ EIA. "Korea, South - Analysis - U.S. Energy Information Administration (EIA)."

²⁴ EIA. "Japan - Analysis - U.S. Energy Information Administration (EIA)." 2013.

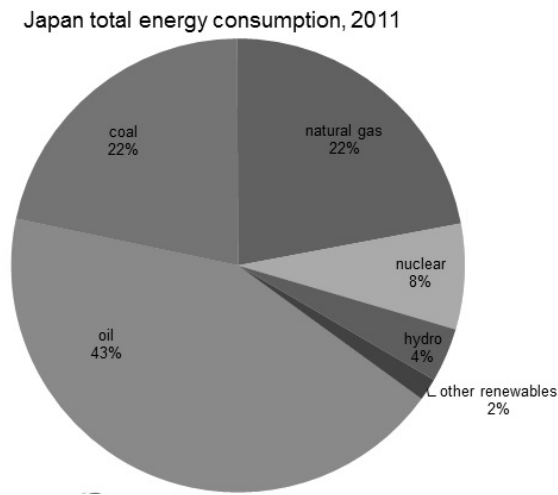


Figure 5: Japan consumption breakdown (Source: www.eia.gov/)

In 2012, Japan consumed about 4.7 million barrels a day, making it the third largest consumer of oil in the world. As forecasted by the EIA, this is expected to steadily decrease in the future. Statistics from 2012 were also inflated because of the Fukushima nuclear disaster, which forced Japan to replace some nuclear energy with oil as well as use extra oil to start repairing damages. This explains some of the expected fall in consumption afterwards because the EIA predicts that once the nuclear power from Fukushima returns, the need for oil will reduce again.²⁵

Like South Korea, Japan imports most of its crude oil, around 83%, from the Middle East. It currently receives most Middle Eastern oil from Saudi Arabia, accounting for 33% of imports. This is followed by the UAE at 22%, then Qatar with 11%, Kuwait with 8%, and finally Iran with 5%.²⁶

Japan has also been trying to move towards other forms of energy to lessen its need for oil. This has especially been evident from the development and implementation of nuclear power. Before the Fukushima incident Japan was ranked third in nuclear energy. Since Fukushima however, Japan has closed down all nuclear power. This is “because of earthquake damage or general maintenance”, but the country plans to construct 12 more reactors by 2020, and plan for nuclear power to make up for 50% of electricity by 2030.²⁷ It also plans to develop other forms of alternative energy. Near the end of 2013 Goldman Sachs planned to invest about \$487 million in “Japanese fuel cell, solar, wind and biomass.”²⁸ Additionally, the government has set a goal for the renewables to make up 25% to 35% of overall energy production by 2030. These developments are still in very early stages though, and it remains to be seen how successful the transition will be.

²⁵ EIA. "Japan - Analysis - U.S. Energy Information Administration (EIA)."

²⁶ EIA. "Japan - Analysis - U.S. Energy Information Administration (EIA)."

²⁷ EIA. "Japan - Analysis - U.S. Energy Information Administration (EIA)."

²⁸ Knowledge@Wharton. "Renewable Energy for Japan: A Post-Fukushima Quest - Knowledge@Wharton." 2013.

The close relationship the US has with Japan today, will allow for an easy transition if the US decides to export more oil. Another benefit the influx of oil can give to Japan is making oil prices at a lower and manageable level.²⁹ All this would further improve relations between the two countries by promoting increased cooperation to benefit each other. It would also give Japan the option to decrease tensions with China over oil exploration of the East China Sea, which involves contested territories.³⁰ US oil could also be an integral part in helping Japan recover from its recent national disaster. Energy security in Japan will increase since the ability to obtain enough energy for its current and future needs would improve.

The surplus of oil from the US would also be beneficial to its transition to alternative energy by making it smoother, and allowing it to focus more on achieving its goals. This means that there is a higher chance for Japan to successfully reduce its dependency on oil, which will, in the long term, strengthen its energy security. The shale oil boom will also reduce oil prices and potentially raise Japan's GDP. According to PWC, in two decades Japan might potentially raise its GDP by 4% if oil prices fall by \$33, and 7% if oil prices fall by \$50 (Figure 2). Like South Korea, a strong Japan is beneficial for the US because it gives them more security in the international community. A developed Japan especially will allow the US to have a stronger presence in the East Asian part of the world. It can lead to more leverage against China; a better deterrence to dissuade them from acting rashly against US interests by having strong allies in their vicinity.

The increased energy cooperation through oil today could also lead to benefits in the future for the energy security of the US. East Asia's planned developments of alternative energy, especially South Korea, is looking promising, and even though the US is also currently developing other forms of energy, having allies that are focused on a more sustainable future in energy can help in a big way later on. Japan's recent spurt of oil consumption is not projected to last long as its nuclear reactors steadily resume normal operations. Its objectives to move towards cleaner, more renewable energies also mean that the oil demand in the country will continue to fall. This suggests that the US cannot safely rely on Japan as a long-term asset that can keep purchasing the same level of oil that the US is selling. This isn't really a problem as the current "oil boom" in the US today is expected to fall also later on, and relations between the two countries should have been strengthened enough by then to open new opportunities.

[Europe]

This section will take a look at the effects of the US shale boom on some of its European allies. The UK will be examined in this section because of its status as a major producer in

²⁹ Ebinger, Charles. "The U.S. Unconventional Hydrocarbon Renaissance and Impact on Japan." Washington, DC: Anderson Court Reporting, 2014.

³⁰ EIA. "Japan - Analysis - U.S. Energy Information Administration (EIA)."

Europe. France will also be examined for the opposite reason; it is a major importer and refiner of oil, but steadily moving away from it.

United Kingdom

The UK is one of the US' closest and oldest allies, unlike the two East Asian countries, the UK is actually known as one of the largest producers of oil in the world. Oil still plays a major part in energy consumption for the UK; during 2011 petroleum still accounts for around 38% of its total energy consumption, followed closely by natural gas at 35%. In January 2013 it was estimated to have over 3.1 billion barrels of proven crude oil reserves, the most of any country in the European Union. The latest data available for production and consumption is from 2012. In that year, oil production was at 1 million barrels a day, 881,000 of this was crude oil. Consumption was 1.5 million barrels a day. Unlike Japan and South Korea, the UK imports the majority of its oil from European countries; Norway at 67%. This is followed by Russia at only 8%, and Nigeria at 7%. The Middle East is not a big factor in oil for the UK at about 2%.³¹

As seen from the graph (**Figure 6**), liquid fuel production has been steadily falling since 2000. In 2012 particularly there was a big fall in production by about 14% from the previous year. Oil production in the UK is expected to remain below 1 million barrels a day through 2014; with production expecting to plateau off in 2013 and beyond.

³¹ EIA. "United Kingdom - Analysis - U.S. Energy Information Administration (EIA)." 2013.

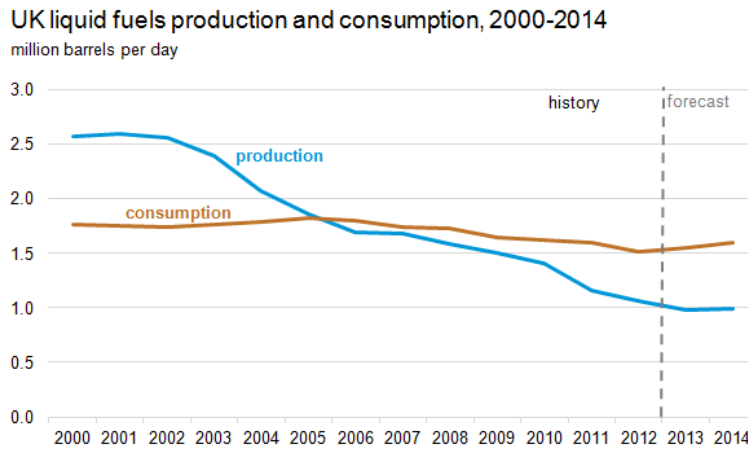


Figure 6: UK liquid fuels production and consumption (Source: www.eia.gov/)

Despite these projections, the UK remains one of the biggest exporters of oil. It was exporting around 690,000 barrels a day in 2011, 82% of which was exported to other EU countries. The Netherlands receives the most British oil at 34%, followed by Germany at 14%, France at 11% and Poland at 4%. The United States is also a big customer for them in terms of oil, making up 13% of its exports in 2011, more specifically, 89,000 barrels a day.³²

Following the trend that is being seen around the world, the UK is also starting to delve into renewable sources of energy to counteract its declining oil production and reduce dependency on other countries for oil. It is planning to develop renewable sources to account for over 30% of total energy production by 2020. This is already going in the right path, albeit slowly, as the prominence of renewables rose from 11% to 12% from 2011 to 2012.³³ Again, if the UK continues its development of renewable energies, there will be less need for imports in the future and the transition will be easier as the UK reduces its oil production.

Because the UK is one of the largest producers of oil, an influx in US oil production may actually have a negative impact on its economy. If US imports fall, the UK will lose some of its export profits. Another potential negative is if the US starts exporting to countries that the UK is already exporting to, therefore cutting off more of its business and straining the relationship between the two countries even further. This is unlikely to happen because their status as allies will more likely than not cause the US to specifically avoid taking any customers. Additionally, the UK mostly exports to European countries allowing them a geographic advantage over the US with lessened transportation fees and wait times.

Although the projected lowering of oil production in the UK for the foreseeable future might mean that it will be forced to relinquish some of its export business away anyway. This could open the door for the US to steadily move into any of the areas that the UK could no

³² EIA. "United Kingdom - Analysis - U.S. Energy Information Administration (EIA)."

³³ EIA. "United Kingdom - Analysis - U.S. Energy Information Administration (EIA)."

longer hold; it should not ruin the relationship between the two countries plus it should make the transition easier.

There are two pathways the UK is leaning towards as it looks toward the future of energy, and both would improve its energy security. One possible pathway that has already seen some success today is the implementation of wind power. Increased wind power has the potential to increase energy security because it decreases dependence on imports and creates sustainable, clean energy to use. The other route that could be taken is following the US' footsteps in implementing fracking to obtain shale resources. Fracking development is in its early stages in the UK, but there have been pushes towards that direction, especially in the shale gas movement. The oil company, Total, in particular has already given substantial investment in this regard.³⁴ According to PwC, the discoveries of abundant shale gas reserves suggest the high probability that shale oil is also present.³⁵ Again this could result in greater energy independence and would economic benefits.

A focus in pushing for the recovery of shale oil in the UK could also result in benefits to society through the employment opportunities that would open up. Just like with the alternative energy route, this would make the UK less dependent on imports. There is the additional benefit of maintaining the status of a major exporter if it is successful in finding abundant shale oil. An improvement in the energy security for the UK through shale would not be beneficial for the US, because there would be another competitor in the business. It would mean a potential scenario where the demand might not meet the growing supply. It would still mean an increase in strength for the UK though, which again would be beneficial from an international security perspective.

Another potential plus though would be the ability of the US to fall back on another source of oil, should the projections turn out to be wrong. The US will also likely never be fully energy secure, especially when it comes to oil, so another future source is always helpful. The influx of oil from the UK can also drive prices down making oil more affordable for everybody.

If it chose to pursue the cleaner option it could also be beneficial for both the UK and the US. Energy security in the UK will still improve for the same reason, and energy security in the US will also improve because there would be more sources the oil can go to in case the US has a surplus. On the opposite side, it would mean higher prices, a potential decrease in demand, and fewer countries to turn to for sources of oil. Either way, the US should not stop its growth in oil production because of the UK.

³⁴ BBC News. "Total to invest \$21m in UK shale gas." 13th, Jan 2014.

³⁵ PwC. "Shale Oil: The Next Energy Revolution."

France

France is another European country that has had a long relationship as allies with the US. It is the 12th largest oil consumer in the world and in 2011 was the 7th largest oil importer.³⁶ About one third of total energy consumption is oil, but the level has been falling since the 1970's from around 66% in 1973 to 29% in 2010.³⁷ France does not have significant oil reserves but is one of the biggest refiners in Europe, and has one of the biggest oil companies in the world, Total.

France is heavily reliant on oil, but imports have decreased in recent years. In 2010, France was importing slightly over two million barrels a day, which accounted for 98% of its oil consumption, in 2012 this number had gone down to 1.6 million barrels a day.³⁸ Most of France's imports are from OPEC countries, 43% from Saudi Arabia and Libya. Another 32% is coming from countries that were under the former USSR.

Total oil consumption in France fell from over two million barrels in 2011 a day to 1.7 million in 2012. The French Administration has forecasted that this number will continue to fall around 20% when looking at numbers from 2005 to 2020. One of the reasons for this decline in consumption and production is the development of alternative sources of energy. Nuclear power in particular has gone up from 2% of total energy consumed in 1973, all the way to 42% in 2010.³⁹ In 2011, nuclear power accounted for 75% of the country's total electricity. There are 58 active reactors. As stated in the National Action Plan for the Promotion of Renewable Energies, France is planning to make renewable energies at least 23% of all energy consumption. This would be a large increase from 9.6% in 2005. The policy is meant, "to reduce dependency on fossil energies as much as possible."⁴⁰ France has banned fracking, which shows their dedication to focusing on developing other sources of energy and moving away from oil.

These developments indicate that energy security in France will improve in the future, if it is successful in meeting their goals since it will definitely become more energy secure by relying less on oil imports and more on their own energy production. On the environmental aspect of energy security, France will also improve because the negative effects that are related to oil will lessen. Another positive of its development of new energy is the new jobs that will be created from the industry.

The influx of shale oil from the US would not affect France much in the long term, but it can still improve energy security in the short term because it would mean another source of supply. It will also result in a decrease in oil prices, making it more affordable for France to

³⁶ EIA. "France - U.S. Energy Information Administration (EIA)." 2013.

³⁷ IEA. "Oil & Gas Security - Emergency Response of IEA Countries." France: International Energy Agency, 2012.

³⁸ EIA. "France - U.S. Energy Information Administration (EIA)."

³⁹ IEA. "Oil & Gas Security - Emergency Response of IEA Countries.", 3

⁴⁰ Republique Francaise. "*National Action Plan for the Promotion of Renewable Energies 2009-2020.*" Republique Francaise. 2009

continue importing at the high level it is currently. France can possibly also see a rise in GDP from the change in prices. The US can still potentially find a customer in France if their oil output gets high enough because it is still in a transitional period. For the time being oil is still needed, and the alliance between the two countries will allow an easier shift to make the US a part of their imports. It gives the US another oil customer, while giving France a cushion as it moves towards other forms of energy.

Even though France cannot be completely relied on as a potential long term oil customer for the US, there is always Total who will undoubtedly still be interested in the oil even in France themselves do not need it anymore. For example because of Total's refining operations, the US might export more crude oil to them so it can in turn sell it to other countries.⁴¹ Total's interest in shale and fracking can already be seen from its investment in the UK as mentioned before.

If France continues to move away from oil, its energy security will improve, and stronger allies are always beneficial for the US in matters of international security. As France moves towards alternative energy there would also be more supply of oil, which benefits the US' energy security because it means more affordable oil and a potential rise in GDP.

[The Americas]

This section will take a look at how the increase in oil production by the US will affect its American neighbors. Canada and Brazil will be the focus of this section because of their current status as major producers and net exporters, and because the US is currently a major importer to these countries.

Canada

Canada is currently the largest exporter of oil to the US. It is a net exporter of oil and the sixth largest oil producer in the world.⁴² As of 2012, oil accounts for over 36.4% of energy demand in Canada, and this number is not expected to change much, with just a slight decrease to 36% expected by 2035.⁴³ As of the end of 2012, the number of proven reserves is estimated to be 171 billion barrels. Canadian crude oil production is expected to increase by 75% from 2012 to 2035, with production expected to reach 5.8 million barrels a day. Canada gets their oil from three main sources, Alberta, the Western Canada Sedimentary Basin, and offshore oil fields in the Atlantic. In 2011, Canadian crude oil production was at 3.7 million barrels a day. Around

⁴¹ EIA. "France - U.S. Energy Information Administration (EIA)."

⁴² EIA. "Canada - Analysis - U.S. Energy Information Administration (EIA)." 2012.

⁴³ NEB. "Energy Reports - Canada's Energy Future 2013 - Energy Supply and Demand Projections to 2035 - An Energy Market Assessment." 2013.

75% of this was from Alberta.⁴⁴ The development of oil sands makes the Canadian oil industry unique.

It is estimated that about 98% of Canadian reserves are from the oil sands. By 2035, oil sands are expected to account for 86% of production, which is much higher than 57% in 2012.⁴⁵ Even though Canada is a net exporter to the US, it is also currently one of the only countries to import oil from them. Imports are expected to rise from 95,000 barrels a day in 2013 to as much as 200,000 barrels a day soon.⁴⁶ This close relationship is demonstrated by the presence of multiple oil pipelines connecting the two countries. The construction of another one, the Keystone XL pipeline, is currently under consideration. If built, this pipeline would connect Alberta to Nebraska and have a capacity of 830,000 barrels a day. There are plans to construct more pipelines, particularly to the West Coast, where Canada can potentially expand oil exports.⁴⁷

Canada is as dependent on the US market to export its oil, as much as the US depends on Canada for oil imports. Around 99% of Canadian oil is being exported solely to the US, thus a decrease in US imports could be detrimental to the Canadian economy.⁴⁸ Since the US is increasing production and will probably start increasing oil exports it would also mean Canada might have another competitor in the future. An influx of oil to the global oil market from the US could also reduce the prices of oil, which would harm Canada since it is a net exporter.

There are already measures being taken to ensure that Canada's energy security is protected in the future. One way it is doing this is by trying to increase its variation of customers for oil exports. This is demonstrated by attempts to create pipelines to the West Coast that would make transport of oil to the Asian market more efficient.⁴⁹ This would reduce Canada's dependency on the US market.

The high probability of the creation of the Keystone XL pipeline also would lead to the creation (albeit temporary) of thousands of jobs on both sides, and would promote a closer relationship between the two countries. As stated in an article in Forbes the "final State Department review found that the pipeline would create upward of 42,000 jobs during the construction period alone, and it would do so without a significant environmental impact."⁵⁰ It would also allow easier and safer access to Canadian oil for the US, which again would further improve energy security in the US. However, Canada will remain one of the only countries the

⁴⁴ EIA. "Canada - Analysis - U.S. Energy Information Administration (EIA)."

⁴⁵ EIA. "Canada - Analysis - U.S. Energy Information Administration (EIA)."

⁴⁶ Krauss, Clifford. "Energy Secretary Calls Oil Export Ban Dated."

⁴⁷ EIA. "Canada - Analysis - U.S. Energy Information Administration (EIA)."

⁴⁸ EIA. "Canada - Analysis - U.S. Energy Information Administration (EIA)."

⁴⁹ EIA. "Canada - Analysis - U.S. Energy Information Administration (EIA)."

⁵⁰ Huber, Albert and Bowe, Peter. "The Keystone Pipeline Would Create Thousands Of Jobs." 7th Feb, 2014.

US will still rely on for oil imports.⁵¹ This makes the creation of the pipeline more beneficial because it would be used in the long run, even as imports decline.

The US shale boom will not be beneficial for Canada's energy security because it will more than likely compromise its ability to ensure that the supply of oil will meet the demand. Since the US will decrease imports as it becomes more energy secure. The US will not benefit if Canada's energy security declines significantly because it might cause a rift in its relationship, which could compromise the US' own energy security. To avoid this, the US could prioritize Canadian oil while cutting out others to maintain the positive oil relationship between the two countries.

Mexico

Mexico, like Canada, is a net exporter of oil. In 2011 it was producing 2.55 million barrels of crude oil a day and exporting 85% of this, approximately 1.1 million barrels a day, to the US. At the end of 2011 Mexico had over 10.2 billion barrels in proven oil reserves. Production is expected to continuously decrease over the years; with production expected to reach as low as 1.4 million barrels a day by 2025. Over 75% of Mexico's production is currently from offshore fields; 50% from the Bay of Campeche, and 25% offshore Tabasco State.⁵²

The projected reduction in oil imports for the US will not be beneficial for Mexico because it will mean a reduction in profits from oil exports. Especially since Mexico today is reliant on oil as a source of wealth; around 34% of government revenues in 2011. A loss in profits from exporting crude to the US can harm the energy security of Mexico because its oil production might not meet the loss in demand. The projected reduction in oil production might cushion the blow though, as Mexico might be forced to reduce its exports anyway to ensure energy security.⁵³

Despite being a net exporter of crude oil, it is still a net importer of refined products.⁵⁴ Because of this, one way to ensure that Mexico's relationship with the US will not be harmed is by helping them refine crude oil. The US might also be able to ease Mexico's reduction in production by starting to export crude oil to Mexico, to make up for any losses in supply if needed.

Brazil

Another country in the Americas with a close relationship to the US in terms of oil is Brazil. According to a 2010 EIA report, it was the 8th largest consumer of energy in the world, and the 10th largest producer. In 2011, oil and liquid fuels accounted for 47% of their energy

⁵¹ The Economist Intelligence Unit. "*Diminishing Dependence: Shrinking US Oil Imports*." 10

⁵² EIA. "Mexico - Analysis - U.S. Energy Information Administration (EIA)." 2012.

⁵³ EIA. "Mexico - Analysis - U.S. Energy Information Administration (EIA)."

⁵⁴ EIA. "Mexico - Analysis - U.S. Energy Information Administration (EIA)."

consumption. In 2013 it was estimated to have over 13 billion barrels of proven reserves, second only to Venezuela in South America. In 2012, Brazil was the largest liquid fuel producer in South America, producing 2.7 million barrels a day, 2.1 million of this being crude oil (EIA). In that same year, it was also exporting 550,000 barrels a day, with the United States being its largest customer, importing 187,000 barrels a day. Brazil's consumption of oil surpassed its production again in 2011; the last time this happened was in 2007, and this trend is expected to continue. In the same year, Brazil imported around 470,000 barrels a day of refined product. The US made up 166,000 barrels a day, which was 6% higher than the year before. Argentina was the only single country that supplied more.⁵⁵

Brazil plans to increase production to 5 million barrels a day and exports to 2.25 million barrels a day by 2021. The most recent major discoveries are in areas called pre-salt basins. The amount of oil and gas in these basins are estimated to potentially go as high as 50 billion barrels; it is currently extracting around 100,000 barrels a day from these fields. The energy corporation Petrobras is already planning to invest \$73 billion for exploration and production of these pre-salt fields. According to the EIA though there are still many technical and economical hurdles to overcome before Brazil can effectively produce these reserves.⁵⁶

Like Canada, Brazil is a major net exporter of oil and the US is its biggest customer. The influx of oil from the US will not be as beneficial to its energy security because exports to the US may decrease. However, its diversified export market strengthens Brazil's energy security. Brazil could counteract a decrease in US imports by increasing exports to its other customers, including India and China. An intelligence report by "The Economist" also predicts that Brazil, with Canada, will be one of the only countries to still export to the US after it has significantly reduced its imports.⁵⁷

As is true for all net oil exporters, a reduction in oil prices as a result of increased US exports would mean a reduction in Brazil's profits. The US will also become another competitor if it begins increasing exports. As consumption increases and it continues to develop though, Brazil might also be able to use some of its oil domestically, thereby counteracting any lost markets.

The likely scenario is that Brazil will be more negatively affected from the influx of oil that will be brought by the US. The US will not benefit from a decline in the energy security from Brazil, especially if it could damage their current relationship. One reason is because the US is still looking to Brazil as one of its few sources of imports in the future. Again, a way to prevent this from happening would be for the US to avoid significantly intervening in its

⁵⁵ EIA. "Brazil - Analysis - U.S. Energy Information Administration (EIA)." 2013.

⁵⁶ EIA. "Brazil - Analysis - U.S. Energy Information Administration (EIA)."

⁵⁷ The Economist Intelligence Unit. "*Diminishing Dependence: Shrinking US Oil Imports.*", 10

established markets. Another way would be to build upon their relationship based on refined oil. The US could continue buying crude oil from Brazil, in order to refine it and sell it back to them.

Conclusion

The increase in domestic oil supply as a result of shale oil development has already proved to be beneficial to US' energy security. Further increase will allow the US to be less reliant on the oil of countries who might conceivably use their exports as leverage against the US. It will also bring North America closer to full self-reliance in oil and gas, yet another advance to US energy security and therefore national security. Rising oil production will also continue to keep per-barrel prices around 6%-10% low relative to other parts of the world.

Security for the US is also directly tied to the security of its allies, especially those in the Americas, NATO, and East Asia (Japan and South Korea). Continued development of shale oil will mean that the US can act as a reliable source of key fuels for these allies, reducing their own dependence on petro-states like Russia and some members of OPEC. Overall, if the US were to accept the role of a major new exporter, it would increase competition in the global oil market, helping stabilize prices and providing a new option for importers. While this new role could result in some degree of added tension with other exporters, the overall benefits to US security and that of its allies would appear worth the risks.

Chapter Eleven

IMPACTS ON THE GLOBAL POSITION OF THE U.S.

Monica Reeder

Abstract

Through analysis of current US relations and movements to engage countries in energy cooperatives, this chapter examines the opportunity for strengthened US leadership in the global energy market. The first section analyzes the US's new position as top oil producer. The final sections examines US interests in the Middle East, as well as increased opportunities for relations with Venezuela, China, and Russia. Production of US shale oil has the potential to change the international playing field in favorable terms for the US, especially regarding energy needs.

Introduction

In October 2013, the US gained a new position as the world's largest producer of crude oil. This has led to a sharp decline in US crude oil imports, particularly from OPEC, and a marked increase in its exports of petroleum products, especially to Canada, Mexico, France, and China. In total, petroleum imports fell from a peak of 61% in 2005 to as low as 32% in early 2014. Meanwhile exports more than quadrupled over this same period, from 0.9 to 4.0 Mbbls/d.¹ Impacts from these changes are already strongly felt in energy relations between the US and other nations. With continued increases in US oil production, such impacts will only grow and, in some cases, intensify.

The strengthening of the US economy as a result of increased oil production has raised questions regarding the global position of the US and possible changes to its foreign policy. This chapter will analyze several of these major concerns. The first area of analysis will be an overview of the US's current global position, followed by a section on its new role as top oil producer in the world. The second area of analysis will consist of the future maintenance of a US presence in the Middle East region, due to a decrease in oil imports from OPEC, as well as relations between the US and Venezuela. The next section will examine US relations with China and how they may transform through increased US production of shale oil and petroleum products, along with encouragement for US companies to share technology with their Chinese counterparts. The third section will analyze the relationship of the US and Russia, which could potentially be strained by the increase in US production. Overall, the global position of the US

¹ Eia.gov. "AEO Table Browser - Energy Information Administration." 2014.
<http://www.eia.gov/oiaf/aeo/tablebrowser/#release=AEO2014ER&subject=0-AEO2014ER&table=1-AEO2014ER®ion=0-0&cases=full2013-d102312a,ref2014er-d102413a> (accessed 20 Jan 2014).

has the potential to strengthen US leadership in the world if it continues to produce and export shale oil and petroleum products, resulting in the decrease of Russian and OPEC influence in the global energy market. In addition, the US can pursue, with greater force, the implementation of global environmental initiatives.

Section I: Overall Position of the US

Until very recently, the US was the world's largest importer of oil.² At the same time, through use of its 5th fleet, it served as the world's guardian of continued oil shipments from the Persian Gulf, through which over a third of all exports travel every day. The US has longstanding arrangements and agreements with Saudi Arabia, the world's single swing producer. This also played a role in America's guardianship: to ensure that oil supplies would continue to the world's importers, including US allies, and keep the global economy running.³

Part of this role also included vulnerability to supply disruptions that could not be prevented. In the past several years, this included loss of supply from Libya, Tunisia, Syria, and Egypt due to the Arab Spring and to conflict in Sudan.⁴ As noted in the previous chapter of this report about energy security, energy is crucial to US security and foreign policy because access to reliable, affordable energy is central to economic strength at home, which is the foundation for US leadership in the world. The US's pursuit of oil sanctions against Iran demonstrated exactly how the US can use its new position to pursue foreign policy interests. Increased production allowed the US to persuade other oil importing nations to eliminate or significantly reduce Iranian imports as part of US policy to deter Iranian nuclear proliferation.⁵

The US has entered a new stage where oil imports have diminished and oil exports have increased. With regard to imports, the reduction is overwhelmingly a result of increasing development and production of shale oil, as illustrated below in **Figure 1**. Oil production has grown exponentially since 2008. The volume of exports, although remarkable, is not even the most important aspect of the US's race to the top of the energy economy.⁶ The US can now protect its allies from other exporters, like Russia, who tie oil delivery to political objectives. Increased US liquefied natural gas (LNG) exports combined with shrinking oil imports will also limit OPEC's ability to control prices, as it has historically done.⁷

² Eia.gov. "U.S. Energy Information Administration (EIA) - Source." 2013.

http://www.eia.gov/forecasts/archive/aeo13/source_oil_all.cfm#tightoil (accessed 20 Jan 2014).

³ Abdulhaffar, Mahmood. "Will the U.S. Fifth Fleet Relocate from Bahrain?" 29th July, 2013,

<http://muftah.org/will-the-u-s-fifth-fleet-relocate-from-bahrain/> (accessed 26 Feb 2014).

⁴ Myers Jaffe, Amy and Edward Morse. "Liquefied Natural Profits: The United States and the Remaking of the Global Energy Economy." *Foreign Affairs* (2013), 1-2. Accessed 6 Feb 2014.

<http://www.foreignaffairs.com/articles/139932/amy-myers-jaffe-and-edward-l-morse/liquefied-natural-profits>.

⁵ Donilon, Tom. "American Power: Farewell to Declinism." *Foreign Affairs* (2013) Accessed 3 Feb 2014.

<http://www.foreignaffairs.com/articles/139509/tom-donilon/energy-and-american-power>.

⁶ Myers Jaffe and Morse, "Liquefied Natural Profits"

⁷ Ibid.

However, the US ban on oil exports is still in place requiring energy companies to obtain permits from the US Dept. of Commerce in order to legally sell crude oil outside the US. The aim of the ban was to secure domestic supply and reserves while decreasing foreign imports during the 1970s oil crises. Removing the ban would allow US oil companies to sell oil around the world and promote US interests in a free-trade energy market, yet some Democratic officials and representatives oppose the idea, arguing that the oil should remain a domestic resource to benefit the US and decrease imports from the Middle East.⁸

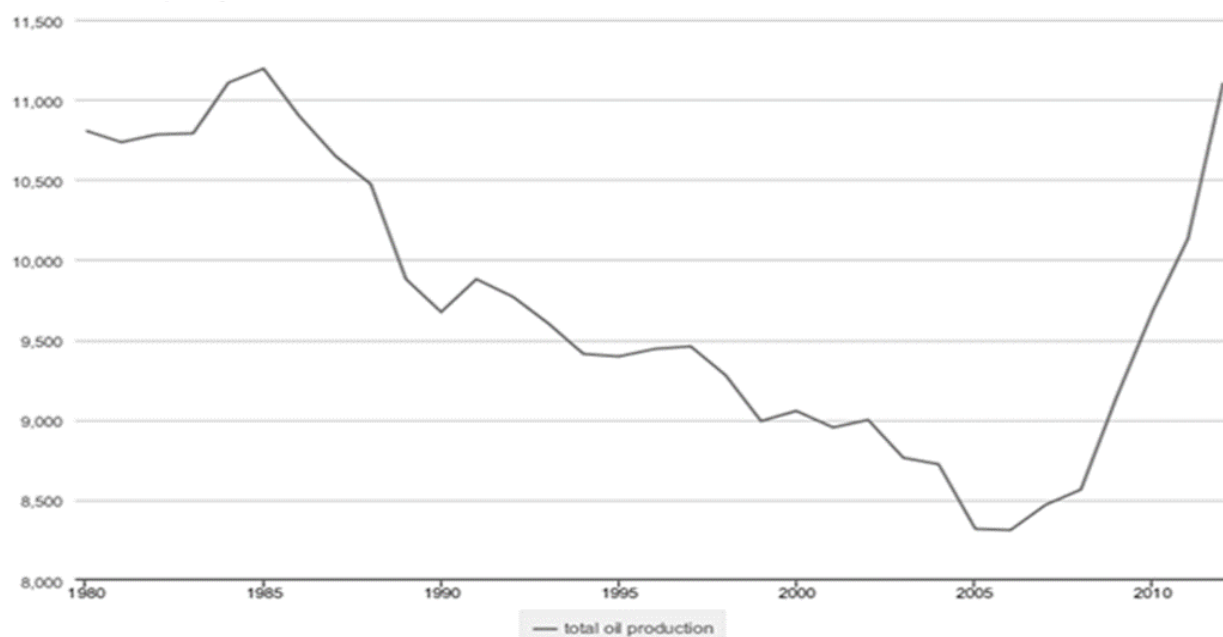


Figure 1: US oil production in Thousand barrels per day, 1980-2012 (Source:EIA).

Section II: Changes in America’s Global Role

While the US will undoubtedly retain its guardian role, its position as vulnerable importer of crude oil and small-scale exporter of petroleum products has dramatically changed and will continue to do so. In the US, multistage fracking has allowed increased extraction of oil leading to an increase from 6.5 Mbbls/d in 2012 to an outlook of 9.6 Mbbls/d in 2019.⁹ The resulting decline in imports has been greatest with respect to OPEC; net imports from cartel countries peaked in 2007 at 5.9 Mbbls/d, then progressively decreased to an average of 3.7 Mbbls/d in

⁸ Clayton, Blake. "The Case for Allowing U.S. Crude Oil Exports." *Council on Foreign Relations* (2013) Accessed 4 Feb 2014. <http://www.cfr.org/oil/case-allowing-us-crude-oil-exports/p31005#>.

⁹ Eia.gov, "U.S. Energy Information Administration (EIA) - Source."

2013.¹⁰ While this can be considered an improvement in overall US energy security, it does not indicate a retreat of national interests in the Middle East.

Though the US remains a net oil importer, it is also now one of the world's top exporters of refined petroleum products. This provides the US with new, favorable leverage on the global stage. The US can use shale oil and growing petroleum product exports to not only help increase its allies' energy security, but also to increase its overall influence in energy circles by promoting the sharing of technology and know-how related to shale oil and gas development. US exports of crude oil have increased to 0.2 Mbbls/d in 2013, up from 0.009 Mbbls/d in 2002. More important is the increase in US exports of petroleum products, which are favorable to importing countries that lack refining capacity. US exports of petroleum products have increased from 0.9 Mbbls/d in 2002 to 4.0 Mbbls/d by the end of 2013.¹¹ **Figure 2** illustrates the increase in US exports of oil and petroleum products to countries around the world, particularly Canada, Mexico, and the Netherlands.

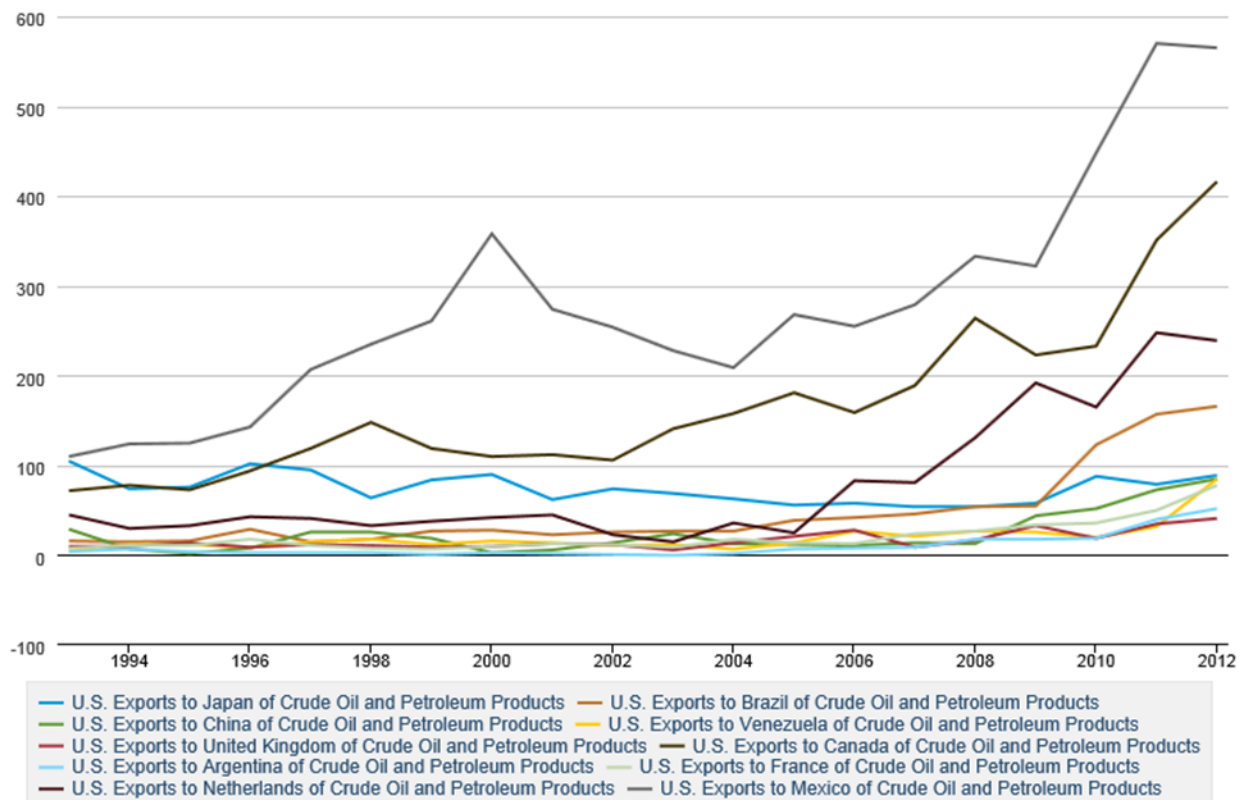


Figure 2: US Oil Exports in Million barrels per day by Destination (1993-2012) Source: US Energy Information Administration

¹⁰ Eia.gov. "U.S. Total Crude Oil and Products Imports." 2014. http://www.eia.gov/dnav/pet/pet_move_impcus_a2_nus_ep00_im0_mdbl_m.htm (accessed 23 Jan 2014).

¹¹ Eia.gov. "Total Crude Oil and Products Exports by Destination." 2014. http://www.eia.gov/dnav/pet/pet_move_expc_a_EP00_EEX_mdbl_m.htm (accessed 6 Feb 2014).

The tight oil revolution in the US has fueled job growth and puts the US in a position to use energy exports and technology as a foreign policy tool. The US's new position as top oil producer has encouraged rethinking by many countries as to who they want to align with. For example, many Asian nations are now looking to the US as an alternative to China, as well as many European countries that are looking to the US as an alternative to Russia.¹² This shift in global favorability after years of disapproval will allow the US to broaden economic relations with a growing Asia and a strong Europe, which can only benefit the US by creating and strengthening trade partners.

Not only will exports help to balance out the US trade deficit, but the extraction of oil in the US has and will continue to create jobs and boost the economy. The fracking revolution is currently projected to create, both directly and indirectly, approximately 2.5 million jobs and add \$350 billion to US GDP by 2015.¹³ Such an increase in US economic growth will increase the nation's ability to maintain its global influence in important areas, not least in energy.

Such advantages for US influence will inevitably be limited by the size of the recoverable oil resource. At present, this remains undetermined. Moreover, oil prices will play an important role. There is a general consensus that US production of oil will peak near 2020 and then begin to decrease, but the extent of this decrease is still uncertain. Future high price scenarios, such as that displayed in **Figure 3**, suggest that new innovations may continue to unlock further resources.¹⁴ However, most current forecasts project a gradual decline in non-OPEC production over the next several decades, thus giving OPEC the upper hand in the energy market. Some analysts argue that in 2040 the US and its allies will have reduced dependency on oil as a result of future breakthroughs in gas efficient transportation, making OPEC's dominance in oil irrelevant.¹⁵

¹² Bremmer, Ian and Kenneth Hersh. "When America Stops Importing Energy." 22nd May, 2013, <http://www.nytimes.com/2013/05/23/opinion/global/when-america-stops-importing-energy.html> (accessed 24 Jan 2014).

¹³ U.S. Department of State. "*World Shale Oil & Gas*." September 5, 2013.

¹⁴ Eia.gov, "U.S. Energy Information Administration (EIA) - Source."

¹⁵ Furman, Jason. "Reducing America's Dependence on Foreign Oil As a Strategy to Increase Economic Growth and Reduce Economic Vulnerability." *The White House Blog* 28th August, 2013. <http://www.whitehouse.gov/blog/2013/08/29/reducing-america-s-dependence-foreign-oil-strategy-increase-economic-growth-and-redu> (accessed 26 Feb 2014).

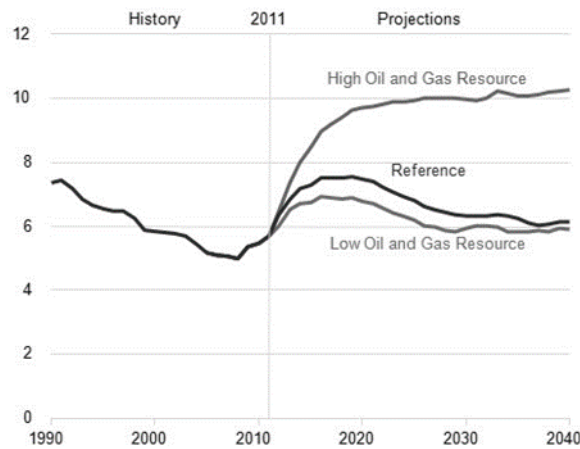


Figure 3: US Oil Resource Scenarios in Million barrels per day (1990-2012) Source: US Energy Information Administration

The US has engaged in the pursuit of cooperation with other countries on the extraction and development of new energy sources within foreign borders. Washington has engaged with countries, such as Poland, Ukraine, Jordan, China, Columbia, Chile, and Mexico, to share responsible practices regarding development of unconventional energy resources, such as tight oil. The US has focused on issues such as water management, air quality, permitting, contracting, and pricing, which are all critical to successful development of policy and investment in the environment.¹⁶ The creation of the Unconventional Gas Technical Engagement Program (UGTEP) in 2010 by the US Department of State is an example of this engagement.¹⁷ Though such programs have mostly focused on tight gas, rather than tight oil, the US can use these as models for leadership in all types of unconventional production around the globe.

Such cooperation is important if the US wishes to avoid the “additional danger of non-U.S. companies, with less advanced technologies, trying to replicate these extraction methods and potentially leading to environmental disaster.”¹⁸ There is worry that fracking in other countries may go unregulated and cause severe damage to the environment. These concerns are important as the US leads the world in a new energy abundant age. Cooperation in the development of shale reserves is a tool the US can use to strengthen relations with countries around the globe—maintaining positive relationships that benefit the US and the environment.

Energy has a very crucial role in the lives of everyone in the world, especially when it comes to economic development and energy sustainability.¹⁹ As noted in the previous chapter of this report, energy security is the foundation for economic growth and national security. The US has expressed willingness to cooperate with any countries wishing to produce their own reserves.

¹⁶ Donilon, “American Power”

¹⁷ State.gov. "Unconventional Gas Technical Engagement Program (UGTEP)." 2014. <http://www.state.gov/s/ciea/ugtep/index.htm> (accessed 27 Feb 2014).

¹⁸ Inter Press Service. "U.S. Moving Toward Controversial New Role in Global Energy Market - Inter Press Service." 2013. <http://www.ipsnews.net/2013/06/u-s-moving-toward-controversial-new-role-in-global-energy-market/> (accessed 22 Feb 2014).

¹⁹ U.S. Department of State. "World Shale Oil & Gas."

This illustrates a desire to share technology and work together to reduce global climate changing factors, such as greenhouse gas emissions, which could be very important for US interests in maintaining stable, positive relations with other countries and combatting global climate change, as well as pursuing other foreign policy interests.



Figure 4: US Imports from OPEC, 1970-2012 (Source: EIA).

Section III: US Relations with the Middle East & OPEC

With increasing independence from OPEC oil, as shown below in **Figure 4**, there is debate regarding maintenance of US presence in the Middle East.²⁰ US oil imports from OPEC have been decreasing since 2007 when they peaked at 5.9 Mbbls/d.²¹ The big question here is whether the US will continue to have strong economic and political interests in the Middle East if OPEC imports are significantly reduced. This kind of concern is only amplified by claims about the possibility of US energy independence.²²

²⁰ Downs, Erica. "China-Middle East Energy Relations." *Brookings* (2013) Accessed 29 Jan. 2014. <http://www.brookings.edu/research/testimony/2013/06/06-china-middle-east-energy-downs>.

²¹ Eia.gov. "U.S. Total Crude Oil and Products Imports."

²² Parker, Ashley. "Romney Unveils Plan for Energy Independence." 23rd August, 2013, <http://thecaucus.blogs.nytimes.com/2012/08/23/romney-unveils-plan-for-energy-independence/?action=click&module=Search®ion=searchResults%230&version=&url=http%3A%2F%2Fquery.nytimes.com%2Fsearch%2Fsite%2Fsearch%2F%23%2Fenergy%2Bindependence%2Bparker%2F> (accessed 3 Feb 2014).

Energy independent or not, the US will likely continue to have interests in the Middle East for several reasons. As long as the Middle East is producing oil, Israel requires US security, and nuclear proliferation concerns exist, then the US will have interests in the region.²³

[Specific Country Relations: Saudi Arabia & Venezuela]

US production of oil has caught the attention of the entire world, but is unlikely to change the overall outlook of OPEC to the point that they change their strategies. However, US relations with Saudi Arabia and Venezuela may have the opportunity to change. OPEC Secretary General Abdalla S. El-Badri said in late 2013 that, “[f]ossil fuels will continue to play the dominant role in meeting demand,”²⁴ which expresses the lack of OPEC’s concern. It is unlikely that US production of shale oil will be able to change OPEC’s long-term dominance in oil, unless OPEC and Russia team up as noted at the end of this chapter. The role of OPEC countries in quenching the world’s thirst for oil is momentarily reduced by rising output from the US, oil sands in Canada, and deep-water production in Brazil, but by the mid-2020s, non-OPEC production is expected to decrease and countries in the Middle East will provide most of the global supply again.²⁵

Saudi Arabia, the top oil producer of OPEC, has experienced shifts in its oil production in the last decade, portraying its role as swing-producer. Oil production decreased to 9.8 Mbbls/d in 2009 then rose sharply over the next few years to 11.7 Mbbls/d in 2012.²⁶ The increase was mainly in response to supply disruptions related to the 2010-2011 Arab uprisings, especially those in Libya. Saudi Arabia’s increase in production demonstrates that the OPEC strategy of producing when it needs to and holding back when it wants to is still a viable playing card in its political deck. Such production is predicted to continue increasing, even in the face of rising US production of crude oil and petroleum products in order to keep prices at or near current levels,²⁷ due to projected increases in demand for oil from developing nations. However, a wild card here is the possible spread of shale oil production to other nations, such as China, now the world’s largest importer.

The US and the Gulf Cooperation Council (GCC) signed agreements in 2012 to maintain cooperative relationships. This illustrates US interest in maintaining positive relations with several oil producing countries that are also part of OPEC. The agreement was put in place to

²³ Downs, “China-Middle East Energy Relations”

²⁴ Russia Today. "Oil to remain dominant on energy market – OPEC." 29th October, 2013, <http://rt.com/search/shortnews/term/Oil+to+remain+dominant+on+energy+market+--+OPEC/> (accessed 13 Feb 2014).

²⁵ Eia.gov, "U.S. Energy Information Administration (EIA) - Source."

²⁶ Eia.gov. "Saudi Arabia - U.S. Energy Information Administration (EIA)." 2013. <http://www.eia.gov/countries/country-data.cfm?fips=SA> (accessed 2 Feb 2014).

²⁷ Haykel, Bernard. "Is there a crisis in US-Saudi relations?" 26th Nov., 2013, <http://america.aljazeera.com/opinions/2013/11/relations-us-saudiarabia.html> (accessed 8 Feb 2014).

establish a joint committee for discussion of areas where the GCC and the US share interests, including opportunities for enhancing economic, commercial, investment and technical cooperation.²⁸ Although not all GCC countries are part of OPEC and not all OPEC countries are part of GCC, Saudi Arabia has a strong leadership position in both and will continue to be very important to US interests, especially after US production of oil declines in the future.

Venezuela is another crucial player in OPEC and its recent domestic events may create opportunities for increased cooperation with the US. Relations with Venezuela are at a critical point after the recent death of the Venezuelan President Hugo Chávez, along with the prospect of new energy relations with the US as US oil production is increasing. Venezuela had 211 billion barrels of proven oil reserves in 2011, the second largest in the world. Its unconventional heavy oil and bitumen make up the larger part of this and could raise the country's proven reserves to over 300 billion barrels in the future. Its production capacity for conventional oil, however, has decreased significantly over the last decade. Indeed, the significance of Venezuela to the American energy sector has been in decline. For this and other reasons, imports from Venezuela to the US have declined by over 50% since 2005, from 1.7 Mbbls/d to 0.7 Mbbls/d in August 2013.²⁹ Nonetheless, the US remains the dominant export destination for Venezuelan crude oil.

The EIA has also examined the US energy relationship with Venezuela from the standpoint of US exports to that country. There has been historical energy cooperation between the two countries, but US exports to Venezuela have increased ten-fold since 2004. The most notable increase has occurred over the last two years due to refinery complications in Venezuela.³⁰ Alongside the death of Chávez, the production of US shale oil has given the US a strong hand to use in relations with Venezuela, which always have ties to mutual energy dependence.

Historically the US and Venezuela have been energy partners, but political differences have made the reliability of Venezuelan oil and cooperation fragile. In 2006 Venezuelan Minister of Oil, Rafael Ramírez, signaled that the Venezuelan government would divert oil supplies intended for the US to other buyers, such as China, as a way to express discontent at the US.³¹ Also, Chávez moved to nationalize more of Venezuela's oil by regulating that national companies had to receive at least 60% of profits from agreements made with foreign companies. This signaled that Venezuela was unlikely to cooperate with energy partners and would continue

²⁸ U.S. Department of State. "*Gulf Cooperation Council to Strengthen Economic Ties with U.S.*" October 1, 2012.

²⁹ Eia.gov. "Venezuela - Analysis - U.S. Energy Information Administration (EIA)." 2014. <http://www.eia.gov/countries/cab.cfm?fips=VE> (accessed 10 Feb 2014).

³⁰ Krauss, Clifford. "Dwindling Production Has Led to Lesser Role for Venezuela as Major Oil Power." 8th March, 2013, http://www.nytimes.com/2013/03/09/world/americas/venezuelas-role-as-oil-power-diminished.html?_r=0 (accessed 5 Feb 2014).

³¹ Forero, Juan. "Venezuela Cautions U.S. It May Curtail Oil Exports." 27th Feb., 2006, http://www.nytimes.com/2006/02/27/international/americas/27venez.html?_r=0 (accessed 5 Feb 2014).

to use oil to pursue Venezuelan interests. This included urging OPEC to raise oil prices, showering allies like Cuba and Nicaragua with subsidized oil exports, and insulting the US while selling it oil.³²

After Chávez's death in March 2013 there is opportunity for positive US-Venezuelan relations and for the pursuit of economic, political, and certainly energy related ties and cooperation. Undoubtedly there are obstacles to these relations due to political disputes as new Venezuelan leaders try to preserve anti-American sentiment to please political elites, but there are potential areas for cooperation.³³ Both countries are signatories of several Western Hemisphere climate and trade agreements, which could be the foundation for further cooperation. Cooperation can involve working toward increased energy security for the Western Hemisphere, as well as addressing and combatting global environment concerns.

Section IV: Impacts on US Relations with China

US relations with China are crucial for future US economic growth. The US-China relationship can be strengthened by the US through increased energy exports to China and the sharing of shale resource development with Chinese energy companies and officials. China's technically recoverable shale oil resources are the world's third largest, just behind Russia and the US.³⁴ Despite these vast resources, the lack of fracking expertise, in addition to geologic complexities in the relevant shales, has prevented successful development to date.³⁵ China is now the world's largest oil importer, having first exceeded the US in September 2013. Moreover, it imports more oil from the Middle East than any other region of the world, accounting for nearly two-thirds of imports. **Figure 5** displays that China received 19% of its imports from Saudi Arabia, 14% from Angola, and 8% from Iran and Iraq, which are all OPEC producers.³⁶ China has acquired more influence in the region through its trade deals with these countries. This has implications for Chinese relations with the Middle East, but more importantly places the US in a unique diplomatic situation.

Countries like China, which is estimated to hold more shale gas than the US and Canada combined, are hungry to learn the secret to successful development and production of their resources. This may be just the diplomatic opportunity the US has been seeking to hold greater

³² Krauss "Dwindling Production Has Led to Lesser Role for Venezuela as Major Oil Power"

³³ U.S. Department of State. "State's Jacobson on U.S. Priorities in Western Hemisphere." September 27, 2013.

³⁴ Downs, Erica. "Implications of the U.S. Shale Energy Revolution for China." *Brookings* (2013) Accessed 29 Jan 2014. <http://www.brookings.edu/blogs/up-front/posts/2013/11/07-shale-energy-revolution-china-downs#>.

³⁵ Hunt, Katie. "China Faces Steep Climb to Exploit Its Shale Riches." 30th Sept., 2013, <http://www.nytimes.com/2013/10/01/business/energy-environment/china-faces-steep-climb-to-exploit-its-shale-riches.html> (accessed 2 Feb 2014).

³⁶ Eia.gov. "China - Analysis - U.S. Energy Information Administration (EIA)." 2013. <http://www.eia.gov/countries/cab.cfm?fips=CH> (accessed 14 Feb 2014).

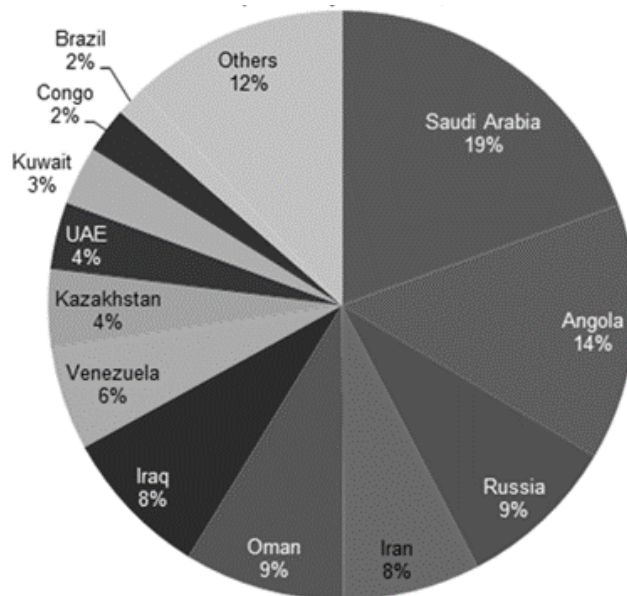


Figure 5: China's Oil Imports, 2013 (Source: EIA).

cooperation with Beijing.³⁷ By sharing its technology and policy practices, the US could curtail the rising influence China has in the Middle East by providing China with its own means of oil and gas production at home.

Alternatively, Chinese influence in the Middle East region could be used as a stabilization tool in conflict-ridden countries, such as Iraq. Additionally, the US and China have a mutual interest to work together on the global energy stage because both countries will benefit from secure, affordable, and cleaner supplies of energy. Washington and Beijing can work together to fulfill their energy goals through regulatory, technical, and industry exchanges.³⁸ Already there have been movements by both countries to cooperate at both governmental and business levels to pursue sustainable energy production, especially with the creation of the US-China Shale Gas Resource Initiative in 2009.

[Rising Chinese Influence in the Middle East]

China has increased its influence in the Middle East through deals with several governments in the region, especially Iraq and Iran. This is potentially harmful to US interests, but could be useful for the US in the long run. After the 2003 Iraq War, China filled the vacuum in Iraq's oil fields that the US intended to fill after its invasion. Because Chinese oil companies are tools of the Chinese state and not beholden to the interests of shareholders, they can accept the small oil profit terms of the Iraqi government because they are more interested in obtaining oil for China's rapidly growing economy. This relationship could be concerning for the US

³⁷ Brennan, Elliot. "Shale Gas: The Key in the US' Asia Pivot?" 8th March, 2013, <http://www.chinausfocus.com/energy-environment/shale-gas-the-key-in-the-us-asia-pivot/> (accessed 3 Feb 2014).

³⁸ U.S. Department of State. "National Security Advisor Donilon on Global Energy Policy." April 24, 2013.

because China now has more influence in the region to impede US interests, but if China is benefitting from the US invasion of Iraq it has not necessarily been bad for US interests.³⁹ Increased Iraqi production by Chinese oil companies has helped US interests by keeping the global oil supply stable as the US pursued sanctions against Iran.

If Chinese influence in the Middle East is concerning, the US can decrease Chinese presence and influence in the region by reducing China's reliance on oil from OPEC. This can be accomplished through increased US oil exports to China and encouragement of US companies to partner with those in China to develop shale oil there. The more business the US does with China the more it can pressure China to cut ties with Iran, which has become an important interest for the US. Chinese oil companies have already been investing in US oil production. Since 2010, China's national oil companies have spent more than \$10 billion on oil assets in the US, most of which has been spent on unconventional projects, such as fracking. Chinese interest in US production of oil can be used as a tool to curb China's imports from Iran. Because proposed acquisitions of US companies should be reviewed by the Committee on Foreign Investment in the United States (CFIUS), which analyzes the proposal for national security risks, any proposals involving countries whose international affairs may collide with US interests will be questioned and even declined.⁴⁰

[US-China Cooperation in Energy]

Over the last decade there has been dialogue between the US and China focused on the development of energy in both countries as well as engagement in the reduction of global carbon emissions. The US-China Joint Statement on Energy Security Cooperation noted that the two countries, as the world's largest producers and consumers of energy, share common interests and responsibilities to ensure energy security and face common challenges. They have discussed ways to diversify their sources of supply, further develop domestic energy resources to meet growing demand needs, and strengthen energy security.⁴¹ *China Focus* noted that "[f]oreign company expertise, particularly that of US companies, may provide significant improvements to the security, and environmental safety, of the growing Chinese economy – a good thing for the world economy and the US."⁴² The US has an interest in cooperation with China because of US-Chinese economic ties, as well as the fact that China is the world's largest producer of carbon emissions.

³⁹ Arango, Tim and Clifford Krauss. "China Is Reaping Biggest Benefits of Iraq Oil Boom." 2nd June, 2013, <http://www.nytimes.com/2013/06/03/world/middleeast/china-reaps-biggest-benefits-of-iraq-oil-boom.html?pagewanted=all> (accessed 2 Feb 2014).

⁴⁰ Downs, "China-Middle East Energy Relations."

⁴¹ The White House. "Joint Fact Sheet on Strengthening U.S.-China Economic Relations." December 5, 2013.

⁴² Brennan, "Shale Gas: The Key in the US' Asia Pivot?"

Part of the new US-China cooperation included the creation of the US-China Shale Gas Resource Initiative in 2009 that aimed to increase the production of shale oil and gas in China by encouraging US companies and officials to work with their Chinese counterparts to share expertise about the fracking process. In April 2010, the US Dept. of Energy and the US Trade and Development Agency hosted a three-day workshop in Beijing for Chinese officials and oil industry members.⁴³ In September 2010, the Tenth US-China Oil and Gas Industry Forum was held in Fort Worth, Texas, which included about 200 government and industry participants from both countries who focused on shale gas development, including a site visit to Fort Worth's Barnett Shale. In 2012, as a part of the initiative, a US-China Shale Gas Training Program was launched, wherein \$378,000, funded by Congress, was spent to send fracking workers from the US to China in order to host workshops to help introduce Chinese energy sector officials and project sponsors to US shale gas production practices, policies and technologies.⁴⁴ Also, the Chinese oil company Shenhua Energy, the world's second largest coal company, joined Energy Corp. of America to drill 25 shale gas wells in the Marcellus shale reserve. The 30-year operation is Shenhua Energy's first venture into foreign shale gas, as it plans to push shale development back home.⁴⁵

The Obama administration has also shown interest in working closely with China to reduce global greenhouse gas emissions. The US-China Shale Gas Resource Initiative also aimed to address this concern and in 2013 both countries made statements regarding their desire to work together to create the Climate Change Working Group in anticipation of the 2013 Strategic and Economic Dialogue (S&ED). The Working Group was made to determine and finalize ways in which the countries can advance cooperation on technology, research, conservation, and alternative and renewable energy.⁴⁶ Following this was a meeting between President Obama and President Xi Jinping where both leaders expressed interests in sharing technological know-how to reduce carbon emissions.⁴⁷ The US shale oil boom has created an atmosphere in which such cooperation can be pursued with certain ease.

⁴³ U.S. Department of State. "Facts on 91 Outcomes from U.S.-China Strategic Track." July 12, 2013.

⁴⁴ Hall, Wynton. "Govt Offering \$378,000 to Teach Chinese Firms U.S. Shale Gas 'Technologies'." 17th December, 2012, <http://www.breitbart.com/Big-Peace/2012/12/17/Govt-Offering-378-000-To-Teach-Chinese-Firms-U-S-Shale-Gas-Technologies> (accessed 13 Feb 2014).

⁴⁵ Globalenergyinitiative.org. "Global Energy Developments to Watch in 2014." 2014. <http://globalenergyinitiative.org/world/117-global-energy-developments-2014.html> (accessed 12 Feb 2014).

⁴⁶ U.S. Department of State. "China-U.S. Joint Statement on Climate Change." April 13, 2013.

⁴⁷ Calmes, Jackie and Steven Lee Meyers. "U.S. and China Move Closer on North Korea, but Not on Cyberespionage." 8th June, 2013, http://www.nytimes.com/2013/06/09/world/asia/obama-and-xi-try-building-a-new-model-for-china-us-ties.html?pagewanted=all&action=click&module=Search®ion=searchResults%230&version=&url=http%3A%2F%2Fquery.nytimes.com%2Fsearch%2Fsite%2F%3Faction%3Dclick%26region%3DMasthead%26pgtype%3DHomepage%26module%3DSearchSubmit%26contentCollection%3DHomepage%26t%3Dqry947%23%2Fus+china+climate+calmes&_r=0 (accessed 4 Feb 2014).

Section V: Impacts on US Relations with Russia

Russia is one of the two top exporters of crude oil in the world and is also a major exporter of petroleum products. Net oil exports (crude and refined products), along with natural gas, are key drivers of the Russian economy and are sold overwhelmingly to European nations and China, **Figure 6**.⁴⁸ As a result, the rise in US oil production and export of petroleum products introduces a new potential competitor to those markets on which Russia is highly dependent. As shown above in **Figure 2**, US exports to the Netherlands have increased substantially and, previously noted, US companies sharing fracking expertise with China could allow China to reduce Russian imports as it taps into its own shale reserves.

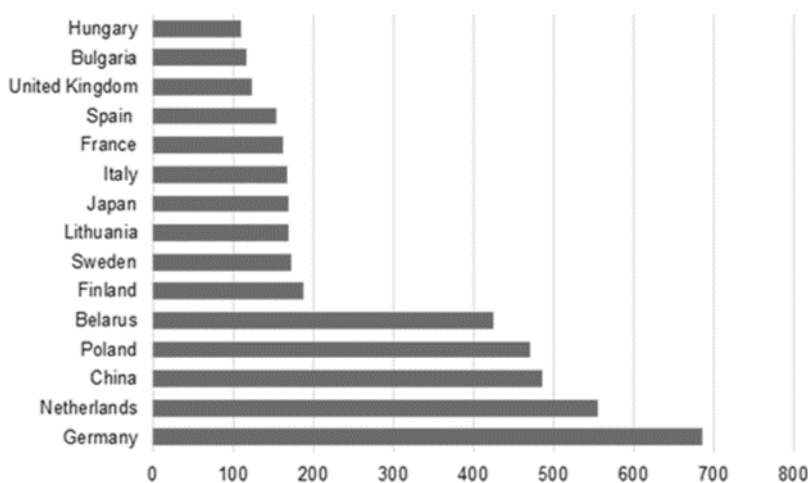


Figure 6: Russian Oil Exports in Thousand barrels per day, 2012 (Source: EIA)

Russia has also been experiencing production issues due to aging infrastructure in refineries, which have not been upgraded in decades. This is part of what accounts for the large gap between US and Russian refinery capacity portrayed in **Figure 7**. Growing U.S. exports of petroleum products will expand this gap further over the next few years.⁴⁹

[Exporting US Oil: Relations with Russia]

These trends raise the possibility of new tensions with Russia, particularly if the US lifts its ban on exporting crude oil and American companies seek to compete for buyers in Europe and China. This is not certain, however, and will depend to a large degree on demand in these

⁴⁸ Eia.gov. "Russia - Analysis - U.S. Energy Information Administration (EIA)." 2014. <http://www.eia.gov/countries/cab.cfm?fips=RS> (accessed 18 Feb 2014).

⁴⁹ Gustafson, Thane. "Russian Oil Industry at a Crossroads as Infrastructure Ages." 4th December, 2012, <http://www.nytimes.com/2012/12/05/business/global/russian-oil-industry-at-a-crossroads-as-infrastructure-ages.html?pagewanted=all> (accessed 16 Feb 2014).

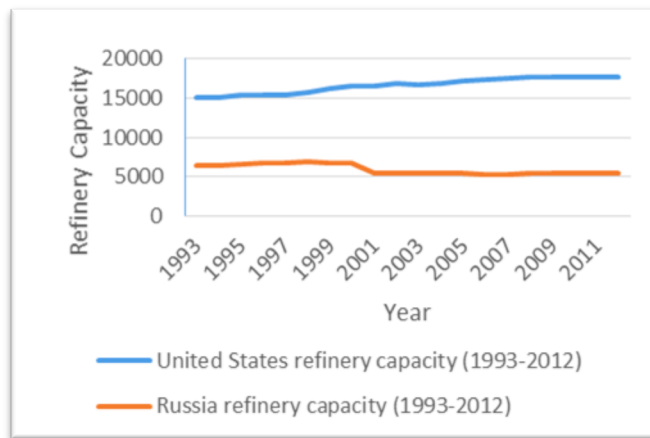


Figure 7: Refinery Capacity of US & Russia, 1993-2012 (Source: EIA).

nations. Moreover, increasing US exports may also help maintain the global oil market as Russia's infrastructure deteriorates.

Based on its experience with Russian gas, it seems likely that Europe would welcome US exports. The recent troubles between Russia and Ukraine, leading to the repeated cut off of gas in winter months⁵⁰ certainly provide motive for this. Russia's efforts to prevent such troubles in the future by building new pipelines, notably Nord Stream (completed) and South Stream (in construction), have not entirely reassured nations in the EU that Moscow is a reliable partner for energy security.⁵¹ Russia has used the delivery of natural gas and other energy sources elsewhere to satisfy political objectives. This has forced countries importing Russian energy to search for alternatives. US energy exports to Europe have already been detrimental to Russia because Europeans now have alternatives to Russian pipeline gas in the form of liquefied natural gas originally intended for the US.⁵²

At the same time there has been dialogue between the US and Russia to cooperate in combating global warming. In 2010 the US-Russia Energy Working Group was created as one of several initiatives under the Bilateral Presidential Commission, which aimed to increase cooperation regarding global concerns. The Working Group demonstrates the importance of dialogue between the two countries and the deployment of clean energy technologies and services, implemented through a range of activities including public-private partnerships, city-to-city pairings, trade missions, and university links.⁵³

⁵⁰ Kramer, Andrew. "Russia Cuts Off Gas Deliveries to Ukraine." 1st January, 2009, <http://www.nytimes.com/2009/01/02/world/europe/02gazprom.html?action=click&module=Search®ion=searchResults%230&version=&url=http%3A%2F%2Fquery.nytimes.com%2Fsearch%2Fsite%2F%23%2Frussia%2Bukraine%2Benergy%2Bkramer%2F> (accessed 13 Feb 2014).

⁵¹ Kramer, Andrew. "Flow Starts in Gas Pipeline From Russia to Germany." 6th September, 2011, <http://www.nytimes.com/2011/09/07/business/global/flow-starts-in-gas-pipeline-from-russia-to-germany.html?action=click&module=Search®ion=searchResults%230&version=&url=http%3A%2F%2Fquery.nytimes.com%2Fsearch%2Fsite%2F%23%2Faction%3Dclick%26region%3DMasthead%26pgtype%3DHomepage%26module%3DSearchSubmit%26contentCollection%3DHomepage%26t%3Dqry652%23%2Frussia+pipelines&r=0> (accessed 28 Feb 2014).

⁵² Myers Jaffe and Morse, "Liquefied Natural Profits"

⁵³ U.S Department of State. "Facts on U.S.-Russian Energy, Energy-Efficiency Cooperation." June 18, 2012.

The increasing presence of the US in the global energy market may force cooperation between Russia and the GCC. If the price of oil declines due to US production of oil, then Russia will not obtain its usual petro dollars. This may push the government to pursue other means of economic growth, such as increasing the manufacturing sectors of the economy that are already in place.⁵⁴ It may also encourage Russia to look to Saudi Arabia for help. So far, long-standing antipathy between Russia and the GCC, as well as the close US-Saudi security relationship, have weighed against an Arab-Russian energy coalition. However, increasing US oil production and exports may change that thinking. Saudi Arabia has already made proposals to Russia about constructing an energy coalition.⁵⁵

Conclusion

The world is entering a new stage where energy supply concerns have been reduced drastically by increasing US production of shale oil, as well as US aid for the development of shale reserves in other countries. Vulnerability to energy disruptions has decreased for the US and its allies. Also, Russian and OPEC dominance in energy markets has been reduced, forcing them to rethink political strategies. This could be an advantage to US interests, or a disadvantage if a Russian-GCC coalition results. Overall the US production of shale oil will continue to increase energy security around the world and create opportunities for US leadership in the production of energy resources and innovations, as well as leadership in global environmental concerns.

⁵⁴ Russia Today. "Russia pivots towards industry, not reliant on oil-Medvedev." 10th Dec., 2013, <http://rt.com/business/medvedev-oil-russia-industry-996/> (accessed 1 Feb 2014).

⁵⁵ Myers Jaffe and Morse, "Liquefied Natural Profits"

PART V

Future Outlook

Part V assesses how future technological innovations will impact the outlook of the shale oil revolution. Chapter Twelve focuses on how advancements in fracking technology have significantly improved the overall efficiency of unconventional drilling, but additionally, how several innovations have been sparked as a response to public concerns. Innovative patterns suggest that fracking technology will continue to evolve, even as the boom stabilizes. Chapter Thirteen examines current and projected oil consumption within US transportation sectors to assess the effect that shale oil production might have on US oil consumption and alternative energy use. Developments in renewable energy technologies and the role they are taking domestically and internationally are deeply analyzed. The role of consumers and producers, as well as government support, is evaluated.

Chapter Twelve

TRENDS IN INNOVATION

Stephanie Tam

Abstract

This chapter showcases new innovations in fracking technology that increase efficiency, address health hazards, and reduce environmental impacts. The first section discusses General Electric's approach to frack water treatment. The second section examines Halliburton's methods of reducing toxic additives in fracking fluids. The third section discusses several companies' approaches to reducing water usage. The final section examines innovations in proppant technology. Based on the current level of innovation in fracking technology, it can be projected that technology will continue to evolve, and is crucial in increasing oil recovery for the future of fracking.

Introduction

Oil and gas service companies are developing new technologies to address the possible environmental and health concerns associated with fracking, as well as to increase oil recovery and the efficiency of production. In order to decrease fresh water consumption, some of the largest service companies in the US, including General Electric (GE), Halliburton, Schlumberger, GasFrac, and Baker-Hughes are creating new approaches to fracking. These approaches include the use of nontoxic, flow-channel, waterless and nitrogen gas fluids, new types of proppants, and new water treatment systems. Some of these companies are also using new forms of drilling and extracting shale oil, as well as new additives in fracking fluids.

Section I: GE's Approach to Frack Water Treatment

A variety of chemicals are added to fracking fluid to reduce friction, increase viscosity, prevent bacterial growth, and inhibit corrosion. Though such chemicals make up a small percentage of fracking fluid, commonly <1% by volume, some of them are known toxins (e.g. ethylene glycol) and are potential contaminants of ground and surface waters. Despite this small percentage of additives, the large overall volume of fluid used in a single fracking operation, up to several millions of gallons, can amount to a significant volume of toxins at each drilling site. As a result, there are concerns over possible contamination where such fluids are not properly contained, treated, or otherwise disposed of. GE is addressing some of these issues, wastewater treatment specifically, to move the industry forward responsibly.

GE claims to have a more energy-efficient process that can reduce the cost of water treatment in half, while also decreasing the chance of toxic waste spills. The new technology is based on desalination, or membrane distillation. Membrane distillation combines heat and

decreased pressure to vaporize water, using membranes to separate pure water vapor from salt water. Normally membrane distillation works by applying heat to the water at one end of the process while at the other side cooling off the water vapor to make it condense. GE has replaced both heating and cooling systems with one single device, a vapor compressor borrowed from industrial refrigerators. GE is conducting multiple pilot-scale tests of a machine that can process about 2,500 gallons of water per day. GE researchers reported that they are on track to reduce the costs of treating salty fracking wastewater in half.¹

GE is building a \$110 million research center and lab in Oklahoma, dedicated to study oil and gas extraction technologies, including fracking.² Jeff Immelt, chairman and CEO of GE, said that the center will “initially focus on technologies that enable safe and efficient production, delivery, and use of unconventional oil and gas, including shale gas.”³ GE is also researching ways to reduce fresh water use by using alternative fluids such as propane. Other possibilities include mixing carbon dioxide or nitrogen with water to create foams, or mixing small amounts of water with solid particles designed to easily flow through the well.⁴

Mark Little, senior vice president at GE, reported that GE’s strategy to improving fracking comes down to looking at “minds and machines together”, meaning that GE is placing new devices in wells to provide people with exact information about what is exactly occurring during fracking. Little also said that GE will get more information on frack water treatment, which can be useful in trying to improve production and profits, and to monitor and reduce environmental impacts in the future.⁵ According to GE researchers, implementing and developing new technological advances in fracking will require constant regulation.⁶

Section II: Halliburton’s CleanSuite™ System

One major company that is investing in making nontoxic fracking fluids is Halliburton. Halliburton is an energy industry based in Houston, Texas, and one of the world’s largest natural gas producers in the world. Halliburton produced a system called CleanSuite™ to address some of the possible environmental and health risks associated with fracking fluids.

[CleanStim™]

One of CleanSuite™’s technologies, CleanStim™, is a fracking fluid formula composed of a gelling agent, a cross-linker or buffer, breakers, and a surfactant. CleanStim™ provides “an extra margin of safety to people, animals, and the environment in the unlikely occurrence of an

¹ Kevin Bullis, “One Way to Solve Fracking’s Dirty Problem,” *MIT Technology Review*. 2013.

² “GE to Build \$110m Fracking Research Center.” *Environmental Leader*. 2013.

³ Ibid.

⁴ Kevin Bullis, “Can Fracking Be Cleaned Up?,” *MIT Technology Review*. 2012.

⁵ Fuel Fix. "Industry giant GE aims to improve fracturing." 2013.

⁶ Bullis, “Can Fracking Be Cleaned Up?”

incident at the well site.”⁷ CleanStim™ is made only from ingredients used by food companies. The formulation is a mixture of “food safe” additives that are designed to suppress the growth of bacteria that can otherwise form sludge and impede the flow of gas and oil.⁸ **Figure 1** outlines CleanStim™ additives. Enzymes, organic acid, inorganic salt, and partially hydrogenated vegetable oil are some of the ingredients that are commonly found in familiar food sources. (For example, fruit juice, food starch, soybean paste, cheese, and coconut milk). Halliburton also ensures that “CleanStim™ fluid system provides excellent performance in terms of pumpability, proppant transport, and retained conductivity. Laboratory tests showed over 90% retained conductivity after 24 hours of flow.”⁹

Generic Constituent Name	Common Use	Hazardous as Appears on MSDS
Enzyme	Soybean Paste*, Fruit Juices and Nectars*, Laundry Detergent, Dishwasher Detergent, Toilet Cleaner, Industrial Pulp and Paper Processing Aid	Yes
Exthoxylated Sugar-Based Fatty Acid Ester	Synthetic Food Flavoring Substance, Natural Baby Wipes, Baby Wash and Shampoo	No
Inorganic Acid	Cheese, Alcoholic Beverages, Wheel Cleaner, Rust Dissolver, Dishwashing Detergent	Yes
Inorganic Salt	Food Starch ♦ Modified, Water Clarifier, Fish Tank Water Treatment	Yes
Maltodextrin	Sweetener, Glaze and Icing Sugar, Coconut Milk and Coconut Cream, Shower Gel	No
Organic Acid	Fruit Juice, Dishwasher Cleaner, All-Purpose Cleaner, Hand Soap	Yes
Organic Ester	Liquid Egg Products, Food Resinous and Polymeric Coatings, Hairspray	Yes
Partially Hydrogenated Vegetable Oil	Confectionary Chocolate Coating, Hair Detangler, Body Lotion, Lip Liner, Soap, Lotion, Cream and Other Skin Care Formulations	No
Polysaccharide Polymer	Canned Fish, Processed Cheese, Dairy-Based Desserts and Drinks, Beer, Toothpaste	Yes
Sulfonated Alcohol	Egg White Solids, Marshmallows, Dishwashing Liquid, Home Dilutable Cleaner, Shampoo, Acne Scrub, Shaving Cream, Liquid Hand Soap	Yes

*Concentration present in consumer product not publicly available

Figure 1: Halliburton CleanStim™ Formulation (Source: halliburton.com)

[CleanStream®]

One of the most common chemicals used in fracking solutions is biocide. Without it, bacteria can rapidly form and spread throughout the wellbore. This can impede the flow of energy and decay the pipes and equipment. In 2011, Halliburton introduced CleanStream®, which controls bacteria growth in fracking fluids by using ultraviolet light technology. The ultraviolet light acts as a replacement for the chemical biocides used for fracking, and treats fracking fluid at rates up to 100 bbl/min. CleanStream® uses a blender suction pump to pull the fracking fluid through the CleanStream® unit. It can conduct eight beats per minute (bpm) per

⁷ Halliburton. “CleanStim® Hydraulic Fracturing Fluid System.” 2014.

⁸ RP Siegel. “Is There Really Such A Thing As Green Fracking?.” *Triple Pundit*. October 23, 2012.

⁹ Halliburton. “CleanStim®.”

suction hose and 100 BPM max rate.¹⁰ CleanStream® can control bacteria growth in fracking fluids and reduce the amount of chemical biocides required for traditional fracking.

[CleanWave™]

Halliburton has also developed technology to reduce the amount of fresh water necessary for fracking. CleanWave™ is a water treatment system that enables the recycling of flowback and produced water after fracking. “Somewhere between 8% to as much as 40% of fluid volume used in fracturing flows back during subsequent cleanup operations. Halliburton’s CleanWave™ mobile units treat flowback and produced water at rates up to 26,000 barrels per day.”¹¹ CleanWave™ uses electrocoagulation, a water treatment process where electricity-based technology removes contaminants. Clay Terry, a strategic business manager for Halliburton, explained, “Essentially, it’s electrocoagulation that is enhanced by surfactants or other additives as a means of promoting flocculation of suspended particles.”¹² CleanWave™ is designed to remove suspended soils, oils, and other insoluble organics, and bacteria from the water supply. **Figure 2**, below, illustrates the effectiveness of CleanWave™. In May 2011, it won the Offshore Technology Conference (OTC) award. OTC recognizes innovative technologies with the Spotlight on New Technology Award, and their award program “showcases the latest and most advanced technologies that are leading the industry into the future”¹³ By reusing the flowback water in fracking and other drilling fluids, CleanWave™ lowers the demand for fresh water usage, resulting in a major decrease in overall fresh water use for fracking.

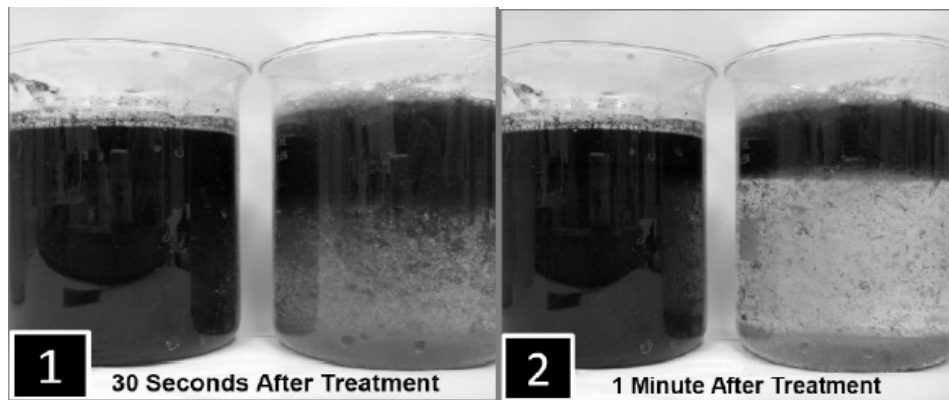


Figure 2: CleanWave™ Water Treatment (Source: halliburton.com)

¹⁰ Halliburton. “Cleanstream® Ultraviolet Light Bacteria Control Process.” 2014.

¹¹ D. Brown. “Hydro Fracturing gets ‘Green Tech’ Treatment.” *AAPG Explorer*. August, 2012.

¹² Brown, “Hydro Fracturing gets ‘Green Tech’ Treatment.”

¹³ Halliburton. “Halliburton’s CleanWave™ Water Treatment Technology Takes Spotlight Award at Offshore Technology Conference.” 2011.

[Haynesville Shale Case Study]

In April 2012, Halliburton implemented their entire CleanSuite™ system in Haynesville the Shale. Halliburton worked closely with El Paso Corporation, an energy industry based in Houston, Texas, and one of North America’s largest natural gas producers. In 2008, El Paso moved into the Haynesville Shale, which underlies southwestern Arkansas, northwest Louisiana, and East Texas. They completed more than 76 wells, each one requiring 4.8 million gallons of fresh water.¹⁴ El Paso sought to reduce its dependency on fresh water usage and decrease the amount of chemical biocides needed for fracking. They ultimately chose to work with Halliburton’s CleanSuite™ technologies. The two energy industries started with multiple pilot programs over a two-year period at different sites. Halliburton states,

“CleanWave® water treatment system enabled the recycling of flowback and produced water at the well sites, which decreased the need for fresh water. “Halliburton’s CleanWave® water treatment system recycled 1.05 million gallons of flowback and produced water at the well site, reducing the need for fresh water by nearly 25%.”¹⁵

El Paso used CleanStream®’s ultraviolet technology to control bacteria growth, eliminating the need for more than 2,400 gallons of biocides for this well.¹⁶

El Paso operators also wanted to enhance their fracking performance and efficiency. Halliburton’s CleanStim® fracking fluid formula ensured increased safety and provided pumpability, proppant transport, and conductivity, which improved El Paso’s overall efficiency. John Jensen, Senior Vice President of Operations of El Paso Exploration and Production said, “Teaming with Halliburton on the use of this ‘green’ suite of technologies was a ‘win’ for us and demonstrate that industry is proactively developing important advancements for hydraulic fracturing.”¹⁷ Halliburton’s entire CleanSuite™ system helped El Paso improve the efficiency of their fracking process, decrease their water consumption, and reduce chemical biocide use in the Haynesville Shale.

[RapidFrac™]

In addition to the CleanSuite™ system, Halliburton has developed a multi-stage fracking system that provides operators with alternative methods of completing horizontal multi-zone wellbores, enabling more accurate placement of fractures with little to no intervention. The system, called RapidFrac™, enables stimulation for multiple targeted zones in either horizontal

¹⁴ Halliburton. “El Paso Corporation completed first natural gas well using all four CleanSuite™ technologies.” Halliburton, 2012.

¹⁵ Halliburton. “El Paso.”

¹⁶ Ibid.

¹⁷ Halliburton. “El Paso.”

or vertical wells without the use of drillable bridge plugs to isolate these zones. This can eliminate the necessity of wire line, coiled, or joined tubing.

RapidFrac™ technology is an all-sleeve completion system that “overcomes the limitations of traditional sleeve systems and completes wells much faster than plug-and-perforation methods.”¹⁸ RapidFrac™ operates by running the sleeves “as part of the casing string and uses a ball to simultaneously open up to six sleeves isolated within an interval. When an interval is completed, Halliburton releases a larger ball for the next interval.”¹⁹ RapidFrac™ overcomes the length limitations of traditional sleeve systems, creating a faster alternative to the “plug-and-perforate” method.

RapidFrac™ can also stimulate multiple sleeves simultaneously, which “allows it to complete up to 15 intervals with 4.5 inch casing—and incorporate up to 90 sleeves—in one horizontal completion, ensuring maximum stimulated reservoir volume.”²⁰ This allows the “plug-and-perforate” method to be completed in half the time and increase efficiency.

In October 2011, Halliburton’s RapidFrac™ system was put to use in the Bakken Shale. Halliburton worked closely with Williams, an energy infrastructure company that focuses on creating global energy in North America by expanding their markets for natural gas. Williams’ wells were completed in just two days, about 50% of the time needed for standard stimulation.²¹ In addition to increasing efficiency, Williams wanted to decrease fracking fluid requirements and improve pumping in the Bakken Shale. Currently, the “plug-and-perforate” method used in fracking requires fluids to pump perforating systems and plugs deep underground into the horizontal wells. Sometimes, this can lead the proppants inside the wells to be pushed too far into the formation, causing production to delay.

Williams found Halliburton’s RapidFrac™ system to be a very effective alternative to the “plug-and-perforate” method for well completion in the Bakken Shale. Williams Stenzel, vice president of Williams, said, “The RapidFrac™ system enabled us to complete a well more quickly than a ‘plug-and-perforate’ system, while delivering increased initial production.”²² Because of the success in improving their pumping time and minimizing their fracking fluid requirements, Williams planned to continue working with Halliburton to integrate RapidFrac™ in their future wells in the Bakken Shale.

¹⁸ Halliburton. “RapidFrac™ Multistage Fracturing System.” 2014.

¹⁹ Ibid.

²⁰ Ibid.

²¹ Halliburton. “Williams halved pumping time and improved initial performance with RapidFrac™ system.” Halliburton, 2011.

²² Halliburton. “Williams halved pumping time.”

Section III: Water Conservation

[Flow-Channel Hydraulic Fracturing]

One common concern in modern-day fracking is the amount of fresh water consumption. Schlumberger, among the world's largest suppliers of technology and information solutions to customers working in oil and gas industries, is one company addressing this concern.

In 2010, Schlumberger developed a new fracking technique called HiWAY flow-channel hydraulic fracturing, demonstrated in **Figure 3**. The HiWAY flow-channel fracturing uses specialized blending equipment and control systems to pump proppants in pulses—creating stable, infinite-conductivity flow channels within the fractures. Flow-channel fracturing creates more open pathways inside the fractures, allowing hydrocarbons to flow through the channels, rather than the proppant. This improves the deliverability of hydrocarbons from the reservoir to the wellbore, and the proppant becomes more of a supporting agent to prevent fracture closure within the channels while fracking.²³ HiWAY flow-channel fracturing has helped preserve the amount of water used in fracking. “Compared to slick water treatments, the HiWAY service uses up to 60% less water. HiWAY fracking has conserved: 350,000,000 gallons of water (8,300,000 barrels).”²⁴ Schlumberger also stated that HiWAY flow-channel fracturing is also using less proppant.

“On average, the HiWAY service helps operators use 40% less proppant per job. Since 2010, HiWAY fracking has saved: 1.2 billion pounds of proppant, which is enough to fill any of the following: 6,000 railroad cars, 320 Boeing 747 interiors, 60 Big Bens (Clock Tower), 9 Washington Monuments, 2 RMS Titanic.”²⁵

HiWAY flow-channel fracturing also decreases the amount of carbon dioxide emissions released during the fracking process. “HiWAY service prevented 12 million pounds of carbon dioxide emissions, equivalent to 140,000 planted seedlings, 1,160 acres of forest, and 780 homes’ electricity on an annual usage.”²⁶ Because of the significant reduction of fresh water and proppant consumption, the average HiWAY channel-fracturing job increases production by more than 20%.

²³ Dennis Denney. “Technology Applications.” 2010. 20.

²⁴ Schlumberger. “HiWAY Flow-Channel Hydraulic Fracturing Technique.” 2014.

²⁵ Ibid.

²⁶ Schlumberger. “HiWAY Flow-Channel Hydraulic Fracturing Technique.” 2014.

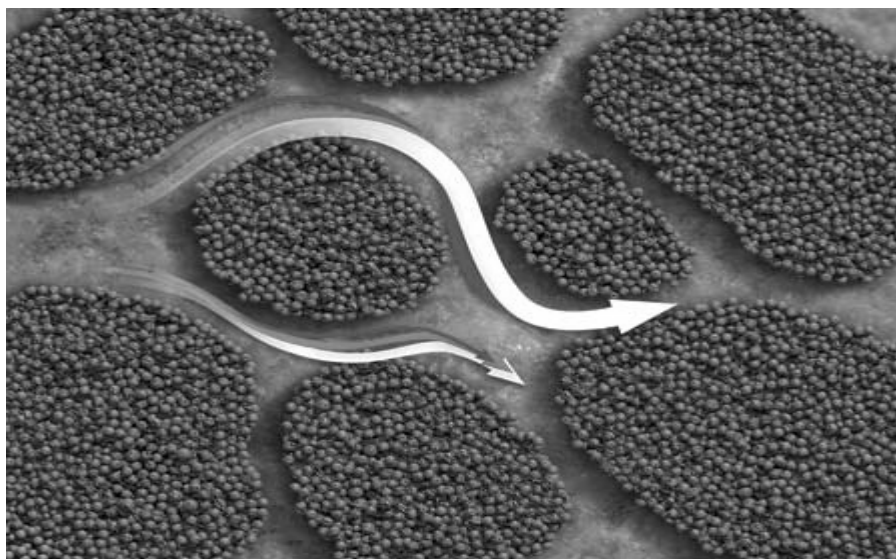


Figure 3: Schlumberger’s HiWAY Flow-Channel Fracturing (Source: slb.com)

In February 2011, Schlumberger applied the HiWAY technology in the Eagle Ford Shale in southern Texas with the goal of improving operational. The logistics of the production in the Eagle Ford were a challenge. The section of the basin where the technology was tested “has generally been stimulated using multistage horizontal completions with high-rate slick-water treatments.”²⁷ These treatments demand millions of gallons of fresh water and millions of pounds of proppants for each well. The large quantity of wells in the Eagle Ford, further limits the availability of these resources. Operators conducted a four-well study. Two wells were stimulated simultaneously using conventional fracking methods, while the other two wells were stimulated with Schlumberger’s HiWAY flow-channel fracking method, explained below:

“The landing of the wells was carefully planned to provide the best possible basis for comparison. The wells treated with the HiWAY technique had been drilled from a single pad, in opposite directions. The other two wells had also been drilled in opposite directions from a single pad located just 3,500 feet away and parallel to the first two wells. The average lateral length for each pair of wells differed by only 1%.”²⁸

During a 60-day study, the HiWAY fracking method increased cumulative oil production by 43% and gas production by 61%.²⁹ HiWAY also considerably decreased the amount of water and proppant consumption; the findings were,

²⁷ Schlumberger. “Case Study: HiWAY Technique Increases Condensate Production by 43% in the Eagle Ford Shale.” 2011.

²⁸ Ibid.

²⁹ Schlumberger. “Case Study: HiWAY Technique Increases Condensate Production by 43% in the Eagle Ford Shale.” 2011.

“These results were obtained while reducing the amount of water and proppant used per well by 58% and 35%, respectively. The operator saved more than 10,000,000 gal of water and 2,600,000 lbm of proppant in the two wells stimulated with HiWAY channel fracturing.”³⁰

Operators at the Eagle Ford site saved five million gallons of water per well and reduced the use of proppants by 1.3 million pounds per well.³¹

In October 2011, Schlumberger conducted another case study in the Eagle Ford Shale in conjunction with Petrohawk Corporation, an independent energy industry that works in the development of shale oil and natural gas resources in the United States. Petrohawk set up numerous wells in the Eagle Ford, and asked for Schlumberger’s assistance in improving their oil and gas production. Identical to the February 2011 case study, the challenge that Petrohawk had in the Eagle Ford was the amount of fresh water required. Schlumberger and Petrohawk set up two wells for assessment: Heim #2H well and Dilworth #1H well. These two wells were used with the HiWAY technology, and were compared with conventionally fracked wells.³² The results from this study, shown in **Figure 4** below, demonstrate that overall production from wells fracked with the HiWAY method was significantly higher than wells using conventional fracking methods. According to a report by Schlumberger,

“The enhanced stimulation of the reservoir provided by HiWAY channel fracturing gave the Heim #2H well a maximum initial rate of 14.5 Mcf/d, or 37% higher initial gas production than the best comparable offset well. The HiWAY technique gave the Dilworth #1H well a maximum initial rate of 820 bbl/d, or 32% higher initial oil production rate than the best comparable offset.”³³

³⁰ Ibid.

³¹ Ibid.

³² Schlumberger. “Case Study: Channel Fracturing Increases Production by 37% for Petrohawk in the Eagle Ford Shale.” 2011.

³³ Schlumberger. “Case Study: Channel Fracturing.”

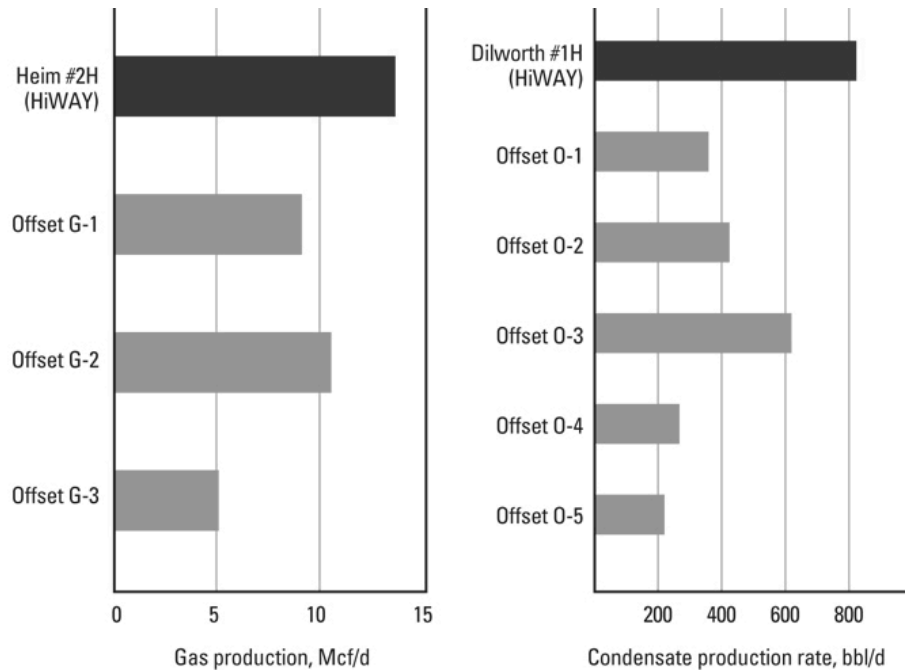


Figure 4: PetroHawk Case Study: Results of Production (Source: slb.com)

Based on these results, Petrohawk has requested to continue working with Schlumberger. Petrohawk confirmed that six more wells have been completed, showing that the production was consistent with the initial test wells.³⁴ Dick Stoneburner, COO and President of Petrohawk said, “Petrohawk has converted 100% of frack services provided by Schlumberger in the Eagle Ford to the HiWAY technique. Currently, Petrohawk is utilizing all available capacity in this solution.”³⁵ Schlumberger’s HiWAY flow-channeling fracking technology significantly increases fracture conductivity while reducing fresh water and proppant consumption, resulting in higher shorter and long-term production, as well as decreasing overall environmental impact.

[Liquefied Petroleum Gas Fracturing]

Another fracking alternative that US oil and gas companies are looking into is completely eliminating fresh water from fracking practices. GasFrac Energy Services Inc. is an energy and fracking industry located in Calgary, Alberta, Canada. In 2008, they developed a thick, patented propane gel in place of using fresh water in order to extract shale oil. GasFrac’s technique is called liquefied petroleum gas (LPG) fracturing. The propane gel is applied by pumping a mix of the gel and sand into shale formations at depth. When the LPG faces extremely high pressure underground, it transforms directly into a vapor, returning to the earth’s surface with the natural

³⁴ Schlumberger. “Case Study: Channel Fracturing.”

³⁵ Ibid.

gas, where it can be recaptured.³⁶ This allows for very high recovery of the frack fluid, approaching 100%, reducing clean up and also post-frack truck traffic.

Currently, oil and gas industries use fresh water for fracking because it is inexpensive and abundant. Sometimes fracking with water can cause formation damage or damage to the reservoir, which can close flow pathways and prevent oil and gas from being produced. Propane gel is most likely to reduce formation damage during fracking, which would increase oil recovery and make a more profitable well. Because LPG fracking does not require water, it is also much safer for employees. LPG fracking technology uses a zero-oxygen, closed system and specialized equipment that protect employees when working out in the shale fields.³⁷

Oil and gas companies have begun looking into waterless fracking. Chevron began testing with the propane gel in five natural gas wells in Colorado.³⁸ In 2012, GasFrac made a two-year contract with BlackBush Oil and Gas in the Carrizo Springs area of the Eagle Ford formation. BlackBush has more than 900 drillable locations for the Eagle Ford and other oil zones within the area. BlackBush was one of the first oil and gas production industries to incorporate GasFrac's LPG fracking technology, and agreed to a longer-term partnership in order to secure GasFrac's equipment.³⁹ Phil Mezey, Co-CEO at BlackBush, saw great, strong results in GasFrac's LPG technology, and said,

“BlackBush looked extensively for an alternative to ‘water fracks’ as we recognized a definite problem in formation damage contributed by introducing water in the fracking process to the formations we are actively developing. Results from our first well with GasFrac has seen oil production at a sustainable rate weeks earlier than with the standard water frack and we are seeing huge savings on disposal of frack fluids.”⁴⁰

There are, however, some concerns revolving around using propane gel in fracking. Although gelled propane minimizes the amount of fresh water being used in fracking, a lot of water is used to create and liquefy the propane. Propane gel can pose some safety risks as well; under normal conditions, propane is a gas. Liquid propane must be held under pressure. If there is a leak above the ground surface, the propane can create a vapor cloud and could explode if there are any ignition sources nearby.⁴¹

Propane can be quite explosive if not treated properly. For example, in January 2012, an LPG gas well that was being drilled in Alberta by Husky Energy, one of Canada's largest energy industries and one of the first industries to use LPG fracking, created a flash fire. Three workers

³⁶ Matt Goodman. “Waterless Fracking Method Targets Natural Gas Industry’s Gaze.” *CBS DFW*. January 12, 2012.

³⁷ GasFrac. “GASFRAC- Home.” 2014.

³⁸ Kent Harrington. “GASFRAC Takes the Water out of Fracking.” *ChEnected*. May 29, 2012.

³⁹ Rigzone. “BlackBrush Extends GASFRAC Contract for Waterless Frac Process.” March 13, 2012.

⁴⁰ *Ibid*.

⁴¹ Scott McNally. “Waterless Fracking?.” *Scientific American*. October 10, 2012.

from Husky Energy suffered severe burns, although there were no life-threatening injuries.⁴² Propane also requires special types of equipment to be operated cautiously and properly, which can be costly. Propane itself is also very expensive. Emmett Capt, GasFrac's Vice President of US Operations, estimates that the cost of an LPG frack to be between \$50,000-\$100,000 more than a well that is hydraulically fractured.⁴³ To address cost and safety concerns, the company is adding more monitoring equipment, raising the number of propane sensors from three to 20 and adding infrared video scanning to detect any gas leaks.

GasFrac claimed that they have multiple safety barriers and still believes that their LPG technology is highly safe. The energy industry states that LPG technology produces more enhanced oil and gas recovery and longer sustained production.

[Nitrogen Gas Hydraulic Fracturing]

Another form of waterless fracking uses nitrogen gas as a base fluid. Nitrogen has been used for fracking in the past, when concerns over formation damage from frack fluids existed. It represents, however, a more recent application in the case of shale oil stimulations, given the large scale and multi-stage nature of the fracking. There are three types of nitrogen gas fracking. The first is pure nitrogen gas fracking, where nitrogen is being used almost exclusively, with only negligible amounts of water present. The nitrogen is maintained as a gas, which has low density, viscosity, and compressibility. Because of these traits, pure nitrogen gas fracking is ineffective at greater depths and is a poor proppant carrier.⁴⁴

The second type is nitrogen foam fracking, which is the most widely used in nitrogen gas fracking. Nitrogen is combined with water and chemical additives, and then cooled to form a foam-like liquid, which is very dense. The nitrogen foam fracking fluid is made up of 53-95% of nitrogen gas.⁴⁵ The nitrogen foam has higher density and viscosity, making it a better proppant carrier and more capable of fracking at greater depths than pure nitrogen gas fracking. However, it is not a completely waterless fracking process.

The third type is nitrogen-energized fracking. It is carried out using fracking fluid made up of less than 53% nitrogen; the remaining fluid is water and small amounts of chemical additives.⁴⁶ The smaller amount of nitrogen is used to energize the liquid phase, which increases flowback, allowing less water to remain trapped underground during fracking. Nitrogen energized fracking can be used at even greater depths than the other types of nitrogen fracking. While it is not as water efficient as higher nitrogen content fracking fluids, it uses tremendously less water than traditional fracking.

⁴² Harrington. "GASFRAC Takes the Water out of Fracking."

⁴³ Goodman. "Waterless Fracking Method."

⁴⁴ Kendall Gurule. "Nitrogen gas tracking." *Frackwire*. July 9, 2013.

⁴⁵ Gurule. "Nitrogen gas tracking."

⁴⁶ Gurule. "Nitrogen gas tracking."

Baker Hughes is one major service company currently providing nitrogen gas fracking. Baker Hughes is an oilfield services company that focuses on shale oil and gas, and provides products and services for drilling, formation evaluation, and reservoir consulting. Baker Hughes developed VaporFrac™, a fracking fluid designed to improve production of shale oil and gas in water sensitive, low-pressure reservoirs. VaporFrac™ combines high-pressure nitrogen and carbon dioxide gas stream, as well as a lightweight proppant slurry. VaporFrac™ pumps the lightweight proppant slurry directly into nitrogen and/or carbon dioxide gas stream at a very high pressure. VaporFrac™ “safely creates a flow stream that is more than 90% gas, and significantly reduces post-frac clean up. The high energy of the gas phase makes for easy flowback. There is a quicker tie into pipelines.”⁴⁷ The benefits that come along with VaporFrac™ include a much lower total volume in proppant, no formation damage, diminished liquids disposal, less equipment, and less fresh water usage.

Section IV: Innovations in Proppant Technology

In addition to developing new technologies in water treatment and conservation, service companies are developing new proppant technologies to increase fracking efficiency. There are new, ultra lightweight proppants proving to be more effective than sand, bauxite, or other traditional materials. Halliburton created a lightweight, low-density proppant called MonoProp™ used for high-porosity fractures. One of the benefits of MonoProp™ is that the partial monolayer created by the proppant itself increases fracture conductivity, increasing overall production. Proppant flowback is heavily reduced due to the trapping of the proppant particles by closing the fracture entirely.⁴⁸ This means that overall, less proppant material is being pumped. MonoProp™ can act as a direct substitute for conventional proppants, and can be combined with conventional gelled fluids. The proppant “provides adequate strength to maintain fracture width but is flexible to prevent crushing and embedment in the fracture face.”⁴⁹ MonoProp™ works well with nitrogen and all water-based fracking fluids, but does not work with acid-type fracking fluids.

Baker Hughes also developed an ultra lightweight proppant called LiteProp™. LiteProp™ is made out of strong, low-density materials that have a much slower settling rate than sand or other conventional proppants. Baker Hughes published a graph (see **Figure 5**), illustrating that LiteProp™ improved in overall production from water fracks compared to wells fractured with conventional proppants using binary foam fracks and conventional cross-linked fluids. “The LiteProp™ ULWP (Ultra Lightweight Proppant) has shown exceptional performance in both new completions and re-stimulations of older, marginal wells.”⁵⁰ Their

⁴⁷ Baker Hughes. “VaporFrac Fracturing Fluid.” 2014.

⁴⁸ Halliburton. “MonoProp™ Low Density Proppant for High-Porosity Fractures.” Halliburton, 2008.

⁴⁹ Halliburton. “MonoProp™.”

⁵⁰ Baker Hughes. “Baker Hughes LiteProp Ultralightweight Proppants.” Baker Hughes, 2012. 2-7.

proppant is applicable to a wide range of fracking fluid systems, including slickwater, light to heavy brines and foams, conventional polymer, etc.

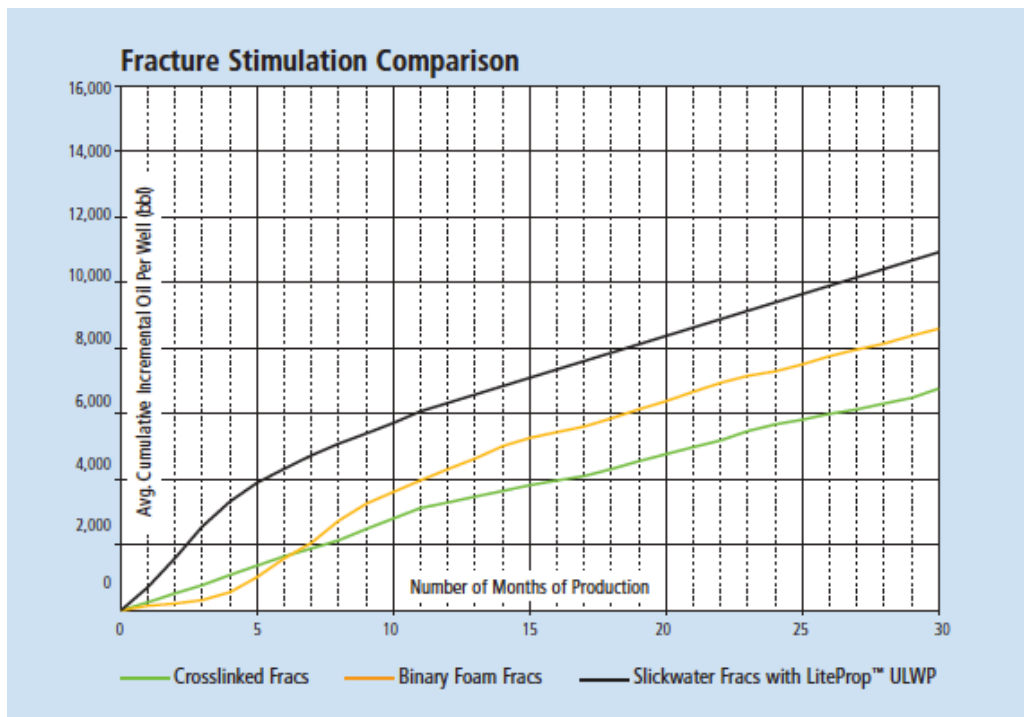


Figure 5: LiteProp™ Fracture Stimulation Comparison (Source: bakerhughes.com)

The LiteProp™ technology was implemented in many different areas. LiteProp™ 125 Proppant was used in Barnett Shale in Tarrant County, Texas. Operators used this kind of proppant for two offset wells: Well A and B. Well A was completed with a conventional proppant treatment and used 565,720 gallons of water and 58,950 lbm of 40/70 white sand. Well B was fractured with 459,720 gallons of slickwater and 27,550 lbm of 20/40 LiteProp™ 125 proppant. Over the first week, Well A produced 4,614 bbl of water with signs of gas within a few days. Well B, on the other hand, recovered 6,016 bbl of fluid in the first week, and a significant amount of gas showed within four days.⁵¹

LiteProp™ was also used in the Devonian Shale gas wells in eastern Kentucky’s Big Sandy field. Operators replaced 20/40 sand with LiteProp™ and nitrogen foam fracks, which achieved higher foam quality and reduced fluid content to significantly improve clean up.⁵² Baker Hughes reported, “Over a period of six months, production from four of five wells treated equaled or exceeded results from offsets treated with conventional foam designs. The treatments also cost about 8% less than lose using conventional proppants.”⁵³ Baker Hughes also said,

⁵¹ Baker Hughes. “Baker Hughes LiteProp.”

⁵² Ibid.

⁵³ Ibid.

“Treatment economics were also improved by greatly reduced post-frack proppant migration. Logistics were simpler due to lower proppant and water volumes required.”⁵⁴ LiteProp™ lowered volumes and concentrations of contemporary proppant materials, as well as a decrease in fresh water supply. There is less equipment involved and the operational logistics for Baker Hughes’s proppant is easier than today’s proppants.

Last year, Preferred Sands, one of North America’s largest fracking sand and proppant manufacturing industries, announced the launch of their first non-phenolic, resin-coating proppant (RCS) technology. The resins used to coat the sand in these products contain non phenol and are thus aimed at reducing environmental impacts. Preferred Sands developed two kinds of proppants: RCS Garnet and RCS Pearl, both aimed at generating higher conductivities with better bond strength and flexibility.⁵⁵ According to Dow, a chemical company that is expanding Preferred Sands’ proppant line, “RCS Garnet was designed specifically for flowback control in low well temperatures with a built-in activator that does not require an additional chemical treatment.”⁵⁶ RCS Pearl on the other hand is designed to perform better flowback control in higher well temperature environments.

In October 2013, Preferred Sands was awarded the “Environmental Initiative of the Year” award for the Mid-continent region during the 2013 Oil and Gas Awards.⁵⁷ The industry was honored for their development in both RCS Garnet and RCS Pearl. Preferred Sands’ proppant technology offers oil and gas customers proppants that are more environmentally safe. The proppants also work under different well conditions and increase efficiency and sustainability of fracked wells.

Conclusion

The examples discussed in this chapter illustrate a high level of innovation in the energy industry in an attempt to address environmental and health concerns as well as improve overall efficiency. Given that shale oil remains at an early phase of development, such innovation will undoubtedly continue. The overall situation is dynamic, and there are major drivers urging such innovation forward, including continued high oil prices, the need to improve recovery and reduce costs, public concern over the environmental impacts of fracking, and the possibility of increased state and federal regulation over the fracking process. Such innovations are extremely important for the future of tight oil developing, not only in the US, but also globally, as the relevant technologies can be applied in any country with a program of tight oil drilling.

⁵⁴ Baker Hughes. “Baker Hughes LiteProp.”

⁵⁵ Preferred Sands. “Preferred RCS Proppants.” 2014.

⁵⁶ Dow Chemical Company. “Preferred Sands Launches New Proprietary Technology for Hydraulic Fracturing Proppants.” February 19, 2013.

⁵⁷ Business Wire. “Preferred Sands Recognized for Its Industry-Leading Environmental Stewardship.” October 30, 2013.

Chapter Thirteen

FUTURE VEHICLE TRANSPORT AND IMPLICATIONS FOR OIL DEMAND

Kelly Gould

Abstract

This chapter examines the present and future effects of shale oil on the US transportation sector by comparing and analyzing Department of Energy budgets, EIA reports, Whitehouse publications, and oil price indexes. The first section provides an overview of the US government's research and development budgets towards technological innovations in transportation. The second section looks at how new US fuel economy standards announced by President Obama will affect US transportation and oil usage. The third section compares costs of fueling vehicles with oil and electricity. The fourth section looks at the relationship of consumers and automakers with alternative energy vehicles (AEVs). The fifth section will examine future energy demand projections for the US transportation sector. The final section will explore options for reducing oil consumption in the US transportation sector. Based on these findings, it can be projected that the future of US transportation will include a reduction of US transportation sector oil demand, policies that support alternative vehicle technology research and development, and greater US energy security.

Introduction

Shale oil contributes to fueling the US transportation sector, and is projected to continue doing so in the future. At the same time, increased US domestic oil production from shale oil raises many concerns about where the future of US transportation is headed; continued fossil fuel use or a transportation fuel evolution.

Many authors have written books asserting concerns about the effects of shale oil on the future of US transportation. For example, in his book, *Snake Oil: How Fracking's False Promise of Plenty Imperils Our Future*, Richard Heinberg expresses concern that shale oil is distracting from the research, development and implementation of technological innovations in transportation. Another common concern is that shale oil will prolong the trend of US fuel efficiency standards being well below those of other nations with top fuel-efficient vehicles. There are also worries that shale oil production could decrease US oil prices enough to deter consumers and automakers to buy and develop alternative energy vehicles (AEVs). Finally, there has been a lot of discourse about the possibility of shale oil production only serving to further US oil dependency, subsequently putting overall US energy security at risk.

Four main axes of evaluation can help to evaluate the effects of shale oil on the future of US transportation. The first axis will compare the Department of Energy's FY 2008 and FY 2014

Budget appropriations for the Office of Energy Efficiency and Renewable Energy (EERE) and the Advanced Research Projects Agency – Energy (ARPA-E), as the main method of assessing whether or not shale oil has impeded governmental funding and development towards innovative and sustainable transportation technology. The second axis will look at US fuel economy standards in order to determine if shale oil has delayed improvements in them. The third axis will examine the effect of shale oil on global oil prices, how those prices compare to the cost of alternative energy sources used in transportation, and whether the addition of shale oil to global supplies has affected car companies’ incentives to invest in developing AEVs or consumers’ willingness to buy them. The fourth axis will consider various options that would strengthen US energy security by reducing the amount of oil used by the transportation sector. These options include fiscal incentives, support for new technology, traffic control measures, and improvement of fuel economy standards. These four axes are practical starting points from which to analyze the implications of shale oil for the future of US transportation.

Section I: Government Funding

Since the start of the shale oil boom in 2008, government funding for research and development of alternative energy transportation options, such as hybrid and electric vehicles, has remained intact. This is demonstrated by the growth in government funding for the ARPA-E and the EERE, as well as the establishment of the EV (Electric Vehicle) Everywhere Grand Challenge, and the Energy Security Trust.

A comparison of the Department of Energy’s FY 2008 budget appropriation for energy efficiency and renewable energy programs and the FY 2014 requested budget appropriation for the same program shows a significant increase in government funding. The FY 2008 budget was \$1.70 billion.¹ In 2014, the FY requested budget was \$2.78 billion. That is a 60.4% increase in budget for research related to the development of renewable energy and alternative energy technologies for vehicles. This portion of the Department of Energy’s annual budget is responsible for funding ARPA-E and EERE, key agencies that work towards US leadership in the development and implementation of advanced vehicle technologies.²

ARPA-E funds research and development of innovative technologies aimed at fueling the economy, creating new jobs, reducing energy imports and energy-related emissions, and improving energy efficiency. Examples of ARPA-E research are projects that focus on power electronics, batteries for electrical energy storage, battery management and sensing, grid networking technology, thermal energy storage, carbon capture technologies, natural gas vehicles, non-photosynthetic biofuels, and rare earth alternatives.³

¹ *Department of Energy FY 2010 Congressional Budget Request: Budget Highlights*, (Department of Energy), 15.

² *Ibid*, 14.

³ *Department of Energy FY 2014 Congressional Budget Request: Budget Highlights*, (Department of Energy), 4.

EERE is the US Government's principal clean energy technology organization in charge of the Research, Development, Demonstration, and Deployment (RDD&D) of technologies that advance end-use energy efficiency in buildings and factories, renewable electricity, and sustainable transportation. The 2014 requested budget for EERE was \$2.8 billion.⁴ Compared to EERE's 2012 budget, 75% more of the 2014 budget will go towards the development and demonstration of the next generation of advanced conventional and alternative powered vehicles.⁵ Research and development by EERE has led to almost every hybrid electric vehicle in use today. EERE technology provides an increase in fuel economy of up to 50% when compared to non-hybrid vehicles.⁶

The EV (Electric Vehicle) Everywhere Grand Challenge, launched in 2012, is one of EERE's most important initiatives supporting technological innovations in transportation. This challenge focuses on making major advancements in electric vehicle technology. The ultimate goal is for the US to become the first country, by 2022, to invent and manufacture plug-in electric vehicles that are on par with gasoline powered vehicles in terms of affordability and convenience.⁷ This challenge has helped decrease the production cost of electric vehicles by an estimated 50% over the last four years.⁸ In addition to reducing production costs, the EV Everywhere Grand Challenge also aims to spur infrastructure development and promote the acceptance of electric plug-in cars as a common transportation option among consumers, to establish a greater market for electric vehicles.⁹

The Department of Energy 2014 Budget will also invest two billion dollars over the next ten years, of federal oil and gas development revenue into developing a new Energy Security Trust (EST). The EST would enable a consistent flow of mandatory funding for research and development of economical alternative forms of transportation that would help to lower US dependence on oil. The EST would help finance research on improving and reducing costs of future technologies that would enable US consumers to operate vehicles by using homegrown biofuels, fuel cells, domestically produced natural gas, and electricity.¹⁰

Production costs and lack of fueling infrastructure are two of the biggest obstacles to plug-in vehicles capturing a larger share of the transportation market. ARPA-E and EERE's work towards improving both of these elements will help to ensure a place for plug-in electric vehicles in the future of transportation. Moreover, government funding and support for ARPA-E, EERE, the EV Everywhere Challenge, and the EST, indicates continued growth in government research and development funds for hybrid and electric vehicle technology, amidst ongoing

⁴ *Department of Energy FY 2014 Congressional Budget Request: Budget Highlights*, (Department of Energy), 14.

⁵ *Ibid*, 3.

⁶ *Ibid*, 28.

⁷ "EV Everywhere Grand Challenge: Road to Success," (Argonne National Laboratory), 2.

⁸ *Department of Energy FY 2014 Congressional Budget Request: Budget Highlights*, (Department of Energy), 28.

⁹ "EV Everywhere Grand Challenge: Road to Success," (Argonne National Laboratory), 2.

¹⁰ "Department of Energy FY 2014 Congressional Budget Request: Budget Highlights," (Department of Energy), 4.

production of US shale oil in order to lead the future of US transportation towards less oil consumption.

Section II: Fuel Economy Standards

AEVs that are within the price range of the average consumer are still a few years away, and shale oil continues to bolster US oil production. A delay in reducing US oil consumption is not expected to take place. The new fuel economy standards for cars and light trucks that President Barack Obama announced in 2011, as well as new standards for commercial trucks that are set to be announced in March 2016, will lessen US transportation oil demand in the future, regardless of increased US domestic oil production via shale oil.

The 2011 standards will affect cars and light trucks to be built in the years 2017-2025. By 2025, vehicles will be required to realize a fuel economy performance of 54.5 miles per gallon. This is the biggest change in fuel efficiency standards since the standards were established under the 1975 Energy Policy Conservation Act. The new standard almost doubles the requirement for current cars, which was set at 27.5 miles per gallon in 1985.¹¹ Under these new standards, from 2017-2025, the US will consume 12 billion fewer barrels of oil from.¹²

When the standards for 2016 were announced, average fuel economy of cars and light trucks was expected to be around 34.1 miles per gallon, and it was assumed that these new efficiency levels would stay around this level until 2035.¹³ The increase to 54.5 miles per gallon under the 2017-2025 standards will lead to a significant reduction in fuel consumption among the US transportation sector, particularly among the light duty fleet and personal vehicles. As the full effects of the new standards come into play, oil consumption continues to decline as shown in.¹⁴

The new standards are expected to reduce the use of oil by 1.4 million barrels of oil per day by 2035 (see **Figure 1**). The Annual Energy Outlook of 2012 projects that by applying 2017-2025 fuel economy standards, there is potential to reduce total US oil consumption by 8%, 16% of which would come from light duty vehicles. The 2017-2025 US fuel economy standards will be a very important addition to the energy security of the US, helping to reduce the amount of imported oil used by the transportation sector.¹⁵

¹¹ "Emission Standards: USA: Cars Fuel Economy (1978-2011)," (dieselnet.com).

¹² Lahood, S. R, "Historic Fuel Efficiency Standards for Cars and Light Trucks | The White House," (whitehouse.gov).

¹³ "Energy Policy Information Center (EPIC)>>EPIC Archive>>EIA projects Significant Oil Use Reductions with New CAFÉ Standards," (energypolicyinfo.com).

¹⁴ *AEO2014 Early Release Overview*. AEO2014 Early Release Overview. Energy Information Association, 8.

¹⁵ "Energy Policy Information Center (EPIC)>>EPIC Archive>>EIA projects Significant Oil Use Reductions with New CAFÉ Standards," (energypolicyinfo.com).

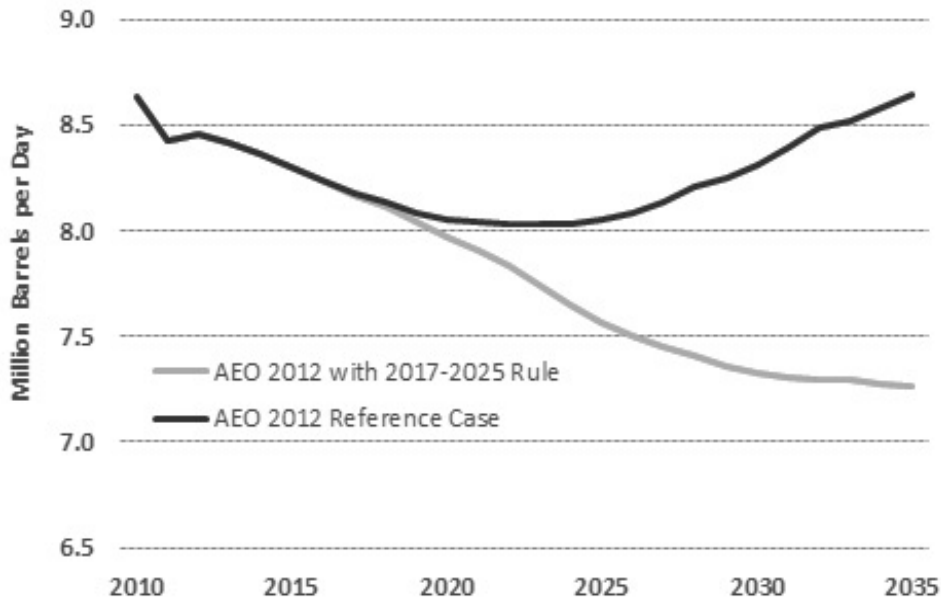


Figure 1: Light Duty Vehicle Oil Consumption Future Outlook (Source: <http://energypolicyinfo.com>)

Stricter fuel efficiency standards for heavy-duty trucks will be announced in March 2016 and will affect 2018 models. While heavier, commercial trucks only account for 4% of the total number of vehicles on US roadways, President Obama’s most recent announcement demonstrates US commitment to reducing oil consumption within the transportation sector and developing US energy security.¹⁶

Section III: Oil & Electricity Prices

Shale oil has boosted US domestic oil production, which has helped to keep US gas pump prices relatively low and stable. This has prompted concerns that shale oil may lower the cost to fuel conventional vehicles to a point where there are no longer incentives for automakers to invest in developing AEVs or for consumers to want to purchase one. The validity of this concern can be determined by comparing the costs of fueling a vehicle with oil and the costs of fueling it with electricity.

With the addition of US shale oil production, West Texas Intermediate (WTI) prices have seen a slight decline relative to North Sea Brent prices. Drastic price drops resulting from US shale oil entering the global market have not occurred, resulting in relatively stable price

¹⁶ Gerken, J, "Obama To Talk Up Benefits Of Fuel-Efficient Trucks," (The Huffington Post).

averages similar to the price average of 2008 when the shale oil boom was starting, shown in **Figure 2**.¹⁷

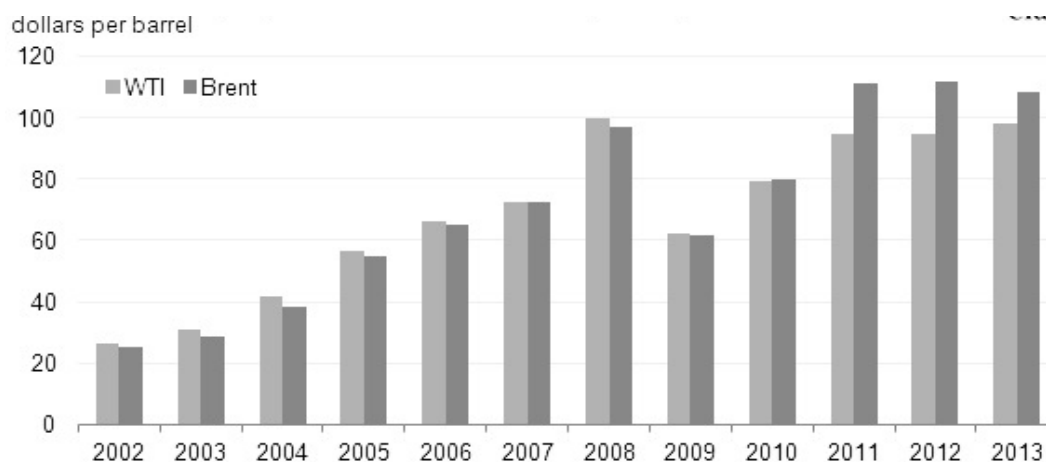


Figure 2: Brent and WTI average annual oil prices, 2002-2013 (Source: EIA)

A principle reason for this is that the US continues to import about 40% of its oil, thereby exposing refiners and other companies to the global market.¹⁸

Energy price forecasts for Brent crude oil, taken from the EIA Short-Term Energy Outlook (STEO), show an average of \$105/bbl in 2014 and \$101/bbl in 2015. WTI crude oil price forecasts averages of \$93/bbl in 2014 and \$90/bbl in 2015. These numbers support a continuation of relatively stable crude oil prices that are expected to persist in 2015, despite shale oil additions to the global oil supply.¹⁹

When fuel costs for gasoline-fueled vehicles are compared to fuel costs of electric vehicles, at their current national averages, electricity comes out on top in terms of being the cheaper form of powering a vehicle.²⁰ The US national average price of gasoline is \$3.33/gallon, while the national average price of electricity is only \$1.21/eGallon (amount of electricity required for an electric vehicle to travel 28.2 miles, the average MPG of a gasoline powered vehicle). This makes it nearly three times as expensive to fuel a gasoline powered vehicle as it does to fuel an electrically powered vehicle.²¹

Such a cost difference is a solid foundation from which to incentivize consumers and automakers to purchase and develop AEVs. Moreover, keeping in mind possible fueling costs when gasoline prices become more volatile, due to world oil supply disruptions that happen

¹⁷ Leahy, M. and Bruel, H, "U.S. crude oil production growth contributes to global oil price stability in 2013 - Today in Energy," (Energy Information Administration).

¹⁸ "How dependent is the United States on foreign oil? – FAQ – U.S." (Energy Information Administration).

¹⁹ "Short-Term Energy Outlook," (Energy Information Administration).

²⁰ Loiseau, J, "Pump vs. Plug: Do You Really Save Money Driving an Electric Car?," (dailyfinance.com).

²¹ "The eGallon: How Much Cheaper Is It to Drive on Electricity?," (energy.gov).

outside the control of the US, consumers and automakers are not likely to completely abandon AEVs in favor of total reliance on shale oil.

Section IV: Consumers, Automakers, & AEVs

Electric vehicles have sold well since their debut on the market, indicating that cheaper fueling costs resonate well with consumers, as well as their little to no tailpipe emissions.

In May of 2013, sales of plug-in electric vehicles were on track to pass 200,000 by spring of 2014, approximately 40 months after introducing the Chevrolet Volt and Nissan Leaf production models. Hybrid electric vehicles, in contrast, took 20 months longer to reach this same milestone. Plug-in electric vehicles are doing well in sales because of the wide variety of models available to consumers. In 2014 eight more plug-in electric vehicle models are set to launch, on top of the 15 already on the market. These models range from a mid-size plug-in hybrid with an all-electric range of 15 miles to a full-size liftback EV that has a travel range of up to 265 miles per battery charge.²²

Number of Vehicle Models that Run on Fuels Other than Gasoline*, 1991-2013									
Model Year	E85	CNG (Dedicated and Bi-Fuel)	Diesel	Plug-In Electric Vehicle	Hybrid	Propane (Dedicated and Bi-Fuel)	Hydrogen	Methanol (M85)	Total
2000	8	15	3	12	2	2	-	-	42
2001	11	16	3	10	2	5	-	-	47
2002	16	18	4	6	3	5	-	-	52
2003	22	16	4	5	3	1	-	-	51
2004	19	16	7	1	3	1	-	-	47
2005	24	5	8	0	8	0	-	-	45
2006	22	5	6	0	8	0	-	-	41
2007	31	1	7	0	11	0	-	-	50
2008	31	1	6	1	16	1	-	-	56
2009	36	1	12	1	19	1	-	-	70
2010	34	1	14	1	20	0	0	-	70
2011	72	1	16	2	29	0	0	-	120
2012	62	6	17	6	31	1	1	-	124
2013	84	11	20	15	38	6	1	-	175

Table 1: Breakdown of AEVs by Fuel Type and Number of Models (Source: Department of Energy)

The data in **Table 1** indicates that automakers have pursued the development and production of plug-in electric vehicles despite the addition of shale oil to the global oil supply. In just one year, the number of plug-in electric vehicle models more than doubled, increasing from six models available to consumers in 2012 to 15 available models in 2013.²³

Further indicators that shale oil has not affected automakers' decisions to continue with AEV development are the number of AEV models automakers have produced and the diversity in fuel options they represent. In 1991 there were 19 AEV models available to consumers that were not powered by gasoline. Seventeen of those vehicles were powered by diesel. In 2013 that number rose to 175 models that run on seven different types of fuel.²⁴

Toyota is the established leader in hybrid electric vehicle (HEV) sales. In 2013, Toyota produced 60% of all hybrids sold in the US.²⁵ Although Toyota dominates the HEV sales field, there has been an overall increase in the number of automakers producing HEVs as seen in **Figure 3**. This diversification of automakers represents their perception that the HEV market has a promising future; one they are willing to compete against other automakers to have a share in. Again, this represents the null effect of shale oil on automakers research and development of AEVs.

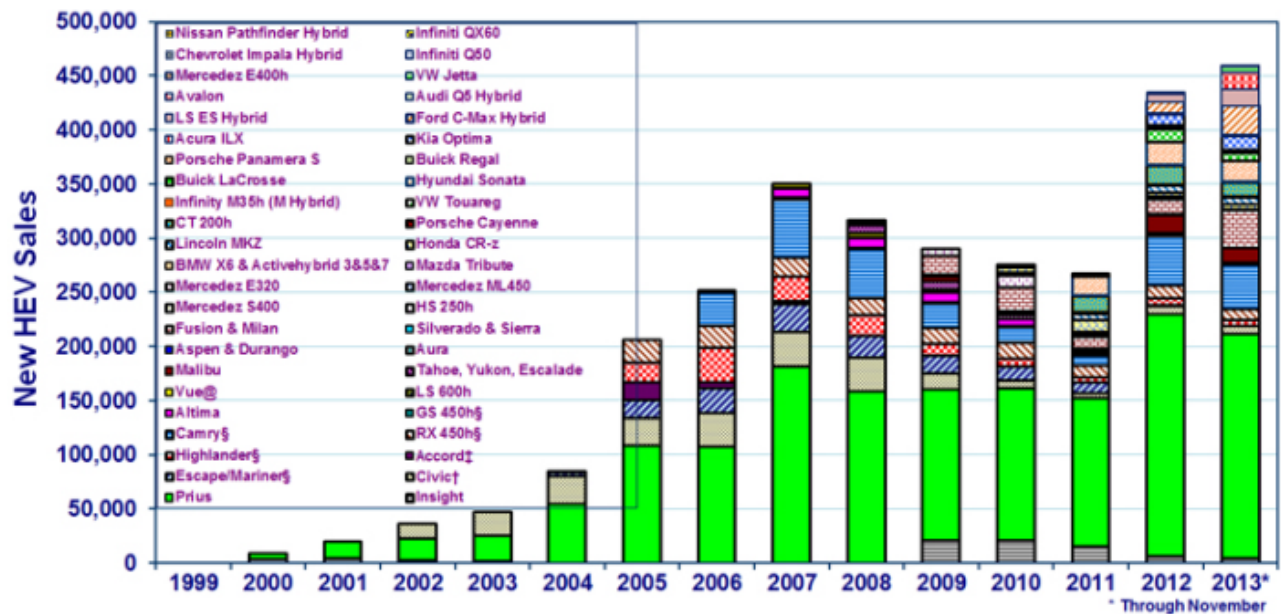


Figure 3: Breakdown of HEVs by sales and automaker (Source: EVsRoll).

²³ "Vehicle Technologies Office: Fact #814: January 27, 2014 More Choices when Buying Vehicles that Use Advanced Technology and Alternative Fuels," (eere.energy.gov).

²⁴ "Vehicle Technologies Office: Fact #814: January 27, 2014 More Choices when Buying Vehicles that Use Advanced Technology and Alternative Fuels," (eere.energy.gov).

²⁵ "Hybrid Car Statistics," (evsroll.com).

Section V: Energy Demand

The US transportation system is highly dependent upon oil. The top demanded energy source in the US is petroleum, 71% of which is used by the transportation sector. Petroleum provides for 93% of the transportation sector's total energy demands.²⁶ Therefore, it seems unrealistic that increased domestic oil production from shale oil can actually prompt the US transportation sector to begin a decline in its oil usage and decrease overall imports of oil. However, continued AEV research and development, stricter fuel economy standards, and a growing AEV market, indicate that the future of US transportation is headed in the direction of a sector with reduced energy demands, resulting in declining foreign oil imports and greater US energy security.

The EIA's Annual Energy Outlook (AEO) 2014 provides one prediction of what energy demand within the US transportation sector will look like in the near future if AEVs and shale oil production are factored in.

The AEO 2014 predicts lower energy consumption by the transportation sector, in contrast to the historical trend of 1% annual growth in energy consumption that was observed from 1975-2012. Transportation sector energy consumption is expected to decline from 26.7 quadrillion Btu in 2012 to 25.5 quadrillion Btu in 2040 due to a decrease in light duty vehicle (LDV) energy consumption. The AEO 2014 expects LDV energy consumption to decrease from 16.0 quadrillion Btu in 2012 to 12.1 quadrillion Btu in 2040. LDVs fueled by gasoline will remain the dominant type of vehicle. Gasoline powered vehicles will have a 78% share of new LDV vehicles in 2040, a decrease from an 82% share they held in 2012. The fuel economy of gasoline powered LDVs will continue to increase, while advanced fuel efficiency subsystem technologies, such as micro hybridization, will be added to 42% of new gasoline powered LDVs in 2040. LDVs that are powered by diesel, electricity, E85, plug-in hybrid or gasoline hybrid electric drive trains, will increase from 18% of new sales in 2012 to 22% in 2040.²⁷

Net imports of energy will see a decline in the AEO 2014. This decline is attributed to increased production of domestic oil, mainly shale oil, as well as to a decrease in demand caused by rising energy prices and continuing improvements of vehicle fuel economy. These imports are expected to decrease to 25% in 2016, yet rise to 32% in 2040 because of the decline in US domestic tight oil that is expected to begin in 2022.²⁸

²⁶ Leahy, M. and Bruel, H, "U.S. crude oil production growth contributes to global oil price stability in 2013 - Today in Energy," (Energy Information Administration (EIA).

²⁷ "AEO2014 Early Release Overview," (Energy Information Administrations (EIA), 8.

²⁸ Ibid, 13.

Exports of crude oil and motor gasoline are projected to increase as demand declines (due to improved vehicle efficiency) and refiners end up with a surplus of motor gasoline. US refiners will look to swap crude oil for heavier crudes that are better suited to be used in modern refineries. In 2012, the net import share of total US energy consumption was 16%. The AEO 2014 projects that number will decrease to only 4% by 2040 due to increased production and exports (**Figure 4**).²⁹

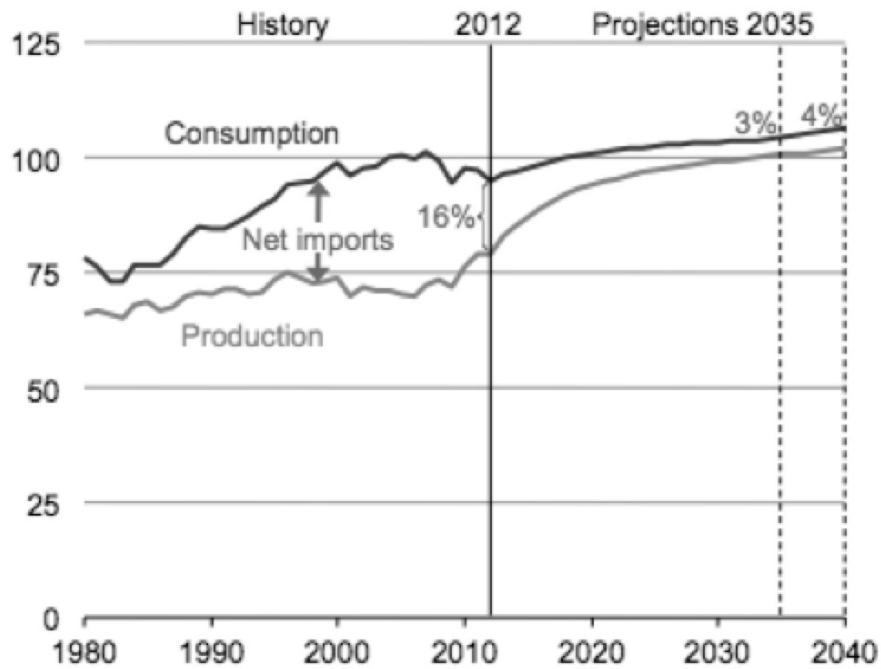


Figure 4: Total US energy production and consumption (quadrillion Btu), 1980-2040 (Source: EIA)

Section VI: Energy Security and the Transport Sector

The optimization and efficient use of oil in the US transportation sector is equally as important to US energy security as increased production and exports. Thus, the US has an interest in implementing a combination of policies to either continue or create opportunities to reduce oil consumption. Main policy options include, but are not limited to: fiscal incentives, support for new transportation technologies, continued improvements in fuel economy standards and AEV fueling infrastructure, traffic control measures, and improved public transportation.

The government can help increase the rate at which more fuel efficient vehicles are being developed and purchased by offering automakers and consumers various incentives. One particular incentive could be imposing higher fuel taxes in order to encourage US drivers to make an earlier switch to cars that run on a cheaper energy. When US gasoline prices hit their

²⁹ “AEO2014 Early Release Overview,” (Energy Information Administrations (EIA), 12.

highest average retail price in history, at \$4.37 per gallon in June 2008 (using the Consumer Price Index to express the 2008 dollars in real December 2013 dollars), there was a significant decline in US oil consumption, as seen in **Figure 5**.³⁰ While higher gasoline prices are correlated with reduced consumption, they usually result from a disruption in supply and not from deliberate increases made by government officials. One potential obstacle to implementing an incentive to accelerate the switch to AEVs by increasing fuel taxes could be backlash from consumers and lobbyists of oil companies that could influence policymakers.

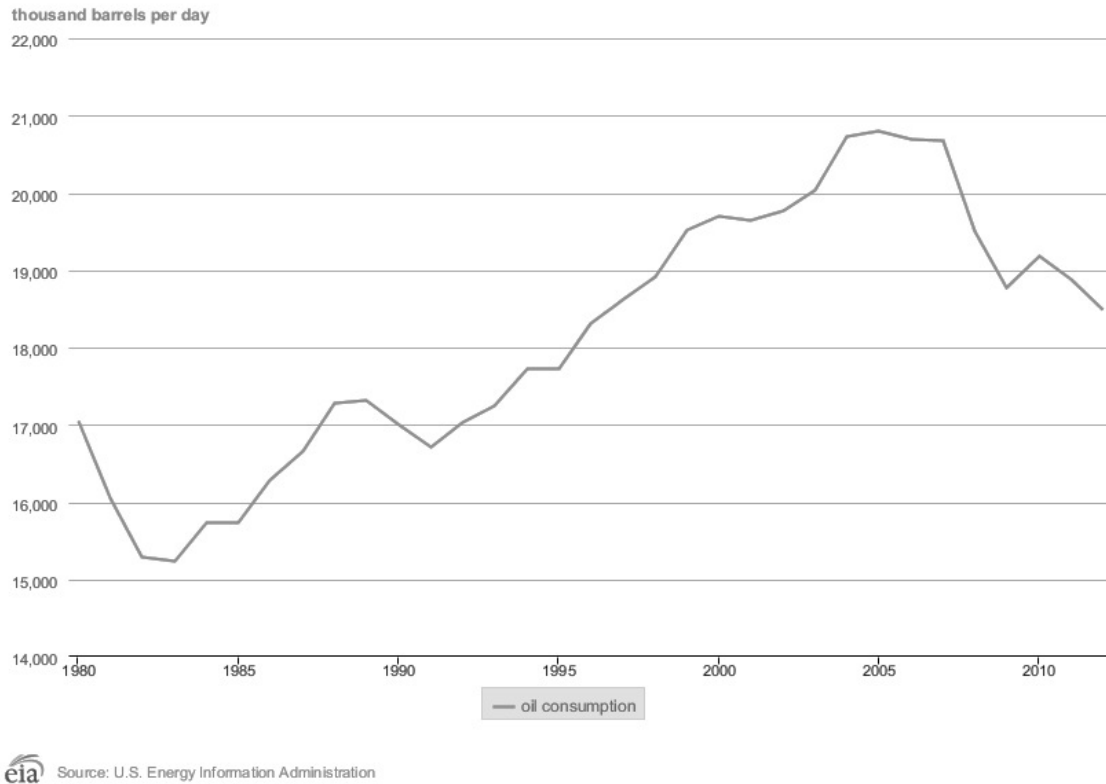


Figure 5: United States oil consumption, 1980-2012 (Source: EIA).

California, with a more extensive list of incentives than any other state, can serve as a national model for increasing AEV purchases. One incentive they offer is that qualified electric and plug-in electric vehicle users are exempt from paying toll fees to use High Occupancy Toll (HOT) lanes, and may also use designated High Occupancy Vehicle (HOV) lanes even without the required number of occupants.³¹

³⁰ “What was the highest U.S. average retail price of regular gasoline? – FAQ – U.S.,” (Energy Information Administration).

³¹ Hartman, K, "State Electric Vehicle Incentives and Information," (ncsl.org).

The Clean Vehicle Rebate Project (CVRP) offers California Air Resources Board (ARB) approved and certified light duty zero emissions and plug-in hybrid vehicles a rebate up to \$2,500.³²

The California Alternative Energy and Advanced Transportation Financing Authority (CAEATFA) helps to finance property that is used in the development and commercialization of innovative transportation technologies, which promote economic development and decrease emissions and energy use.³³

The Drive Clean! Rebate Program funds rebates up to \$3,000 to be used for the purchasing or leasing of new vehicles that meet the San Joaquin Valley Air Pollution Control District standards. Many of these vehicles are natural gas and plug-in electric models.³⁴

Various insurance agencies offer a discount to HEV and AFV owners of up to 10% on particular insurance coverage.³⁵

The California Energy Commission, by way of the Alternative and Renewable Fuel Vehicle Technology Program, works to provide fleet owners, business, consumers, vehicle and technology producers, workforce training institutions, and academic establishments with financial incentives to achieve an ultimate goal of developing and implementing renewable and alternative fuels as well as innovative transportation technology.³⁶

Free, metered parking is offered in San Jose, Hermosa Beach, and Santa Monica, contingent upon the displaying of a Clean Air decal for EV owners. Sacramento offers free parking in designated downtown surface lots and parking garages to owners in possession of a certified EV parking pass. The California Department of General Services (DGS) and California Department of Transportation (DOT) require at least 50 parking spaces and 50 park-and-ride lots be reserved for owners of AEVs.³⁷

In addition to possibly implementing federal incentives similar to those already in place in California, DOE offices and programs pertaining to the research and development of AEV technologies, such as EERE and ARPA-E, continued and adequate funding for these offices and programs will help to achieve the goal of reducing oil consumption within the US transportation sector.

³² Hartman, K, "State Electric Vehicle Incentives and Information," (nsl.org).

³³ Ibid.

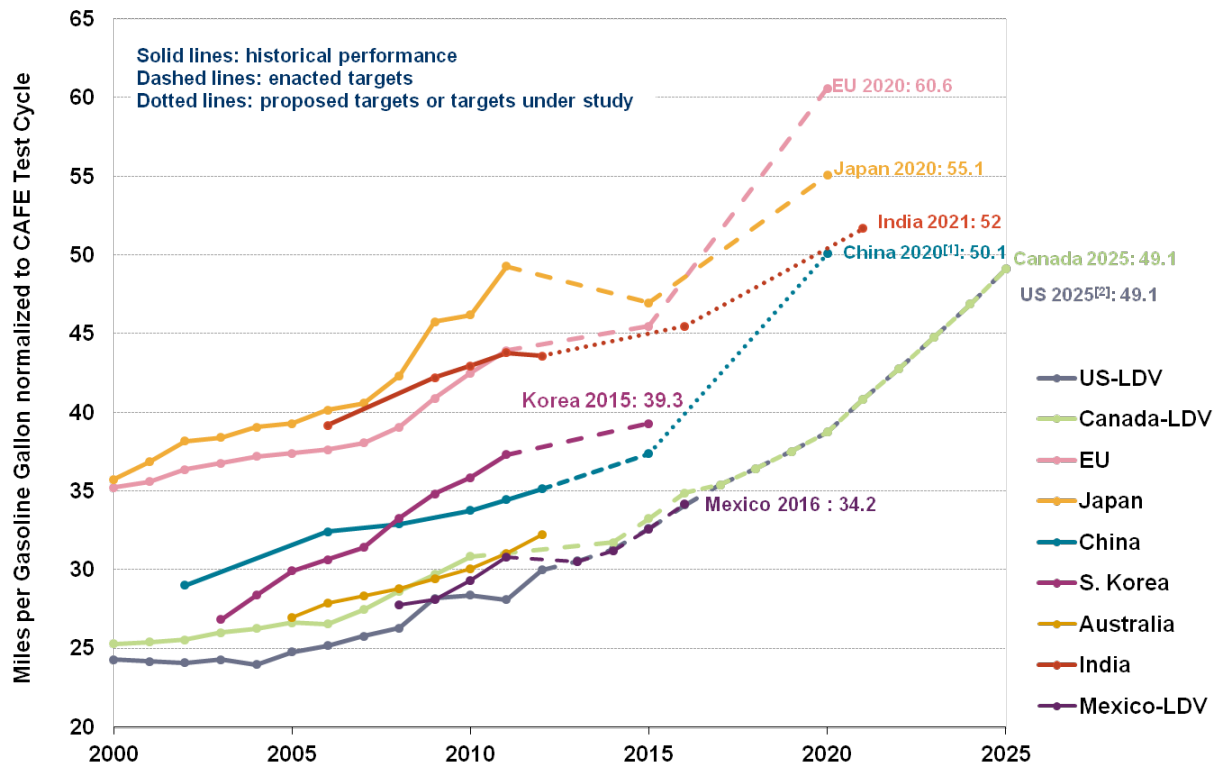
³⁴ Ibid.

³⁵ Ibid.

³⁶ Ibid.

³⁷ Ibid.

Continued improvements of fuel economy standards and AEV fueling infrastructure are also key elements in increasing US energy security. Although Obama recently raised fuel economy standards, the US still lags behind Japan and the EU for enacted vehicle fuel efficiency standards (see **Figure 6**).³⁸ Additionally, there are only 29,013 alternative energy fueling stations (combined number of Biodiesel, CNG, E85, Electric, HY, LNG, and LPG fueling stations) in the US, compared to 121,446 gas stations.³⁹



[1] China's target reflects gasoline vehicles only. The target may be higher after new energy vehicles are considered.
 [2] US, Canada, and Mexico light-duty vehicles include light-commercial vehicles.
 [3] Supporting data can be found at: <http://www.theicct.org/info-tools/global-passenger-vehicle-standards>.

Figure 6: Miles per Gasoline Gallon measured by CAFE Test Cycle (Source: The ICCT).

Higher required fuel efficiency standards will push automakers to pursue developing more AEV models. Ensuring there will be an adequate amount of AEV fueling stations across the nation will provide reassurance to automakers and consumers alike, resulting in more AEVs on US roads. Moreover, if US fuel efficiency standards were to equal those of the EU and Japan, automakers that develop models that achieve such standards would benefit by being able to sell their vehicles in every world market.

³⁸ "Global Comparison of Light-Duty Vehicle Fuel Economy/GHG Emissions Standards," (The International Council on Clean Transportation (ICCT)), 3.

³⁹ "Alternative Fuels Data Center: Alternative Fueling Station Counts by State," (afdc.energy.gov).

Finally, another option that the US could utilize in the future is implementing traffic control measures that would reduce the number of vehicles on the road. This includes better public transit and city congestion charges.

Fiscal investments in a greater number of fast, reliable, public transportation systems in both major and smaller cities across the US are another option to reduce domestic oil consumption. The American Public Transportation Association (APTA) reported that 39% of transportation agencies across the US stated, “overcrowded conditions were such that they were turning away passengers.”⁴⁰ Public transit systems that are ready to accommodate and efficiently transport people, who choose to take public transportation instead of buying an AEV as their contribution towards reducing US oil consumption, will further reduce US oil usage.

Public transportation system improvements would be needed if city congestion charges were implemented. The idea behind these charges is to prevent pollution and reduce inner-city traffic by implementing a daily fee for people wanting to drive within a typically congested city zone. Implementing a city congestion charge would reduce oil consumption due to the daily fee leading people to forego their personal vehicles in favor of public transportation. If modeled after the city congestion charge that was started in London in 2003, the revenues generated by the daily congestion fees could be used as a source of funding for improvements to public transportation systems.⁴¹

A combination of the oil reducing options of fiscal incentives, support for new transportation technologies, continued improvements in fuel economy standards and AEV fueling infrastructure, traffic control measures, and improved public transportation, will help to decrease oil usage within the US transportation sector even as shale oil production continues. A decrease in oil demand, from both domestic and foreign suppliers, will allow the portion of shale oil that helps to fuel the US transportation sector to be redirected and used towards lessening the dependency on foreign oil of other sectors.

Conclusion

The six sections within this chapter provide contrasting evidence to the four concerns about shale oil and its effects on the future of US transportation, which were discussed in the introduction. These sections indicate that shale oil production has not: impeded research, development and implementation of technological innovations in transportation; hindered improvements in fuel economy standards; resulted in dramatic drops in oil prices which deter

⁴⁰ Plumer, B, "Is public transit habit-forming?," (Washington Post).

⁴¹ "Congestion Charge System in London ∴ Sustainable Development Knowledge Platform," (sustainabledevelopment.un.org).

consumers and automakers from buying and developing AEVs; increased US oil dependency or imports.

The future of US transportation, despite shale oil production, will continue along a path towards producing vehicles with improved fuel economy standards, developing and deploying alternative energy vehicle technologies, and implementing policies that lead to reduced oil usage. Combined, these actions will contribute towards greater US energy security.

Conclusion

Despite the development and innovation that has already been seen, the shale oil revolution remains in an early stage. It will continue to evolve rapidly and in a dynamic manner, adding to US energy security and economic strength while also leaving the short and long-term environmental impacts relatively uncertain. Evaluations on its ultimate potential are still preliminary; there is a high potential for progress nationally and internationally, yet also for significant local costs.

Development of fracking technology and shale oil production has been extremely rapid. This has had positive effects in quickly reducing petroleum imports, adding jobs, and producing revenue for many communities, yet it has also made it impossible for infrastructure and regulation to keep pace. Many thousands of wells have been drilled and put on production since 2010. Lags in pipeline and oil transportation infrastructure have left large volumes transported by truck and rail, such as in the Bakken play, increasing the risk of spills and explosions, as already proven by several incidents. Insufficient gas infrastructure has led to flaring in all of the major shale oil plays. Cases of water contamination, both of aquifers and streams, have also been documented. These instances are rare and in many cases temporary. Investigations have shown that faulty cementing of well casing, not fracking, has been responsible for aquifer contamination. Yet poor handling and disposal of fracking wastewater has led to some examples of surface water pollution.

Shale oil development at its current stage is therefore not without its risks. These risks represent externalities, whose costs are not always borne by direct stakeholders in oil production and transport. Makeshift regulatory action and limited policy have together been unable to create a standardized framework for lowering risk, while supporting continued drilling and production. Such a framework, creating a consistent set of rules and guidelines, is sorely needed by oil companies, landowners, railroads, wastewater treatment operators, local government, and other stakeholders.

In order to move beyond the current boom to a period of stabilization and efficient growth/development, shale oil production and fracking must be addressed by federal policy through a broader, more long-term outlook. The national and international benefits of the shale oil revolution to the U.S. are considerable, fairly clear, and will grow. Shale oil, in fact, is only the larger component of the tight oil category, whose total potential, in light of continued advances in fracking technology, must be understood as immense.

This is also true for other nations, including China, Australia, Britain, and other parts of the EU. The prospect of shale oil, as a new element in the global energy landscape, will likely be consequential beyond both our region and time. There are serious implications that must be taken

into consideration by federal policy. This Task Force considers the following to be among the most important:

- Advantages accruing to the United States from shale oil development have come very quickly and exceeded nearly all expectations. Oil security has been the key concern of US energy policy for over 40 years, ever since the 1973-74 oil crisis, and to find a substantial part of this concern erased within a few brief years has done much to elevate the confidence and international standing of the country. For these reasons, as well as the many economic benefits stemming from shale oil production, such development should be encouraged by federal policy, within certain limits. At the same time, the success of shale oil does not mean the US should disengage from its role in protecting global oil trade. Key US allies, including the countries of NATO, Japan, and Korea, will continue to depend long-term on imports from OPEC, despite any increased exports from the US.
- How the United States chooses to move forward with increased supply in the global oil market will have significant implications on geopolitical relationships, especially with other oil exporting countries. The US has the potential to insert itself as a new production center, both of petroleum products and, possibly, crude oil, shifting established trade relations. Oil is among the most highly traded and politicized commodities. If the US does become a major new exporter, it is more than likely this will be perceived by OPEC and Russia as the use of oil as a foreign policy tool, thus as a potential threat. The US must be somewhat cautious in how it proceeds, or least aware that any overt move to lower the power of these petro-states, particularly with major importers such as Europe and Japan, could lead to unanticipated responses.
- On the domestic side, lack of information and barriers between the federal government, oil industry and the public have created uncertainty in the impacts of fracking in regards to environmental health. Short-term environmental consequences of the new surge in drilling and fracking, for example water contamination, have s been linked to bad practices and, while unavoidable at some level (given the scale of development), could be significantly reduced by implementing higher standards for oil companies. However, the creation and enforcement of environmental policy remains weak, allowing problems to continue. Further, the long-term environmental impacts of shale oil still are unknown. As the shale oil boom encouraged rapid production, little focus was placed on environmental considerations or research. Moreover, as the boom has expanded, new and unexpected challenges have emerged, such as the growing extent of gas flaring and the explosive nature of Bakken crude. Though companies have begun to respond with innovations to reduce immediate

environmental impacts and appease short-term anxieties, the long-term implication for public health remains unknown.

- The politics of shale oil and fracking in terms of US regulation is complex, shown in the potential conflict between state and federal jurisdiction. States have taken the lead in creating regulation and policy so far. The geographical distribution of shale across the United States often sparks more localized concerns, and therefore localized responses by county and state governments. However, such responses have been highly variable, creating imbalances and inconsistencies across the nation and making federal regulation hard to design and implement. The situation can be partly resolved if federal regulators, after considering all relevant information and drawing on field expertise, provide a set of evolving guidelines for states to consider in their own policy efforts. At the same time, specific federal regulations need to be established as well, governing areas currently overseen by US agencies but not yet covering shale oil fracking, e.g. frack water treatment and recycling, testing of crude oil destined for interstate transport. Whether fracking policy continues to rely within the hands of the states or expand to a federal framework will have large implications on if and how fracking is standardized and oil companies are monitored.
- The economics behind the shale oil revolution has significant domestic and global implications. Differences in the structure and experience of the oil industry in other nations, subsurface ownership rights, tax rates, and other “above ground” factors make it unlikely that the US case will be replicated anywhere else, except perhaps in Canada. Still, the potential to develop shale oil (and gas) in countries overseas, especially in Europe, is a potential channel to boost domestic economies. However, this could only be a short-term outcome. In the long-term, massive increases in shale oil production are unlikely to bring a major fall in oil prices. Saudi Arabia has already responded to US production increases by cutting its output in order to keep prices near \$100 a barrel. Certainly there is a limit to such response; however, forecasts today do not show tight oil becoming more than about 8%-9% of total world supply over the next 30 years. Such forecasts also estimate that any large increases in shale oil production outside the US will not be forthcoming until the mid-late 2020s, by which time US output will have started to decline. These forecasts, however, are preliminary at best. Any timeline for the spread of the shale oil revolution to other nations, including US allies, would be shortened by the overseas dissemination of know-how and technology from America’s oil fields.

The shale oil revolution has positioned the United States to become a leader in fracking and the development of unconventional energy sources. Shale oil and its future as a leading

energy source interacts on many different levels of US interests, on both a domestic and global scale. The long-term implications intersect to form a delicate environment in which the benefits and detriments must be balanced in order to establish sustainable growth and potential self-sufficiency. If approached strategically, the US has the chance to set themselves as a model for other countries. While the ease of with which this can be done should not be overestimated, the United States undoubtedly has the resources and capabilities to lead the way through the transformation of the energy landscape.

Policy Recommendations

Based on the implications of shale oil development and hydraulic fracturing within the US, this Task Force proposes the following recommendations to shape the future of US leadership in sustainable unconventional energy development:

- **Lift the ban on exports of US crude oil.** The ban on crude oil exports, instituted as part of the 1975 Energy Policy and Conservation Act, was intended to protect consumers against short-term volatility and price spikes. There are two big reasons to lift the ban. First, it has never worked very well, as shown for example by the 2008 price spike. Second, the situation of US crude oil has completely reversed from what it was in the 1970s: instead of declining production, rendering the nation more vulnerable to OPEC, oil output has rapidly grown, reducing imports dramatically, especially from the Middle East. Today, the US has the opportunity to actually stabilize the oil market further by diversifying global supply, promoting free trade of crude, and thus also strengthening energy security for itself, its allies, and all major importers. US oil exports to its allies can reduce their dependence on petro-states and blunt any use of the so-called oil weapon. As major new exporter, U.S. can offer Europe leverage they can use to bargain for better terms with Russian producers. Additionally, US refineries have not all received the updates necessary to properly refine shale oil. Exporting crude oil to refining countries, such as South Korea and Japan, can strengthen their economies as well.
- **Expand Existing Programs Related to the Sharing of Technology and Knowledge Related to Shale Development.** This would include the following three programs: the US-China Shale Gas Initiative; the Unconventional Gas Technical Engagement Program; and the Energy Governance and Capacity Initiative. These programs should all be expanded to include tight oil generally, and shale oil in particular. They should be closely coordinated and used to promote exchanges and training related to geologic and engineering knowledge, safe drilling and fracking techniques, an understanding of environmental risks, and remediation possibilities. This will help US relations with other nations, including China, and will promote the US as a responsible world leader in the area of energy technology and environmental stewardship.
- **Fast Track Pipelines on Federal Lands; Approve Keystone XL.** The policy recommendations of this Task Force recognize environmental risks as an externality that needs to be incorporated into the overall economics of shale oil and its transport. In order to keep pace with the fast rate of production of shale oil, appropriate energy infrastructure

that will transport extracted oil to American refineries and consumers will be necessary if the US is to pursue a global leadership role in the development of unconventional oil. Growing demand for oil, along with innovation in fracking technology, is increasing the strain on existing oil transportation infrastructure, thus it is important to expedite the construction of new pipelines, which continue to be most viable alternative to truck and rail transport, with respect to safety and sustainability. Fast tracked pipeline projects should be no less subjected to strict safety regulations than that of other major energy infrastructure projects in order to ensure long-term safety and sustainability. One such pipeline that should be approved is the *Keystone XL Project*, which will contribute to a more efficient domestic pipeline system. The issue of environmental degradation, however, must be taken account, thus the approval of the Keystone XL Pipeline should be contingent upon the re-routing of the pipeline away from the Sandhills region to avoid potentially catastrophic environmental and health consequences in the case of an oil spill.

- **Where Possible, Reroute and Reduce Oil Transport via Rail; Create Incentives to Accelerate Building of Safer (double-hulled) Tanker Cars.** In large part due to the recent shale oil boom, oil production has surpassed current railway capabilities, thus creating the need for new railway infrastructure. This task force first and foremost recommends prioritizing new pipeline infrastructure over new railway infrastructure in order to reduce the amount of oil transported by rail, which continues to be a dangerous method of transport with respect to environmental and health risks. However, in cases where pipeline cannot be built, new railway infrastructure must be built *away* from populated or ecologically sensitive areas, such as towns and important natural water reservoirs, swampland, farmland or forests. In order to avoid further environmental degradation and health risks, this task force recommends that current oil transported via railway be rerouted under similar conditions that new rail infrastructure is contingent upon. In the path towards US leadership in shale oil, there is no room for further tragedies resulting from railway car explosions and populations at risk for health issues associated with rail transport.
- **Improve Fuel Efficiency Standards and Transition to Natural Gas.** In order to truly become a global leader in the energy arena, the US must focus on reducing its oil consumption, which will enable it to increase oil exports, as it develops more unconventional sources of oil, thus strengthening economic partnerships with foreign nations all the while playing an important role in the global effort to reduce carbon dioxide emissions and the subsequent effects of climate change that result from them. A few ways that the US should consider reducing its rate of oil consumption is through

increased CAFE Standards and the switch to natural gas. The US already lags far behind in vehicle efficiency, compared to Japan and European nations, thus it is imperative that the US reach or exceed current CAFE Standards in these countries by 2020 or sooner. In addition, the switch to natural gas for light and heavy-duty trucks will be an important step in the reduction of oil consumption, as these types of vehicles utilize vast quantities of oil and release higher rates of emissions. The domestic abundance and relative inexpensiveness of natural gas, makes it a viable alternative to oil in regards to the transportation sector. The US should pledge to have all new light and heavy-duty trucks running on natural gas by 2020.

➤ **Re-diverting \$24.2 billion in Revenue by Closing Oil Company's Tax Loopholes.**

This Task Force recommends the approval of President Obama's proposal to close tax loopholes currently in place for oil companies, which will generate \$24.2 billion in revenue. Part of this sum should be pledged towards conducting long-term baseline studies that will help accurately assess the health and environmental impacts that may result from fracking. These studies would be conducted with the help of the National Academy of Sciences and the National Research Council, which would also issue comprehensive reports on related findings and their implications.

In addition, another part of the \$24.2 billion should be re-diverted towards tax incentives for oil and gas companies that decrease water usage through sustainable means, such as recycling. This change in water reduction should be measured as the change from current water usage rather than total water usage. Tax incentives should also be offered for oil companies who choose to voluntarily disclose the chemical components of fracking fluids, which is a step in the right direction towards transparency between the industry, the government and the public.

The remaining sum should be used to create a remediation fund that will go towards several efforts: 1) any emergency cleanup or other action needed on federal lands that lies outside the responsibility of private firms; 2) to help provide people whose water has been scientifically proven to be adversely affected by drilling and/or fracking activities; 3) to help to provide states and local communities with clean up of existing environmental damages, such as those that result from old and abandoned oil wells that contaminate water supplies and soil. A major goal for this fund will be to strengthen public support for shale oil development and to show the willingness of industry to contribute towards responsible action.

Continued shale oil development needs a supportive legal and regulatory environment, but must be balanced by transparency, environmental protection, safety, and remediation to help build public confidence.

- **Create a National Advisory Board on Energy Policy.** Due to the interconnectedness of issues in energy policy, a new board should be created to centralize the energy policy decision-making process. This board should be a permanent body within the executive branch of the US government. It should include a subcommittee specifically focusing on tight oil and gas. This advisory board should analyze data and make policy recommendations regarding energy decisions, taking into account issues of national security, environmental risks, and diplomatic relations. Regulatory authority should be as clear and concentrated as possible, to simplify policy creation and enforcement. Such authority, if it must be divided among several or more agencies, should be consistently coordinated. Possible structures for this board are as follows:
- Restructure the Office of Science & Technology Policy to combine its divisions on Technology and Innovation, Environment and Energy, and National Security and International Relations.
 - Create an Office of Tight Oil and Gas within the Department of Energy. Use a strengthened and expanded Shale Gas Research and Development division as its main source of data.
 - Create a new advisory board in the executive branch, separate from other departments. This would allow for the greatest centralization of energy policy decision-making.

Bibliography

Chapter One

- Aga.org. "How to Measure Natural Gas - Natural Gas." 2014.
<http://www.aga.org/KC/ABOUTNATURALGAS/ADDITIONAL/Pages/HowtoMeasureNaturalGas.aspx> (accessed 27 Feb 2014).
- AOGHS. "Shooters – A “Fracking” History." 2013. <http://aoghs.org/oilfield-technologies/shooters-well-fracking-history/> (accessed 22 Feb 2014).
- Azzarello, Samantha. "Energy Price Spread: Natural Gas vs. Crude Oil in the US." CME Group, 2014.
- Beckwith, Robin. *Hydraulic Fracturing: The Fuss, The Facts, The Future. Hydraulic Fracturing: The Fuss, The Facts, The Future.* Joint Production Technologies (JPT), 2014.
<http://www.spe.org/jpt/print/archives/2010/12/10Hydraulic.pdf>. (accessed 22 Feb 2014).
- Cohen, David Michael. "USGS names Bakken play the largest oil accumulation in Lower 48." 2008.
- Finch, RW, JL Skees, WW Aud, JL Johnson, C Esphahanian, JT Hansen and Others. "Evolution of Completion and Fracture Stimulation Practices in the Jonah Field Sublette County WY." (1996).
- Geertsma, J, F De Klerk and Others. "A rapid method of predicting width and extent of hydraulically induced fractures." 21, no. 12 (1969): 1--571.
- Khristianovic, S. A. and Y. P. Zheltov. "Paper 6132: Formation of Vertical Fractures by Means of Highly Viscous Liquid." 1955.
- Kneller, Stephen R, Sally G Zinke, Robert W Mcdermott, Troy G Graham and Sarah E Shearer. "Unlocking the Potential of a Tight Gas Sand Giant: Pinedale Field, Wyoming." (2006).
- MacRae, Michael. "Fracking A Look Back - ASME." 2012. <https://www.asme.org/engineering-topics/articles/fossil-power/fracking-a-look-back> (accessed 22 Feb 2014).
- Martineau, David F. "History of the Newark East field and the Barnett Shale as a gas reservoir." 91, no. 4 (2007): 399--403.
- McMahon, Tim. "Historical Oil Prices: InflationData.com." 2014.
http://inflationdata.com/inflation/inflation_Rate/Historical_Oil_Prices_Table.asp (accessed 22 Feb 2014).
- Montgomery, Carl T. and Michael B. Smith. *Hydraulic Fracturing: History of An Enduring Technology. Hydraulic Fracturing: History of An Enduring Technology.* Joint Production Technologies (JPT), 2010. <http://www.spe.org/jpt/print/archives/2010/12/10Hydraulic.pdf>. (accessed 22 Feb 2014).
- Montgomery, Scott L., Daniel M. Jarvie, Kent A. Bowker and Richard M. Pollastro. "Mississippian Barnett Shale, Fort Worth basin, north-central Texas: Gas-shale play with multi-trillion cubic foot potential." 89, no. 2 (2004): 155-175.
- Perkins, TK, LR Kern and Others. "Widths of hydraulic fractures." 13, no. 09 (1961): 937--949.
- Perry, Kent and John Lee. "Unconventional Gas Reservoirs: Tight Gas, Coal Seams, and Shales." National Petroleum Council, Global Oil and Gas Study, 2007.
- Trembath, Alex, Jesse Jenkins, Ted Nordhaus and Michael Shellenberger. "Where The Shale Gas Revolution Came From: Government's Role In The Development Of Hydraulic Fracturing In Shale." Breakthrough Institute Energy & Climate Program, 2012.
- Unknown. "Estimated global distribution of fracturing equipment." Digital image, 2010.
<http://www.spe.org/jpt/print/archives/2010/12/10Hydraulic.pdf> (accessed 22 Feb 2014).
- Van Poolen, HK, John M Tinsley, Calvin D Saunders and Others. "Hydraulic Fracturing-Fracture Flow Capacity vs Well Productivity." (1958).
- Wang, Zhongmin and Alan Krupnick. "US Shale Gas Development: What Led to the Boom?." Resources for the Future, 2013.

Chapter Two

- Bloomberg. "Colorado Cities Sued Over Fracking Bans by Oil, Gas Group." 2013. <http://www.bloomberg.com/news/2013-12-04/colorado-cities-sued-over-fracking-ban-by-oil-gas-group.html> (accessed 4 Feb 2014).
- Brady, William. *Hydraulic Fracturing Regulation in the United States: The Laissez-Faire Approach of the Federal Government and Varying State Regulations*. Denver: University of Denver, Sturm College of Law, n.d..
- Broder, John. "New Fracking Rules Proposed for U.S. Land." 16th May, 2013, http://www.nytimes.com/2013/05/17/us/interior-proposes-new-rules-for-fracking-on-us-land.html?_r=0 (accessed 6 Feb 2014).
- Brown, Cassarah. "State Revenues and the Natural Gas Boom: An Assessment of State Oil and Gas Production Taxes." *National Conference of State Legislatures*, 2013. <http://www.ncsl.org/research/energy/state-revenues-and-the-natural-gas-boom.aspx#table2> [Accessed: 11 Feb 2014].
- Gas Production Taxes*. [online] Available at: <http://www.ncsl.org/research/energy/state-revenues-and-the-natural-gas-boom.aspx#table2> [Accessed: 11 Feb 2014]
- Chu, Steven. *Charge to Secretary of Energy Advisory Board Natural Gas Subcommittee to Examine Fracking Issues*. Washington D.C.: Department of Energy, 2011.
- Colaneri, Katie. "Ferlo Introduces 'Open-Ended' Fracking Moratorium Bill", *StateImpact*, 2013. <http://stateimpact.npr.org/pennsylvania/2013/09/18/ferlo-introduces-open-ended-fracking-moratorium-bill/> [Accessed: 11 Feb 2014].
- Coloradoindependent.com. "Colorado senators rally round fracking-awareness home-buyer protection bill | The Colorado Independent." 2014.
- Conlin, Michelle and Brian Grow. "They own the house, but not what lies beneath." 9th October, 2013, <http://graphics.thomsonreuters.com/13/10/USA-FRACKING:RIGHTS.pdf> (accessed 2 Feb 2014).
- "Crude Oil and Natural Gas Waste." *U.S. Environmental Protection Agency*, 2013.
- Davis, Charles and Katherine Hoffer. "Federalizing energy? Agenda change and the politics of fracking." *Policy Sciences* 45, no. 3 (2012): 221--241. <http://www.jstor.org/stable/41683146>.
- Davis, Charles. "The politics of "fracking": Regulating natural gas drilling practices in Colorado and Texas." *Review of Policy Research* 29, no. 2 (2012): 177--191.
- "Enforcement Basic Information." *U.S. Environmental Protection Agency*.
- "Exemption of Oil and Gas Exploration and Production Wastes from Federal Hazardous Waste Regulations." *U.S. Environmental Protection Agency*, 2002.
- "Few Answers on Fracking Violations." CNN. 2012. video.
- "Fracking Update: What States Are Doing to Ensure Safe Natural Gas Extraction." *National Conference of State Legislatures*, 2014. <http://www.ncsl.org/research/energy/fracking-update-what-states-are-doing.aspx> (accessed 2 Feb 2014).
- Galbraith, Kate. "Strong Rules on Fracking in Wyoming Seen as Model." *The New York Times*, 22nd November, 2013.
- Gottlieb, Charles. "Regulating Natural Gas Development Through Local Planning and Land Use Controls." *New York Zoning Law and Practice Report* 12, no. 6 (2014) Accessed 2 Feb 2014. <http://cce.cornell.edu/EnergyClimateChange/NaturalGasDev/Documents/NY%20ZONING%20HYDROFRACKING%20FINAL.pdf>.
- Hakim, Danny and Nicholas Confessore. "Cuomo Will Seek to Lift Ban on Hydraulic Fracturing." *The New York Times*, 30th June, 2011.
- Hammer, Rebecca and Jeanne Vanbriesen. *In Fracking's Wake: New Rules are Needed to Protect Our Health and Environment from Contaminated Wastewater*. National Resources Defense Council, 2012.

- Harris, Andrew. "Colorado Cities Sued Over Fracking Bans by Oil, Gas Group" *Bloomberg Sustainability*, 2013. <http://www.bloomberg.com/news/2013-12-04/colorado-cities-sued-over-fracking-ban-by-oil-gas-group.html>
- Hodge, Mary and Dominick Moreno. *A bill for an act concerning a disclosure of possible separate ownership of 101 the mineral estate in the sale of real property*. SENATE BILL 14-009. Colorado General Assembly, Denver. 2014.
- "Industrial & Municipal Waste Disposal Wells (Class I)." *U.S. Environmental Protection Agency*, 2012.
- Kaplan, Thomas. "Millions Spent in Albany Fight to Drill for Gas." *The New York Times*, November 26th, 2011. http://www.nytimes.com/2011/11/26/nyregion/hydrofracking-debate-spurs-huge-spending-by-industry.html?pagewanted=all&_r=0 (accessed 22 Feb 2014).
- Kinney-Lang, Shelby. "Colorado senators rally round fracking-awareness home-buyer protection bill" *The Colorado Independent*, January 29th, 2014. <http://www.coloradoindependent.com/145749/colorado-senators-rally-round-fracking-awareness-home-buyer-protection-bill> [Accessed: 4 Feb 2014].
- Lennon, L. 2013. *Coalbed Methane*. http://serc.carleton.edu/research_education/cretaceous/coalbed.html [Accessed: 22 Feb 2014].
- Manuel, John. "Mining: EPA tackles fracking." *Environmental health perspectives* 118, no. 5 (2010): 199.
- Matlok, Staci. "Mora County faces new lawsuit over drilling ban." 20th January, 2014, http://www.santafenewmexican.com/news/local_news/mora-county-faces-new-lawsuit-over-drilling-ban/article_c450c244-e949-596e-a4e2-8a487131843d.html (accessed 2 Feb 2014).
- Mufson, Steven. "Obama administration issues draft fracking regulations." *The Washington Post*, May 16th, 2013. http://www.washingtonpost.com/business/economy/obama-administration-issues-draft-fracking-regulations/2013/05/16/bff501bc-be58-11e2-97d4-a479289a31f9_story.html (accessed 22 Feb 2014).
- "Natural Gas Extraction - Hydraulic Fracturing." *U.S. Environmental Protection Agency*, 2013. Ncsl.org. "State Revenues and the Natural Gas Boom: An Assessment of State Oil and Gas Production Taxes." 2013. <http://www.ncsl.org/research/energy/state-revenues-and-the-natural-gas-boom.aspx#table2> (accessed 11 Feb 2014).
- New York's Environmental Conservation Law." In untitled conference. Article 23, Title 3. Department of Environmental Conservation, n.d..
- Nolon, John R and Victoria Polidoro. "Hydrofracking: Disturbances Both Geological and Political: Who Decides?." *The Urban Lawyer* 44, no. 3 (2012) <http://environment.yale.edu/content/documents/00002783/Hydrofracking-Disturbances-Both-Geological-and-Political-Who-Decides.pdf>.
- "Oil and Gas Effluent Guidelines." *U.S. Environmental Protection Agency*, 2013.
- "Oil and Gas; Hydraulic Fracturing on Federal and Indian Lands." *US Department of the Interior*, 2013.
- "Oil and Natural Gas Sector: New Source Performance Standards and National Emission Standards for Hazardous Air Pollutants Reviews." *U.S. Environmental Protection Agency*, 2012.
- Pirog, Robert. "CRS Report for Congress Prepared for Members and Committees of Congress Oil and Natural Gas Industry Tax Issues in the FY2014 Budget Proposal." *Congressional Research Service*, 2013.
- Pless, Jacquelyn. *Natural Gas Development and Hydraulic Fracturing A Policymaker's Guide*. National Conference of State Legislatures, 2012.
- "PROGRESS REPORT Study of the Potential Impacts of Hydraulic Fracturing on Drinking

- Water Resources." *U.S. Environmental Protection Agency*, 2012. Accessed January 28, 2014. <http://www2.epa.gov/sites/production/files/documents/hf-report20121214.pdf>
- Reuters. "Analysis: Why bankrupt W.R. Grace is thriving." 2013. <http://www.reuters.com/article/2013/06/16/us-wrgrace-bankruptcy-idUSBRE95F06U20130616> (accessed 10 Feb 2014).
- Senatorferlo.com. "Press Release: Senator Ferlo Announces Fracking Moratorium Legislation « State Senator Jim Ferlo." 2013. <http://www.senatorferlo.com/press-release-senator-ferlo-announces-fracking-moratorium-legislation> (accessed 22 Feb 2014).
- Serc.carleton.edu. "Coalbed Methane." 2013. http://serc.carleton.edu/research_education/cretaceous/coalbed.html (accessed 22 Feb 2014).
- Siegel, Jim. "Revised fracking-tax proposal has few fans." 2014, <http://www.dispatch.com/content/stories/local/2014/02/13/revised-fracking-tax-proposal-has-few-fans.html> (accessed 16 Feb 2014).
- "Split Estate," *Bureau of Land Management*, http://www.blm.gov/wo/st/en/prog/energy/oil_and_gas/best_management_practices/split_estate.html (accessed 5 Feb 2014).
- StateImpact Pennsylvania. "The oil and gas law of the land: your guide to Act 13." 2014. <http://stateimpact.npr.org/pennsylvania/tag/impact-fee/> (accessed 4 Feb 2014).
- StateImpact Pennsylvania. "Ferlo Introduces 'Open-Ended' Fracking Moratorium Bill." 2013. <http://stateimpact.npr.org/pennsylvania/2013/09/18/ferlo-introduces-open-ended-fracking-moratorium-bill/> (accessed 11 Feb 2014).
- StateImpact Pennsylvania. "Bucks Republican lawmaker wants severance tax on shale gas drilling." 2013. <https://stateimpact.npr.org/pennsylvania/2013/12/13/bucks-republican-lawmaker-wants-severance-tax-on-shale-gas-drilling/> (accessed 11 Feb 2014).
- The Huffington Post. "New Danger Found In Asbestos-Plagued Town." 2013. http://www.huffingtonpost.com/2011/07/05/libby-montana-asbestos-wood-piles_n_890222.html (accessed 10 Feb 2014).
- Trembath, Alex, Jesse Jenkins, Ted Nordhaus and Michael Shellenberger. "Where the Shale Gas Revolution Came From." *The Breakthrough Institute* (2012): 9. Accessed 1 Mar 2014.
- Warner, Barbara and Jennifer Shapiro. "Fractured, Fragmented Federalism: A Study in Fracking Regulatory Policy." *Publius: The Journal of Federalism* (2013) <http://publius.oxfordjournals.org/content/43/3/474.full.pdf+html>.
- Weinhold, Bob. "The future of fracking: new rules target air emissions for cleaner natural gas production." *Environmental health perspectives* 120, no. 7 (2012): 272.
- Wines, Michael. "Colorado Cities' Rejection of Fracking Poses Political Test for Natural Gas Industry." *The New York Times*, November 7th, 2013. http://www.nytimes.com/2013/11/08/us/colorado-cities-rejection-of-fracking-poses-political-test-for-natural-gas-industry.html?_r=1& (accessed 6 Feb 2014).

Chapter Three

- Eia.gov. "Energy & Financial Markets - U.S. Energy Information Administration (EIA) - U.S. Energy Information Administration (EIA)." 2013. <http://www.eia.gov/finance/markets/supply-opec.cfm> (accessed 08 Feb 2014).
- Eia.gov. "Energy & Financial Markets – What Drives Crude Oil Prices?" n.d.. <http://www.eia.gov/finance/markets/demand-oecd.cfm> (accessed 08 Feb 2014).
- Opec.org. "OPEC : OPEC Share of World Crude Oil Reserves." 2013. http://www.opec.org/opec_web/en/data_graphs/330.htm (accessed 21 Jan 2014).
- Reece, Mieke. "The IEA oil data system." *The IEA oil data system*. (Moscow: International Energy Agency, 2012): 6.

- <http://www.iea.org/media/workshops/2012/trainingmoscow/Session3Reece.pdf>. (accessed 9 Feb 2014).
- BP Statistical Review of World Energy. *BP Statistical Review of World Energy*. BP, (2013): 3, 6, 8, 9. http://www.bp.com/content/dam/bp/pdf/statistical-review/statistical_review_of_world_energy_2013.pdf. (accessed 5 Feb 2014).
- World Energy Outlook 2013 Factsheet. *World Energy Outlook 2013 Factsheet*. International Energy Agency, (2013): 1, 3. http://www.iea.org/media/files/WEO2013_factsheets.pdf. (accessed 21 Feb 2014).
- The Outlook for Energy: A View to 2040. *The Outlook for Energy: A View to 2040*. Exxon Mobil Corporation, (2014): 11, 13, 21-22, 36-37. <http://corporate.exxonmobil.com/en/energy/energy-outlook>. (accessed 9 Feb 2014).
- World Energy Outlook 2013. *World Energy Outlook 2013*. London: International Energy Agency, (2013): 1, 3-4, 8. <http://www.worldenergyoutlook.org/pressmedia/recentpresentations/LondonNovember12.pdf>. (accessed 10 Feb 2014).
- World Energy Outlook 2012. *World Energy Outlook 2012*. International Energy Agency, (2012): 1, 4. <http://www.iea.org/publications/freepublications/publication/English.pdf>. (accessed 30 Jan 2014).
- BP Energy Outlook 2035. *BP Energy Outlook 2035*. BP, (2014): 13, 25-27, 39. http://www.bp.com/content/dam/bp/pdf/Energy-economics/Energy-Outlook/Energy_Outlook_2035_booklet.pdf. (accessed 21 Feb 2014).
- BP Energy Outlook 2030. *BP Energy Outlook 2030*. BP. (2013): 34-35. http://www.bp.com/content/dam/bp/pdf/statistical-review/BP_World_Energy_Outlook_booklet_2013.pdf. (accessed 13 Feb 2014).
- Oil & Gas Security Emergency Response of IEA Countries. *Oil & Gas Security Emergency Response of IEA Countries*. International Energy Agency, (2012): 3, 5-6. http://www.iea.org/publications/freepublications/publication/China_2012.pdf. (accessed 21 Feb 2014).
- Short-Term Energy Outlook (STEO). Short-Term Energy Outlook (STEO). U.S. Energy Information Administration, (2014): 29. http://www.eia.gov/forecasts/steo/pdf/steo_full.pdf. (accessed 26 Feb 2014).
- Global Energy Trends: Focus on oil & gas. Global Energy Trends: Focus on oil & gas. Mexico City: International Energy Agency, (2012): 7, 11. http://www.iea.org/media/mvdh/Mexico_Seminar.pdf. (accessed 13 Feb 2014).
- Technically Recoverable Shale Oil and Shale Gas Resources: An Assessment of 137 Shale Formations in 41 Countries Outside the United States. Technically Recoverable Shale Oil and Shale Gas Resources: An Assessment of 137 Shale Formations in 41 Countries Outside the United States. U.S. Energy Information Administration, (2013): 2. <http://www.eia.gov/analysis/studies/worldshalegas/pdf/overview.pdf>. (accessed 27 Feb 2014).
- Wu, Kang, Fereidun Fesharaki, Sidney Westley and Widhyawan Prawiraatmadja. "Oil in Asia and the Pacific: Production, Consumption, Imports, and Policy Options." *Asia Pacific Issues* no. 85 (2008): 1, 2.

Chapter Four

- AEIdeas. "Another US energy milestone: Daily oil production last week topped 8 million barrels for the first time since January 1989." 2013. <http://www.aei-ideas.org/2013/11/another-us-energy-milestone-daily-oil-production-last-week-topped-8-million-barrels-for-the-first-time-since-january-1989/> (accessed 19 Feb 2014).
- Bizjournals.com. "Largest oil producers in the Eagle Ford Shale, slideshow - San Antonio

- Business Journal." 2014. http://www.bizjournals.com/sanantonio/blog/2013/02/largest-oil-producers-in-the-eagle.html?s=image_gallery&date=2013-02-07 (accessed 21 Feb 2014).
- Bloomberg. "Eagle Ford Shale Boom Fuels 'Madhouse' in South Texas Counties." 2013. <http://www.bloomberg.com/news/2013-03-14/eagle-ford-shale-boom-fuels-madhouse-in-south-texas-counties.html> (accessed 21 Feb 2014).
- Cline Shale Site. "Cline Shale Site - The latest and greatest on the Cline Shale." 2014. <http://clineshalesite.com/> (accessed 21 Feb 2014).
- Coga.org. "Colorado Oil & Gas Association." 2014. <http://www.coga.org/index.php/FastFacts/Niobrara#sthash.VDwEyGpy.dpbs> (accessed 21 Feb 2014).
- Cunningham, Nick and Warren Dym. "*The U.S. Tight-Oil Boom Geopolitical Winner or Long-Term Distraction?*." American Security Project, 2013.
- DailyFinance.com. "Is the Bakken Beginning to Wither Away? - DailyFinance." 2013. <http://www.dailyfinance.com/2013/11/11/is-the-bakken-beginning-to-wither-away/> (accessed 19 Feb 2014).
- DailyFinance.com. "Ohio More Than Doubles Oil and Gas Production in 2013 - DailyFinance." 2014. <http://dailyfinance.com/2014/01/06/oil-production-in-ohio-more-than-doubled-in-2013/> (accessed 21 Feb 2014).
- Dmr.nd.gov. "Active Drilling Rig List." 2014. <https://www.dmr.nd.gov/oilgas/riglist.asp> (accessed 21 Feb 2014).
- Dmr.nd.gov. "North Dakota Drilling and Production Statistics." 2014. <http://www.dmr.nd.gov/oilgas/stats/statisticsvw.asp> (accessed 21 Feb 2014).
- Dnr.louisiana.gov. "Newest Successful Well Project Completed in Tuscaloosa Marine Shale - Department of Natural Resources | State of Louisiana." 2012. <http://dnr.louisiana.gov/index.cfm?md=newsroom&tmp=detail&aid=946> (accessed 21 Feb 2014).
- Dnr.louisiana.gov. "Tuscaloosa Marine Shale - Department of Natural Resources | State of Louisiana." 2014. <http://dnr.louisiana.gov/index.cfm?md=pagebuilder&tmp=home&pid=909> (accessed 21 Feb 2014).
- drillinginfo - Oil & Gas Intelligence | better, faster decisions. "Secret of 5 Top Bakken Shale Producers - Drillinginfo." 2013. <http://info.drillinginfo.com/5-top-bakken-shale/> (accessed 21 Feb 2014).
- Eaglefordshale.com. "Chesapeake Energy | Eagle Ford Shale." 2014. <http://eaglefordshale.com/companies/chesapeake-energy/> (accessed 21 Feb 2014).
- Eaglefordshale.com. "EOG Resources | Eagle Ford Shale." 2014. <http://eaglefordshale.com/companies/eog-resources/> (accessed 21 Feb 2014).
- Eia.gov. "Analysis & Projections - U.S. Energy Information Administration (EIA) - U.S. Energy Information Administration (EIA)." 2011. <http://www.eia.gov/analysis/studies/usshalegas/> (accessed 24 Feb 2014).
- Eia.gov. "Bakken oil production forecast to top 1 million barrels per day next month - Today in Energy - U.S. Energy Information Administration (EIA)." 2013. <http://www.eia.gov/todayinenergy/detail.cfm?id=13811> (accessed 21 Feb 2014).
- Eia.gov. "Oil and gas industry employment growing much faster than total private sector employment - Today in Energy - U.S. Energy Information Administration (EIA)." 2013. <http://www.eia.gov/todayinenergy/detail.cfm?id=12451> (accessed 19 Feb 2014).
- Energyandcapital.com. "Niobrara Shale Stocks." 2013. <http://www.energyandcapital.com/articles/niobrara-shale-stocks/3618> (accessed 21 Feb 2014).
- Federal Reserve Bank Of Minneapolis. "*Data on Demographic, Economic and Financial Activity*

- in the Bakken.*" Federal Reserve Bank of Minneapolis, 2012.
- Headwaters Economics. "Unconventional Oil Revenues to Local Governments." 2014.
<http://headwaterseconomics.org/energy/state-energy-policies> (accessed 19 Feb 2014).
- Mariettatimes.com. "Eastern Ohio leads state in gas production - MariettaTimes.com | News, Sports, Jobs, Ohio, Community Information - The Marietta Times." 2014.
<https://www.mariettatimes.com/page/content.detail/id/556281/Eastern-Ohio-leads-state-in-gas-production.html?nav=5003> (accessed 24 Feb 2014).
- Mason, James. "Bakken's maximum potential oil production rate explored Social Media Tools." *Energy* 4, (2012): 02.
- Nobleenergyinc.com. "DJ Basin - nobleenergyinc.com." 2014.
<http://www.nobleenergyinc.com/Operations/U-S-Onshore/DJ-Basin-265.html> (accessed 24 Feb 2014).
- Nordeng, Stephen and Lynn Helms. "*Bakken Source System Three Forks Formation Assessment.*" North Dakota Department of Mineral Resources, 2010.
- ODNR Division of Oil & Gas Resources. "Shale Well Drilling & Permitting." 2014.
<http://oilandgas.ohiodnr.gov/shale#SHALE> (accessed 22 Feb 2014).
- Ogj.com. "Aurora reports Eagle Ford results with Marathon." 2013.
<http://www.ogj.com/articles/2013/07/aurora-reports-eagle-ford-results-with-marathon.html> (accessed 24 Feb 2014).
- Ogfj.com. "Granite Wash News, Wells, Formation, Markets and Resources: Oil & Gas Financial Journal." 2014. <http://www.ogfj.com/unconventional/granite-wash.com.html> (accessed 22 Feb 2014).
- Ogfj.com. "IHS describes complexity of Bone Spring oil play." 2012.
<http://www.ogfj.com/articles/2012/03/ihs-describes-complexity-of-bone-spring-oil-play.html> (accessed 22 Feb 2014).
- Ogj.com. "Apache fracs Wolfcamp wells without fresh water in dry Barnhart project area." 2014.
<http://www.ogj.com/articles/uogr/print/volume-2/issue-1/wolfcamp/apache-fracs-wolfcamp-wells-without-fresh-water-in-dry-barnhart-project-area.html> (accessed 18 Feb 2014).
- Ogj.com. "Baker Hughes: US drilling rig count climbs to 1,785." 2014.
<http://www.ogj.com/articles/2014/01/baker-hughes-us-drilling-rig-count-climbs-to-1-785.html> (accessed 18 Feb 2014).
- Ogj.com. "Texas: Energy adds Bone Spring/Avalon acreage." 2011.
<http://www.ogj.com/articles/2011/01/texas--energy-adds.html> (accessed 22 Feb 2014).
- Ogj.com. "URTeC: Wolfcamp play dwarfs Bakken, Eagle Ford." 2013.
<http://www.ogj.com/articles/2013/08/urtech-wolfcamp-play-dwarves-bakken-eagle-ford.html> (accessed 22 Feb 2014).
- Ogj.com. "Wolfcamp shale graduates to 'world class' play." 2013.
<http://www.ogj.com/articles/uogr/print/volume-1/issue-3/urtec-wolfcamp/wolfcamp-shale-graduates-to-world-class-play.html> (accessed 22 Feb 2014).
- Ohio.com. "Drilling is having population impacts on Great Plains." 2013.
<http://www.ohio.com/blogs/drilling/ohio-utica-shale-1.291290/drilling-is-having-population-impacts-on-great-plains-1.381210> (accessed 21 Feb 2014).
- Oilindependents.org. "www.oilindependents.org » Utica – The Shale Revolution Coming to Ohio." 2014. <http://oilindependents.org/utica-the-shale-revolution-coming-to-ohio/> (accessed 22 Feb 2014).
- P2energysolutions.com. "The Tuscaloosa Marine Shale Brings New Attention to Louisiana | P2 Energy Solutions." 2014. <http://www.p2energysolutions.com/tobin-talk/tuscaloosa-marine-shale-brings-new-attention-louisiana> (accessed 22 Feb 2014).
- Pless, Jacquelyn. "*Regulating Hydraulic Fracturing: States Take Action.*" National Conference of State Legislatures, 2010.

- Porter, David. "Eagle Ford Shale Task Force Report." Railroad Commission of Texas, 2013.
- Press.ihs.com. "U.S. Unconventional Oil and Gas Revolution to Increase Disposable Income by More than \$2,700 per Household and Boost U.S. Trade Position by More than \$164 billion in 2020, New IHS Study Says | IHS Online Pressroom." 2013. <http://press.ihs.com/press-release/economics/us-unconventional-oil-and-gas-revolution-increase-disposable-income-more-270> (accessed 22 Feb 2014).
- Ratner, Michael and Mary Tiemann. "An Overview of Unconventional Oil and Natural Gas: Resources and Federal Actions." Congressional Research Service, 2013.
- Robertson, Helen. "Shale a Boon for US Economy." *Petroleum Economist* (2013): 1.
- Rrc.state.tx.us. "Eagle Ford Information." 2014. <http://www.rrc.state.tx.us/eagleford/> (accessed 22 Feb 2014).
- Rrc.state.tx.us. "Permian Basin for RRC - Content Page." 2014. <http://www.rrc.state.tx.us/permianbasin/> (accessed 22 Feb 2014).
- Seekingalpha.com. "Cline Shale: Another Home Run For U.S. Shale Oil?." 2014. <http://seekingalpha.com/article/1839552-cline-shale-another-home-run-for-u-s-shale-oil> (accessed 22 Feb 2014).
- Seekingalpha.com. "Eagle Ford Shale: Economic Side Effects Of Downspacing." 2014. <http://seekingalpha.com/article/1963201-eagle-ford-shale-economic-side-effects-of-downspacing> (accessed 19 Feb 2014).
- Seekingalpha.com. "Occidental Petroleum In The Permian." 2014. <http://seekingalpha.com/article/1960521-occidental-petroleum-in-the-permian> (accessed 22 Feb 2014).
- Seekingalpha.com. "Permian Basin's Cline Play Reinforces Growth Potential." 2013. <http://seekingalpha.com/article/1852711-permian-basins-cline-play-reinforces-growth-potential> (accessed 22 Feb 2014).
- Shaleexperts.com. "Austin Chalk Overview - Maps - Geology - Counties." 2014. <http://www.shaleexperts.com/plays/austin-chalk/Overview?nav> (accessed 22 Feb 2014).
- Shaleexperts.com. "Granite Wash, News, Companies, Drilling Rigs, Acreage, Well Permits, Operators." 2014. <http://www.shaleexperts.com/plays/granite-wash/?menu> (accessed 22 Feb 2014).
- Shaleexperts.com. "Niobrara Shale, News, Companies, Drilling Rigs, Acreage, Well Permits, Operators." 2014. <http://www.shaleexperts.com/plays/niobrara-shale> (accessed 22 Feb 2014).
- Shaleexperts.com. "Wolfcamp Shale Overview - Maps - Geology - Counties." 2014. <http://www.shaleexperts.com/plays/wolfcamp-shale/Overview?nav> (accessed 22 Feb 2014).
- The Belfer Center for Science and International Affairs. "US Shale Oil Report." Harvard Kennedy School, 2013.
- The Niobrara News. "Noble Energy Niobrara Plan Focuses on Optimal Downspacing." 2014. <http://www.niobranews.net/niobrara-geology/noble-energy-niobrara-plan-focuses-optimal-downspacing/> (accessed 24 Feb 2014).
- townhall.com. "Sarah Jean Seman - North Dakota Oil Fields Spur Employment and Population Growth." 2013. <http://townhall.com/tipsheet/sarahjeanseman/2013/12/30/census-report-north-dakota-employment-and-population-grow-due-to-oil-fields-n1770016> (accessed 22 Feb 2014).
- Unconventional Gas Center. "Granite Wash Operators Await Better Gas Prices, Target Oilier Zones." 2013. http://www.ugcenter.com/Granite-Wash/Granite-Wash-Operators-Await-Gas-Prices-Target-Oilier-Zones_116704 (accessed 22 Feb 2014).
- US Energy Information Administration. "Drilling Productivity Report." US Energy Information Administration, 2014.

- US Energy Information Administration. "*Outlook for US Shale Oil and Gas*." Houston: US Energy Information Administration, 2014.
- US Energy Information Administration. "*Technically Recoverable Shale Oil and Shale Gas Resources: An Assessment of 137 Shale Formations in 41 Countries Outside the United States*." US Department of Energy, 2013.
- Usgs.gov. "USGS Release: USGS Releases First Assessment of Shale Gas Resources in the Utica Shale: 38 trillion cubic feet (10/4/2012 5:24:04 PM)." 2014.
<http://www.usgs.gov/newsroom/article.asp?ID=3419#UvBSYXddUpE> (accessed 22 Feb 2014).
- Wyomingenergynews.com. "The Niobrara Shale Drives Colorado Oil Production to 50-Year High — Wyoming Energy News." 2013.
<http://www.wyomingenergynews.com/2013/03/regional-update-the-niobrara-shale-drives-colorado-oil-production-to-50-year-high/> (accessed 22 Feb 2014).

Chapter Five

- Aizhu, Chen. "China's ragtag shale army a long way from revolution." *Reuters*, March 11, 2013.
- Alessi, Robert and Jeffrey Kuhn. "British government lifts year-old fracking moratorium." *DLA Piper*, 12 December, 2012.
- Barbee, Darren "The Great Wall: China Struggles to Emulate US Shale Success." *Unconventional Oil and Gas Center*, 31 December, 2013.
- Biello, David. "Can Fracking Clean China's Air and Slow Climate Change?." *Scientific American*, 27 January, 2014.
- Blenda, Carol. "The Shale Revolution and Emerging Markets." *Harvard Law School Blog* 21 August, 2013. <http://blogs.law.harvard.edu/carolblenda/2013/08/> (accessed 21 Feb 2014).
- Bridges, Brianna. "Demand Chemical Plant Clean Up Pollution in China's Longest River." *Forcechange.com*, 2014.
- Cernoch, Filip and Lukasz Kister. *Shale gas in Poland and the Czech Republic: Regulation, Infrastructure and Perspectives of Cooperation*. International Institute of Political Science., 2012. http://www.iips.cz/data/files/Publikace/Shale_Gas.pdf. (accessed 21 Feb 2014).
- Cges.co.uk. "*China's oil demand to 2020*." 2014. <http://www.cges.co.uk/news/1026-chinas-oil-demand-to-2020> (accessed 21 Feb 2014).
- Chazan, Guy. "Russia gears up for shale boom." *FT.com*, 31 March, 2013.
- Chelney, Stan. "European Union Decision Clears the Way For Fracking Investment." *Energy Legal Blog* 3 February, 2014. <http://www.energylegalblog.com/archives/2014/02/03/5099> (accessed 21 Feb 2014).
- EIA. *China*. Washington D.C.: EIA, 2013.
http://www.eia.gov/analysis/studies/worldshalegas/pdf/chaptersxx_xxvi.pdf. (accessed 21 Feb 2014).
- PIM LTD. "China's Shale Gas Development Briefing." Shanghai: *PIM LTD*, 2013.
- Ciensi, Jan. "Eni joins shale gas exodus from Poland." *Financial Times*, 15 January, 2014.
- Daltorio, Tony. "How to Invest in the Global Shale Oil and Gas Boom." *Money Morning*, 8 October, 2013.
- Daly, John. "It's Official - China Embraces Oil Shale and Fracking." *OilPrice*, 2 September, 2012.
- Dunnahoe, Tayvis. "Beyond US border, Mexico primes shale potential." *OGJ*, 1 May, 2013.
- Easton, Adam. "Poland: shale investors warn against planned tough rule changes." *Beyond Brics* 7 June, 2013. <http://blogs.ft.com/beyond-brics/2013/06/07/poland-shale-investors-warn-against-planned-tough-rule-changes/#axzz2tvitoSFU> (accessed 21 Feb 2014).

- Eia.gov. "China - Analysis - U.S. Energy Information Administration (EIA)." 2013. <http://www.eia.gov/countries/cab.cfm?fips=CH> (accessed 21 Feb 2014).
- Eia.gov. "Poland - U.S. Energy Information Administration (EIA)." 2014. <http://www.eia.gov/countries/country-data.cfm?fips=PL> (accessed 23 Feb 2014).
- Eia.gov. "Shale oil and shale gas resources are globally abundant - Today in Energy - U.S. Energy Information Administration (EIA)." 2013. <http://www.eia.gov/todayinenergy/detail.cfm?id=11611> (accessed 21 Feb 2014).
- Eia.gov. "Poland - U.S. Energy Information Administration (EIA)." 2014. <http://www.eia.gov/countries/country-data.cfm?fips=PL> (accessed 21 Feb 2014).
- Breitling Energy Corporation. "China's shale gas supremacy | Pros and cons of hydraulic fracking | Energy hungry China." 2012. <http://www.breitlingenergy.com/energy-hungry-china-seeks-shale-gas-supremacy/> (accessed 21 Feb 2014).
- EUCERS. *Newsletter*. London: EUCERS, 2014. <http://www.kcl.ac.uk/sspp/departments/warstudies/research/groups/eucers/newsletter31.pdf> (accessed 21 Feb 2014).
- Evans-Pritchard, Ambrose. "Poland's shale drive will transform Europe, if it does not drop the ball." *Telegraph*, 21 August, 2013.
- Feodoroff, Timothe, Jennufer Franco and Ana Martinez. *Old Story, New Threat: Fracking and the global land grab*. Old Story, New Threat: Fracking and the global land grab. 2013. http://www.tni.org/sites/www.tni.org/files/download/fracking_-_old_story_new_threat_oct13.pdf (accessed 21 Feb 2014).
- Hart, Melanie and Daniel Weiss. "Making Fracking Safe in the East and West Environmental Safeguards on Shale Gas Production Needed as China Begins Development." *Center for American Progress*, 21 October, 2011.
- Hornby, Lucy and Ed Crooks. "Oil and gas: A new frontier - FT.com." *Financial Times*, 7 January, 2014.
- Focus on Tight Oil and Shale Gas Production Impact on Saudi Arabia..* Riyadh: Jawda Investment, 2013. http://www.jadwa.com/en/media/get/20131217_The-Outlook-for-Unconventional-Oil-Gas-Production-Full-report.pdf (accessed 21 Feb 2014).
- Frackinginjurylaw.com. "Landowner Rights | Fracking Injury Law." 2014. <http://frackinginjurylaw.com/fracking-lawsuits/landowner-rights/> (accessed 21 Feb 2014).
- Game Changer: How Shale Is Transforming Global Energy--And Affecting Industries And Ratings*. New York: Standard and Poor's, 2014. <http://marcelluscoalition.org/wp-content/uploads/2014/01/197319624-Untitled.pdf> (accessed 21 Feb 2014).
- Grealy, Nick. "Sea change for Poland shale gas." *No Hot Air*, 23 January, 2014.
- Haas, Benjamin. "China Fracking Quake-Prone Province Shows Zeal for Gas." *Bloomberg*, 1 August, 2013.
- Jian-Chun, Guo and Zhao Zhi-Hong. "China vigorously promoting shale gas exploration, development." *Oil&Gas Journal* (2014) Accessed 22 Feb 2014. <http://www.ogj.com/articles/print/vol-110/issue-3/exploration-development/china-vigorously-promoting.html>.
- Jinzhou, Zhao, Yang Hai and Li Yongming. "China developing strategy for horizontal fracturing technology." *Oil&Gas Journal* (2013) Accessed 22 Feb 2014. <http://www.ogj.com/articles/print/volume-111/issue-7/drilling-production/china-developing-strategy-for-horizontal-fracturing.html>.
- Johnson, Corey and Tim Boersma. "Energy (in) security in Poland the case of shale gas." *Energy Policy* 53, (2013): 389--399.
- Snyder, Parker and Wojciech Kość. "Ecstasy to Agony." *CleanTech Poland*, 30 December, 2013.

- Linklaters.com. "Linklaters - Year to Come – China Law in 2014." 2014.
<http://www.linklaters.com/Publications/year-review-year-to-come/2013-2014/Pages/Year-Come-Chinese-Law-2014.aspx> (accessed 21 Feb 2014).
- Lee, Edwin. "Shale Gas In China: How Far From Dream To Reality?." *Chadbourne & Parke LLP*, 2014.
- Mcmahon, Jeff. "Six Reasons Fracking Has Flopped Overseas." *Forbes*, 7 April, 2013.
- Scotland Against Spin. "The Great Polish Shale Fail: A Warning To Britain/GWPF - Mock, Vanessa. "Brussels' new climate goals to fall short of EU green ambitions." *Wall Street Journal*, 16 January, 2014.
- Msp.gov.pl. "Shale gas extraction in Poland – review of current works and prospects for coming years." 2012. <http://msp.gov.pl/en/polish-economy/economic-news/3374,Shale-gas-extraction-in-Poland-review-of-current-works-and-prospects-for-coming-.html> (accessed 22 Feb 2014).
- Msp.gov.pl. "Shale gas in Poland – review of progress of works and prospects of shale gas extraction." 2013. <http://msp.gov.pl/en/polish-economy/economic-news/4118,dok.html> (accessed 22 Feb 2014).
- Nakano, Jane. *Prospects for shale gas development in Asia*. Washington: Center for Strategic and International Studies, 2012.
- Naturalgaseurope.com. "Poland Fires Deputy Environment Minister over Slow Shale Gas Process." 2013. <http://www.naturalgaseurope.com/poland-shale-gas-deputy-environment-minister-fired> (accessed 22 Feb 2014).
- Nyga - Łukaszewska, Honorata. "Poland's Energy Security Strategy." *Journal of Energy Security*, 15 March, 2011.
- Nicola, Stefan. "No Fracking in Germany for Now Backed in Merkel Coalition." *Bloomberg*, 8 November, 2013.
- Ogfj.com. "Global update on shale development." 2014.
<http://www.ogfj.com/articles/print/volume-10/issue-9/features/global-update-on-shale-development.html> (accessed 26 Feb 2014).
- Opppw.com. "News - Press releases - OPPPW." 2014.
http://www.oppw.com/news/press_releases?more=528970946 (accessed 23 Feb 2014).
- Paiz.gov.pl. "Formal and legal context for investments in shale gas fields and other natural resources | Inwestycje w Polsce." 2014. http://www.paiz.gov.pl/polish_law/shale_gas (accessed 23 Feb 2014).
- Pirani, Simon, Jonathan Stern and Katja Yafimava. *The Russo-Ukrainian gas dispute of January 2009: a comprehensive assessment*. Oxford Institute for Energy Studies, 2009.
<http://storage.globalcitizen.net/data/topic/knowledge/uploads/20110630223130533.pdf>. (accessed 23 Feb 2014).
- Platts.com. "Poland looks to give shale gas sector new boost." 2014.
<http://www.platts.com/latest-news/natural-gas/warsaw/feature-poland-looks-to-give-shale-gas-sector-26594799> (accessed 23 Feb 2014).
- "Poland: The Promise and Perils of Shale Gas Exploration." *Natural Gas Europe*, 8 September, 2013.
- Polishshale.pl. "Grabowski: 40 new boreholes this year | polishshale.pl - Shale Gas in Poland." 2014. <http://polishshale.pl/grabowski-40-new-boreholes-this-year/> (accessed 23 Feb 2014).
- Polishshale.pl. "Karpinski: shale will still be our priority | polishshale.pl - Shale Gas in Poland." 2014. <http://polishshale.pl/karpinski-shale-will-still-be-our-priority/> (accessed 23 Feb 2014).

- Polskie Radio dla Zagranicy. "Polish shale gas exploration 'too slow'." 2014.
<http://www.thenews.pl/1/12/Artykul/158440,Polish-shale-gas-exploration-too-slow>
 (accessed 23 Feb 2014).
- Poprawa, Paweł. "Poland Geology: USD 1bn v the Rocks." *CleanTech Poland*, 2013.
- Rapier, Robert. "Prepare for the Chinese Energy Juggernaut." *The Energy Collective*, 5 September, 2014.
- Rapoza, Kenneth. "Within Four Years, China To Consume More Oil Than U.S.." *Forbes*, 25 August, 2014.
- Kramer, Andrew. "Chevron and Ukraine Set Shale Gas Deal." *New York Times*, 5 November, 2014.
- Riaz, Saleha. "Future of shale gas in China is promising, according to new analysis." *Shale Energy Insider*, 14 January, 2014.
- Richardson, John. "US Support For Big China Shale Gas Challenge." *Asia Chemical Connections*, 21 December, 2014.
- Rutkowski, Mirosław. "Shale Gas in Poland." *Shale Gas Information Platform*, May, 2013.
- Sanleonenergy.com. "Lewino-1G2: Successful Vertical Frac Leads To Horizontal Well." 2014.
<http://www.sanleonenergy.com/media-centre/news-releases/2014/january/23/lewin-1g2-successful-vertical-frac-leads-to-horizontal-well.aspx> (accessed 23 Feb 2014).
- Search.rigzone.com. "Rigzone." 2014. http://search.rigzone.com/iPhone/article.asp?a_id=128441
 (accessed 23 Feb 2014).
- Shalegas-europe.eu. "Poland." 2013. <http://www.shalegas-europe.eu/en/index.php/resources/shale-opportunities-in-europe/poland> (accessed 23 Feb 2014).
- Shale-gas-information-platform.org. "Rutkowska Article: SHIP - Shale Gas Information Platform." 2014. <http://www.shale-gas-information-platform.org/categories/legislation/expert-articles/rutkowska-article.html> (accessed 23 Feb 2014).
- Shale Oil and Gas Resources. "IHS: Shale Oil Boom Could Go Global." 2013.
<http://shalestuff.com/controversy-2/ihs-shale-oil-boom-global/article09282> (accessed 23 Feb 2014).
- Shale oil: the next energy revolution*. PricewaterhouseCooper LLP, 2013.
https://www.pwc.com/en_GX/gx/oil-gas-energy/publications/pdfs/pwc-shale-oil.pdf
 (accessed 23 Feb 2014).
- Slideshare.net. "Oil Security 2025: U.S. National Security Policy in an Era of Domes...." 2014.
<http://www.slideshare.net/IRSmartt/oil-security-2025-us-national-security-policy-in-an-era-of-domestic-oil-abundance> (accessed 21 Feb 2014).
- Suttikulpanich, Duke, Ying Wang and Akash Gupta. "China Shale Gas." Standard Chartered, 2013.
- Sykes, Justin. "The Future of Shale Gas is Bright in the U.S.." *Americans for Tax Reform*, 8 January, 2014.
- Taxand. "To Frack or Not to Frack." 2014.
<http://www.taxand.com/sites/default/files/taxand/portal-documents/Taxand's%20Take%20-%20Global%20energy%20tax%20-%20to%20frack%20or%20not%20to%20frack%20-%20FINAL.pdf> (accessed 23 Feb 2014).
- Technically Recoverable Shale Oil and Shale Gas Resources: An Assessment of 137 Shale Formations in 41 Countries Outside the United States*. Washington D.C.: EIA, 2013.
<http://www.eia.gov/analysis/studies/worldshalegas/pdf/overview.pdf>. (accessed 23 Feb 2014).

- The Economist. "Mad and messy regulation." 2014.
<http://www.economist.com/blogs/easternapproaches/2013/07/shale-gas-poland> (accessed 23 Feb 2014).
- The Guardian. "France cements fracking ban." 2013.
<http://www.theguardian.com/environment/2013/oct/11/france-fracking-ban-shale-gas> (accessed 23 Feb 2014).
- Tollefson, Jeff. "China slow to tap shale-gas bonanza." *Karoo shale gas*, 21 February, 2013.
- Tomsen, Jennifer and Marc Davies. "Shale Gas in Asia: Significant Reserves, Substantial Challenges." *Bloomberg Law*, 2014.
- Unconventional Gas Center. "Poland's Top Fracer Predicts First Commercial Gas Flows In 2014 As Eni Pulls Out." 2014. http://www.ugcenter.com/International-Shales/Polands-Top-Fracer-Predicts-Commercial-Gas-Flows-2014-Eni-Pulls-Out_128077 (accessed 23 Feb 2014).
- UPI. "Russian joint venture with Shell targets shale oil in Siberia." 2014.
http://www.upi.com/Business_News/Energy-Resources/2014/01/14/Russia-taps-into-Siberian-shale/UPI-59421389700671/ (accessed 23 Feb 2014).
- Wbj.pl. "Poland delays hydrocarbon tax until 2020 - Warsaw Business Journal - Online Portal - wbj.pl." 2014. <http://www.wbj.pl/article-62809-poland-delays-hydrocarbon-tax-until-2020.html> (accessed 23 Feb 2014).
- Wbj.pl. "US report: 'Too soon to dismiss' Poland's shale potential - Warsaw Business Journal - Online Portal - wbj.pl." 2014. <http://www.wbj.pl/article-63019-us-report-too-soon-to-dismiss-polands-shale-potential.html> (accessed 23 Feb 2014).
- Winning, David. "China Starts First Shale Gas Project." *Wall Street Journal*, 27 November, 2009.
- Wittmeyer, Hannah. "China, Fracking, and Environmental Leadership?." *Frackwire*, 13 September, 2013.
- Wong, Jimmy and Toby Shek. *China shale gas – Not all it is fracked up to be. China shale gas – Not all it is fracked up to be*. Hong Kong: CIMB, 2014.
http://pg.jrj.com.cn/acc/Res/CN_RES/INDUS/2013/11/29/9171cd91-c6dc-4ff3-a451-b5e36d8191d9.pdf. (accessed 23 Feb 2014).
- Yang, Chi-Jen, Yipei Zhou and Robert B Jackson. "China's Fuel Gas Sector: Review and Prospects."

Chapter Six

- American Public Health Association. "*The Environmental and Occupational Health Impacts of High-Volume Fracturing of Unconventional Gas Reserves.*" 2012.
- Apha.org. "American Public Health Association: Policy Statement Database." 2014.
<http://www.apha.org/advocacy/policy/policyserach/default.htm?id=1439> (accessed 9 Feb 2014).
- Basu, Niladri, Mark Bradley, Casey McFeely and Marie Perkins. "*Public Health Technical Report | Public Health and Hydraulic Fracturing in Michigan.*" University of Michigan, 2013.
- Catskillmountainkeeper.org. 2014. *Food Supply Dangers from Fracking*. [online] Available at: <http://www.catskillmountainkeeper.org/our-programs/fracking/whats-wrong-with-fracking-2/farming-and-fracking/> [Accessed: 23 Jan 2014].
- Ellsworth, William L. 2013. Injection-induced earthquakes. *Science*, 341 (6142).
- Environment America Research & Policy Center. "*Fracking by the Numbers Key Impacts of Dirty Drilling at the State and National Level.*" 2013.
- Environment.yale.edu. 2014. *Fracking Outpaces Science on Its Impact | EnvY : The Journal of the Yale School of Forestry and Environmental Studies*. [online] Available at:

- <http://environment.yale.edu/envy/stories/fracking-outpaces-science-on-its-impact> [Accessed: 23 Jan2014].
- Environmental Protection Agency. 2012. *Understanding the Basics of Gas Flaring*. [report] Columbus.
- Epa.gov. "Methane Emissions | Climate Change | US EPA." 2014. <http://epa.gov/climatechange/ghgemissions/gases/ch4.html>. (accessed 8 Feb 2014).
- Epa.gov. "What are Endocrine Disruptors? Endocrine Disruptor Screening Program. US EPA." 2014. <http://www.epa.gov/endo/pubs/edspoverview/whatare.htm> (accessed 27 Jan 2014).
- Epa.gov. "Strontium | Radiation Protection | US EPA." 2014. <http://www.epa.gov/radiation/radionuclides/strontium.html> (accessed 08 Feb 2014).
- Finkel, Madelon L. "The Rush to Drill for Natural Gas: A Public Health Cautionary Tale." *American Journal of Public Health* 101, no. 5 (2011).
- Forsyth, Jim. "Report: Fracking Fails to Recycle Huge Amounts of Water." *WOAI Local News*, 6th Feb, 2014.
- Fracfocus.org. "Chemical Use In Hydraulic Fracturing | FracFocus Chemical Disclosure Registry." 2014. <http://fracfocus.org/water-protection/drilling-usage> (accessed 2 Feb 2014).
- "Fracking and Farmland: What Farmers and Landowners Need to Know About the Risks to Air, Water, and Land." *The Ohio Ecological Food and Farm Association* (2011).
- Gold, Russell and Tom McGinty. "Energy Boom Puts Wells in America's Backyards- Hydraulic Fracturing Largely Driving Transformation of the Nation's Landscape." *The Wall Street Journal*, 25th, Oct, 2013.
- Goldstein, Bernard. "The Public Health Implications of Unconventional Gas Drilling." Speech, February 1, 2012. Committee on Science, Space, and Technology. <http://science.house.gov/sites/republicans.science.house.gov/files/documents/hearings/HHRG-112-SY20-WState-BGoldstein-20120201.pdf>
- Hammer, Rebecca and VanBriesen, Jeanne. 2012. *In Fracking's Wake: New Rules are Needed to Protect Our Health and Environment from Contaminated Wastewater*. D:12-05-a. [report] Natural Resources Defense Council.
- Intergovernmental Panel on Climate Change. "*Climate Change 2013 The Physical Science Basis. Working Group I Contribution to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change.*" New York: Cambridge University Press, 2013.
- Jacobs, Justin. Gas Flaring Complicates Bakken Oil Boom. *Petroleum Economist*. 2013.
- Krauss, Clifford. Industry in North Dakota to Cut Flared Natural Gas. *New York Times*, 29th Jan. 2014.
- Lewis, Renee. New study links fracking to birth defects in heavily drilled Colorado. *Aljazeera America*, 30th January. 2014.
- Mckenzie, Lisa M., Guo, Ruixin, Witter, Roxana Z., Savitz, David A., Newman, Lee S. and Adgate, John L, *Birth Outcomes and Maternal Residential Proximity to Natural Gas Development in Rural Colorado*. [report] 2014.
- Mitta, Mike. 2012. Rigorous evidence slim for determining health risks from natural gas fracking. *JAMA*, 307 (20).
- Natural Resources Defense Council. 2014. *Five Primary Disposal Methods for Fracking Wastewater All Fail to Protect Public Health and Environment*. [report] New York.
- Nicot, Jean-Philippe. "Assessment of Industry Water-Use in the Barnett Shale Gas Play (Fort Worth Basin)." Bureau of Economic Geology, Jackson School of Geosciences, The University of Texas at Austin, 2014.
- Nicot, Jean-Philippe and Bridget R. Scanlon. "Water Use for Shale-Gas Production in Texas, US." Bureau of Economic Geology, Jackson School of Geosciences, University of Texas, Austin, 2012.
- Osha.gov. "HAZARD ALERT – Worker Exposure to Silica during Hydraulic Fracturing." 2014. https://osha.gov/dts/hazardalerts/hydraulic_frac_hazard_alert.htm (accessed 11 Feb 2014).

- Peduzzi, Pascal and Harding Rohr Reis, Ruth. "Gas fracking: Can we Safely Squeeze the Rocks?" *Environmental Development* 6, (2013).
- Prud'homme, Alex. *Hydrofracking*. Oxford: Oxford University Press, 2014.
- Ramanujan, Krishna. Study suggests hydrofracking is killing farm animals, pets. *Cornell Chronicle*, 7th March. 2012.
- Salmon, Ryan and Logan, Andrew. *Flaring Up: North Dakota Natural Gas Flaring More Than Doubles In Two Years*. [report] Boston: Ceres. 2013.
- Shackford, Stacey. "Natural gas from fracking could be 'dirtier' than coal, Cornell professors find." *Chronicle Online* (2011).
- Schmit, Julie. "Report: Fracking raising water supply worries." *USA Today*, 5th Feb, 2014.
- Schultz, Aarik. *Hydraulic fracturing and natural gas drilling*. New York: Nova Science Publishers, 2012.
- Thompson, Tamara. *Fracking*. Farmington Hills: Greenhaven Press, 2013.
- United States Environmental Protection Agency. "*Study of the Potential Impacts of Hydraulic Fracturing on Drinking Water Resources Progress Report*." Washington DC: 2012.
- United States House of Representatives Committee on Energy and Commerce. "*Chemicals Used in Hydraulic Fracturing*." 2011.
- U.S. Senate. Committee on Energy and Natural Resources. *Shale Gas and Water Impacts*. (S. Prt. 112). Washington: Government Printing Office, 2012. (YREN2:S.HRG. 112-247).
- Volz, Conrad D, Ferrar, Kyle, Michanowicz, Drew, Christen, Charles, Kearney, Shannon, Kelso, Matt, and Malone, Samantha, *Effluent from Pennsylvania Brine Treatment Inc., Josephine Facility: Implications for Disposal of Oil and Gas Flowback Fluids from Brine Treatment Plants*. [report] University of Pittsburgh Graduate School of Public Health, 2011.
<http://www2.epa.gov/sites/production/files/documents/contaminantcharacterizationofeffluent.pdf>.
- Water.epa.gov. "Basic Information about Barium in Drinking Water | Basic Information about Regulated Drinking Water Contaminants | US EPA." 2014.
<http://water.epa.gov/drink/contaminants/basicinformation/barium.cfm> (accessed 08 Feb 2014).
- Yosemite.epa.gov. "EPA Issues Updated, Achievable Air Pollution Standards for Oil and Natural Gas." 2014.
<http://yosemite.epa.gov/opa/advpress.nsf/bd4379a92ceceac8525735900400c27/c742df7944b37c50852579e400594f8f!OpenDocument> (accessed 10 Feb 2014).

Chapter Seven

- The Associated Press. "Rent in Williston, N.D. tops averages in New York City and Los Angeles." *NY Daily News*, Feb. 17, 2014. <http://www.nydailynews.com/life-style/real-estate/average-rent-williston-n-tops-costs-nyc-article-1.1617187> (accessed Feb 19, 2014).
- Austen, Ian. "In Quebec Town, Fires Are Out, but Recovery Is Distant." *New York Times*, Jul. 6, 2013. <http://www.nytimes.com/2013/07/25/world/americas/in-quebec-town-fires-are-out-but-recovery-is-distant.html> (accessed Feb. 27, 2014).
- Broder, John, and Dan Frosch. "U.S. Delays Decision on Pipeline Until After Election." *New York Times*, Nov. 10, 2013. <http://www.nytimes.com/2011/11/11/us/politics/administration-to-delay-pipeline-decision-past-12-election.html?action=click&module=Search®ion=searchResults%230&version=&url=http%3A%2F%2Fquery.nytimes.com%2Fsearch%2Fsite%2Fsearch%2F%3Faction%3Dclick%26contentCollection%3Dart%2520%2526%2520Design%26region%3DTopBar%26module%3DSearchSubmit%26pgtype%3Darticle%23%2Fsandhills+keystone> (accessed Feb. 28, 2014).

- "BTS Releases Freight Transportation Services Index (TSI); Freight Shipments Rose 1.2% in November from October." *U.S. Department of Transportation*.
http://www.rita.dot.gov/bts/sites/rita.dot.gov.bts/files/bts02_14.pdf (accessed Feb. 10, 2014).
- Campoy, Ana. "Drilling Strains Rural Roads." *The Wall Street Journal*, Jul. 26, 2012.
<http://online.wsj.com/news/articles/SB10000872396390444840104577551223860569402> (accessed Feb. 16, 2014).
- "Canada." *U.S. Energy Information Administration*.
<http://www.eia.gov/countries/cab.cfm?fips=CA> (accessed Feb. 14, 2014).
- Carmichael, Robert S. "Trans-Alaska Pipeline." *Encyclopedia of Environmental Issues, Rev. ed.* Ed. Craig W. Allin. Vol. 4 (2011): 1231-1233. *Gale Virtual Reference Library*.
http://go.galegroup.com/ps/i.do?id=GALE%7CCX1946300711&v=2.1&u=wash_main&it=r&p=GURL&sw=w&asid=e3c55ccaa3ef23c1c565650c8e96a97c (accessed Feb. 27, 2014).
- "Crude oils have different quality characteristics." *U.S. Energy Information Administration*.
<http://www.eia.gov/todayinenergy/detail.cfm?id=7110> (accessed Feb. 20, 2014).
- Deam, Jenny. "In parched states, fracking's thirst grows." *Los Angeles Times*, Feb. 19, 2014.
<http://www.latimes.com/nation/la-na-colorado-fracking-20140220,0,3689568.story#axzz2uPFvqIZJ> (accessed Feb. 26, 2014).
- "Documents on the Oil Field Exemptions From Highway Safety Rules, Explored and Annotated by the Times." *New York Times*, May 14, 2012.
<http://www.nytimes.com/interactive/2012/05/15/us/exemptions-documents.html#document/p34/a49973> (accessed Feb. 12, 2014).
- Efstathiou Jr., Jim and Angela Greiling Keane. "North Dakota Oil Boom Seen Adding Costs for Rail Safety." *Bloomberg*, Jan. 14, 2014. <http://www.bloomberg.com/news/2013-08-13/north-dakota-oil-boom-seen-adding-costs-for-rail-safety.html> (accessed 28 Feb 2014).
- Eilperin, Juliet. "Obama to tighten fuel efficiency standards for big trucks." *The Washington Post*, Feb. 18, 2014. <http://www.washingtonpost.com/blogs/post-politics/wp/2014/02/18/obama-to-tighten-fuel-efficiency-standards-for-big-trucks/> (accessed Feb. 12, 2014).
- "Extracting oil sands for the Keystone XL pipeline." *The Washington Post*.
<https://www.youtube.com/watch?v=Dh6far2zbWc> (accessed Feb. 28, 2014).
- "Exxon Valdez Spill Profile." *United States Environmental Protection Agency*.
<http://www2.epa.gov/emergency-response/exxon-valdez-spill-profile> (accessed Feb. 25, 2014).
- "Final Supplemental Environmental Impact Statement on Keystone XL Project." *U.S. Department of State*. <http://keystonepipeline-xl.state.gov/documents/organization/221190.pdf> (accessed Feb. 12, 2014).
- "Freight Railroads Join U.S. Transportation Secretary Foxx in Announcing Industry Crude By Rail Safety Initiative." *Association of American Railroads*.
<https://www.aar.org/newsandevents/Press-Releases/Pages/Freight-Railroads-Join-U-S-Transportation-Secretary-Foxx-in-Announcing-Industry-Crude-By-Rail-Safety-Initiative.aspx#.UxDp5vRdWDo> (accessed Feb. 10, 2014).
- Gold, Russell, and Lynn Cook. "U.S. News: Cities Grapple With Oil-Train Safety." *The Wall Street Journal Europe*, Jan. 16, 2014.
<http://search.proquest.com.offcampus.lib.washington.edu/docview/1477654432?accountid=14784> (accessed Feb. 10, 2014).
- Hennessy-Fiske, Molly. "Fracking brings oil boom to south Texas town, for a price." *Los Angeles Times*, Feb. 15, 2014. <http://articles.latimes.com/2014/feb/15/nation/la-na-texas-oil-boom-20140216> (accessed Feb. 18, 2014).
- "Keystone XL Tar Sand Pipeline." *National Wildlife Federation*. http://www.nwf.org/pdf/Policy-Solutions/Keystone%20XL%20Fact%20Sheet_2.pdf (accessed Feb. 27, 2014).

- Mcdonnell, Tim, and James West. "It's the Wild F*ing West Out There." *Mother Jones* 37, no. 6 (November 2012): 58-59. *Academic Search Complete*, EBSCOhost (accessed Feb. 28, 2014).
- "Mobilities." *Encyclopedia of Identity*. Ed. Ronald L. Jackson. Vol. 1 (2010): 464-467. *Gale Virtual Reference Library*.
http://go.galegroup.com/ps/i.do?id=GALE%7CCX1700600165&v=2.1&u=wash_main&it=r&p=GVRL&sw=w&asid=6120334758b2218cabf5364c1589b471 (accessed Feb. 27, 2014).
- "Moving Crude Oil by Rail." *Association of American Railroads*.
<https://www.aar.org/keyissues/Documents/Background-Papers/Crude-oil-by-rail.pdf> (accessed Feb. 10, 2014).
- "New Keystone XL Pipeline Application." *U.S. Department of State*. <http://www.keystonepipeline-xl.state.gov/> (accessed Feb. 14, 2014).
- "North Dakota oil production reaches new high in 2012, transported by trucks and railroads." *U.S. Energy Information Administration*. <http://www.eia.gov/todayinenergy/detail.cfm?id=10411> (accessed Feb. 15, 2014).
- Owens, Edward H. "Komi Pipeline Crude Oil Spill." *United States Environmental Protection Agency*. <http://www.epa.gov/osweroe1/docs/oil/fss/fss00/komi.pdf> (accessed Feb. 23, 2014).
- "Rail delivery of U.S. oil and petroleum products continues to increase, but pace." *U.S. Energy Information Administration*. <http://www.eia.gov/todayinenergy/detail.cfm?id=12031> (accessed Feb. 14, 2014).
- "Reports, Trends & Statistic." *American Trucking Association*.
http://www.truckline.com/_layouts/ATARedesign/News_and_Information_Reports_Energy.aspx? (accessed Feb 11, 2014).
- "Revised Draft SGEIS on the Oil, Gas and Solution Mining Regulatory Program – Potential Environmental Impact Part B." *New York State Department of Environmental Conservation*. http://www.dec.ny.gov/docs/materials_minerals_pdf/rdsgeisch6b0911.pdf (accessed Feb. 25, 2014).
- "Russia Oil Spill." *American University*. <http://www1.american.edu/ted/KOMI.HTM> (accessed Feb. 26, 2014).
- "Safety Alert: Preliminary Guidance from Operation Classification." *Pipeline and Hazardous Materials Safety Administration*.
<http://www.phmsa.dot.gov/portal/site/PHMSA/menuitem.ebdc7a8a7e39f2e55cf2031050248a0c/?vgnextoid=c6efec1c60f23410VgnVCM100000d2c97898RCRD&vgnnextchannel=d248724dd7d6c010VgnVCM10000080e8a8c0RCRD&vgnnextfmt=print> (accessed Feb. 27, 2014).
- "Secondary Energy Infobook." *National Energy Education Development Project*.
<http://www.switchenergyproject.com/education/CurriculaPDFs/SwitchCurricula-Secondary-Introduction/SwitchCurricula-Secondary-EnergyInfobook.pdf>. (accessed 26 Feb 2014).
- "TSB and NTSB call on Canadian and U.S. regulators to improve the safe transportation of crude oil by rail." *Transportation Safety Board of Canada*. <http://www.tsb.gc.ca/eng/medias-media/communiqués/rail/2014/r13d0054-20140123.asp> (accessed Feb. 15, 2014).
- Walsh, Bryan. "Fracking for Natural Gas May Help Us Save Water." *Time*, Dec. 23, 2013
<http://science.time.com/2013/12/23/fracking-for-natural-gas-isnt-so-water-wasteful/> (accessed Feb. 17, 2014).
- Wendy, Tadros A. "Rail Safety and Public Confidence". *The Globe and Mail*, Oct. 16, 2013.
<http://www.tsb.gc.ca/eng/medias-media/articles/rail/2013/GlobeMail-OpEd-WT-20131016.asp> (accessed Feb. 28, 2014).

- "Williston Basin crude oil production and takeaway capacity are increasing." *U.S. Energy Information Administration*. <http://www.eia.gov/todayinenergy/detail.cfm?id=5870> (accessed Feb. 26, 2014).
- Winkley, Ben. "Bakken Shale Really Is Explosive." *The Wall Street Journal*, Feb. 24, 2014, <http://blogs.wsj.com/moneybeat/2014/02/24/bakken-shale-really-is-explosive/> (accessed Feb. 20, 2014).

Chapter Eight

- Artists Against Fracking. "About." 2012. <https://artistsagainstfracking.com/about/> (accessed 15 Feb 2014).
- Biederman, David. "Colorado Has Been Fracking For 40 Years; Why All The Fuss?." 27th Feb, 2014, <http://www.forbes.com/sites/realspin/2014/02/27/colorado-has-been-fracking-for-40-years-why-all-the-fuss/> (accessed 1 Mar 2014).
- Blackmon, David. "Shale, Fracking Are Not The Main Cause Of Texas Water Shortages." 21st August, 2013, <http://www.forbes.com/sites/davidblackmon/2013/08/21/shale-fracking-are-not-the-main-cause-of-texas-water-shortages/> (accessed 9 Jan 2014).
- Boudet, H., Clarke, C., Bugden, D., Maibach, E., Roser-Renouf, C. and Leiserowitz, A. 2014. "Fracking" controversy and communication: Using national survey data to understand public perceptions of hydraulic fracturing. *Energy Policy*, 65 pp., 59.
- Bunch, Will. "The Chevron Guarantee: Our well won't explode... Or your pizza's free!." 17th Feb, 2014, <http://www.philly.com/philly/blogs/attytood/Chevron-Endure-our-fracking-fire-and-the-pizzas-on-us.html> (accessed 22 Feb 2014).
- Campbell, James and Diane Noserale. "Naturally Occurring Methane Found in Some Sullivan County Water." 18th June, 2013, <http://www.usgs.gov/newsroom/article.asp?ID=3619#.UwhD7PSzDBG> (accessed 29 Jan 2014).
- Cart, Julie. "New Mexico county first in nation to ban fracking to safeguard water." 28th May, 2013, <http://articles.latimes.com/2013/may/28/local/la-me-fracking-ban-20130529> (accessed 20 Feb 2014).
- Choi, Charles. "Confirmed: Fracking practices to blame for Ohio earthquakes." 4th Sept, 2013, <http://www.nbcnews.com/science/science-news/confirmed-fracking-practices-blame-ohio-earthquakes-f8C11073601> (accessed 16 Feb 2014).
- Ritter, Bill. *COGCC Gasland Correction Document*. Denver, CO: Department of Natural Resources, 2010. <http://cogcc.state.co.us/library/GASLAND%20DOC.pdf>). (accessed 4 Feb 2014).
- Colbert Nation. "Colbert Report: Mark Ruffalo." 2012. <http://www.colbertnation.com/the-colbert-report-videos/411275/march-28-2012/mark-ruffalo> (accessed 14 Jan 2014).
- Detrow, Scott. "Fox's "Gasland" Wins Emmy Award." 15th Sept, 2011, <https://stateimpact.npr.org/pennsylvania/2011/09/15/foxs-gasland-wins-emmy-award/> (accessed 20 Jan 2014).
- Devine-Wright, Patrick. "Rethinking NIMBYism: The role of place attachment and place identity in explaining place-protective action." *Journal of Community & Applied Social Psychology* 19, no. 6 (2009): 426-441.
- Ellsworth, William L. "Injection-induced earthquakes." *Science* 341, no. 6142 (2013).
- Food and Water Watch. "Local Resolutions Against Fracking." 2014. <http://www.foodandwaterwatch.org/water/fracking/fracking-action-center/local-action-documents/> (accessed 21 Feb 2014).
- Food and Water Watch. "Why Ban Fracking?." 2014. <https://www.foodandwaterwatch.org/water/fracking/> (accessed 21 Feb 2014).

- FracTracker. "FracTracker." 2014. <http://www.fractracker.org/> (accessed 01 Feb 2014).
- Gerken, James. "Mark Ruffalo Addresses Fracking On 'Colbert Report' Interview." 30 March, 2012, http://www.huffingtonpost.com/2012/03/30/mark-ruffalo-fracking-colbert-report_n_1392584.html (accessed 03 Feb 2014).
- "Gas Rush Stories: A Landowner." Kirsi Jansa. 2013. video.
- "GASLAND Trailer 2010." HBO. 2010. video.
- Gas Rush Stories. "About Gas Rush Stories." 2013. <http://www.gasrushstories.com/grs/About.html> (accessed 1 Feb 2014).
- Hansen, Anders. "The media and the social construction of the environment." *Media, Culture and Society* 13, no. 4 (1991): 443--458.
- Horn, Steve. "NY Assembly Passes Two-year Fracking Moratorium, Senate Expected to Follow." 7th March, 2013, http://www.huffingtonpost.com/steve-horn/ny-assembly-fracking-moratorium_b_2831272.html (accessed 02 Feb 2014).
- Hudgins, Anastasia. "Fracking's Future in a Coal Mining Past: Subjectivity Undermined." *Culture, Agriculture, Food and Environment* 35, no. 1 (2013): 54--59.
- The Huffington Post. "Did Fracking Actually Contaminate This Town's Water?." 2012. http://www.huffingtonpost.com/2012/03/20/dimock-pa-fracking-epa-water_n_1368148.html (accessed 23 Jan 2014).
- iSpot.tv. "America's Natural Gas Alliance TV Commercial, 'Georgia Power, Think About It'." 2014. <http://www.ispot.tv/ad/721t/americas-natural-gas-alliance-georgia-power-think-about-it> (accessed 20 Feb 2014).
- Jaspal, Rusi, Andrew Turner and Brigitte Nerlich. "Fracking on YouTube: Exploring Risks, Benefits and Human Values.." *White Horse Press* (2014).
- Konschnik, Kate, Margaret Holden and Alexa Shasteen. "Legal Fractures in Chemical Disclosure Laws: Why the Voluntary Chemical Disclosure Registry FracFocus Fails as a Regulatory Compliance Tool." *Harvard Law School: Environmental Law* (2013): 1-15.
- Kusnetz, Nicholas. "North Dakota's Oil Boom Brings Damage Along With Prosperity." 7th June 2012, <http://www.propublica.org/article/the-other-fracking-north-dakotas-oil-boom-brings-damage-along-with-prosperi> (accessed 20 Feb 2014).
- Levy, Alison. "Mark Ruffalo and Rachel Maddow on the Frack Threat to Our Water." 5th Oct, 2010, http://www.huffingtonpost.com/alison-rose-levy/mark-ruffalo-and-rachel-_b_750508.html (accessed 14 Jan 2014).
- Lustgarten, Abraham. "So, Is Dimock's Water Really Safe to Drink?." 20th March, 2012, <http://www.propublica.org/article/so-is-s-water-really-safe-to-drink> (accessed 25 Jan 2014).
- Malewitz, Jim and Neena Satija. "In Oil and Gas Country, Water Recycling Can Be an Extremely Hard Sell." 21st Nov, 2013, <http://www.nytimes.com/2013/11/22/us/in-oil-and-gas-country-water-recycling-can-be-an-extremely-hard-sell.html?pagewanted=1&r=1> (accessed 9 Jan 2014).
- Marcellus Shale Documentary Project. "About." 2014. <http://www.the-msdp.us/about> (accessed 1 Feb 2014).
- Mansfield, Michael. "The villages of southern France take on Sarkozy over shale gas." 20th April, 2011, <http://www.theguardian.com/environment/2011/apr/20/southern-france-sarkozy-shale-gas> (accessed 21st Jan 2014).
- Matlock, Staci. "World is watching Mora County battle vs. fracking." 23rd Nov, 2013, http://www.santafenewmexican.com/news/local_news/world-is-watching-mora-county-battle-against-fracking/article_edc8353d-3c1e-5ce1-ba74-d8c12d682fab.html (accessed 20 Feb 2014).
- Moskowitz, Peter. "After fracking blast, Chevron offers pizza." 18th Feb, 2014, <http://america.aljazeera.com/articles/2014/2/18/after-fracking-blastchevronofferspizza.html> (accessed 22 Feb 2014).

- Nevarro, Mireya. "Ruffalo Embraces a Role Closer to Home." 2nd Dec, 2014, <http://www.nytimes.com/2011/12/04/fashion/mark-ruffalo-actor-embraces-anti-fracking-role.html?pagewanted=all> (accessed 14 Jan 2014).
- The New York Times. "Editorial: The Halliburton Loophole." 2nd Nov, 2009, http://www.nytimes.com/2009/11/03/opinion/03tue3.html?_r=2& (accessed 4 Feb 2014).
- Open Secrets. "America's Natural Gas Alliance, 2010." 2014. <http://www.opensecrets.org/lobby/clientsum.php?id=D000046794&year=2010> (accessed 20 Feb 2014).
- Open Secrets. "Oil & Gas: Money to Congress." 2014. <http://www.opensecrets.org/industries/summary.php?ind=E01&cycle=2014&recipdetail=M&sortorder=U> (accessed 20 Feb 2014).
- PennFuture. "Drilling and Mining: History of Drilling in Pennsylvania." 2014. <http://www.pennfuture.org/content.aspx?SectionID=218&MenuID> (accessed 04 Feb 2014).
- Pennsylvania Department of Environmental Protection. *Oil and Gas Well Drilling and Production in Pennsylvania. Oil and Gas Well Drilling and Production in Pennsylvania.* Department of Environmental Protection, 2011. <https://thompson.house.gov/sites/thompson.house.gov/files/PA%20DEP%20Oil%20and%20Gas%20Well%20Drilling%20and%20Production.pdf>. (accessed 1 Mar 2014).
- Pennsylvania Department of Environmental Protection. "Pennsylvania Mining History." 2014. <http://www.dep.state.pa.us/msi/mininghistory.html> (accessed 13 Feb 2014).
- Pennsylvania Historical & Museum Commission. "Barbara T. Zolli on "A Drop of Oil"." 2009. http://www.portal.state.pa.us/portal/server.pt/community/history/4569/drake_well__oil150/471308 (accessed 22 Feb 2014).
- Physicians Scientists & Engineers for Healthy Energy. "*Fluid Migration Mechanisms Due To Faulty Well Design and/or Construction: An Overview and Recent Experiences in the Pennsylvania Marcellus Play.*" Damascus Citizens for Sustainability, 2012.
- Plumer, Brad. "Is fracking a 'bridge' to a clean-energy future? Ernest Moniz thinks so.." 4th March, 2013, <http://www.washingtonpost.com/blogs/wonkblog/wp/2013/03/04/is-fracking-a-bridge-to-a-clean-energy-future-ernest-moniz-thinks-so/> (accessed 16 Feb 2014).
- Politics PA. "Democratic State Committee Roundup." 2013. <http://www.politicspa.com/democratic-state-committee-roundup/48796/> (accessed 20 Feb 2014).
- Polson, Jim. "FracFocus Fails as Fracking Disclosure Tool, Study Finds." 23rd April, 2013, <http://www.bloomberg.com/news/2013-04-23/fracfocus-fails-as-fracking-disclosure-tool-study-finds.html> (accessed 20 Feb 2014).
- Rabe, Barry G and Christopher P Borick. "Fracking for natural gas: public opinion on state policy options." *Center for Local, State, and Urban Policy (CLOSUP), Survey Report: Fracking* (2011).
- Ruffalo, Mark and Phil Radford. "Don't let America get 'fracked'." 25th April, 2013, <http://www.cnn.com/2013/04/25/opinion/radford-ruffalo-natural-gas-fracking/> (accessed 22 Feb 2014).
- Scott, A. O. "Deep Down, He Wants to Help." 27th Dec, 2012, http://www.nytimes.com/2012/12/28/movies/promised-land-with-matt-damon-directed-by-gus-van-sant.html?_r=0 (accessed 13 Feb 2014).
- Sierra Club Board of Directors. "*Revised Fracking Policy.*" 22 Feb, 2013.
- Sierra Club. "Beyond Natural Gas: Dirty, Dangerous, and Run Amok." 2012. <http://content.sierraclub.org/naturalgas/> (accessed 16 Feb 2014).

- Soroghan, Mike. "Groundtruthing Academy Award Nominee 'Gasland'." 24th Feb, 2011, <http://www.nytimes.com/gwire/2011/02/24/24greenwire-groundtruthing-academy-award-nominee-gasland-33228.html?pagewanted=all> (accessed 20 Jan 2014).
- United States Environmental Protection Agency. "Abandoned Mine Drainage." 2014. http://water.epa.gov/polwaste/nps/acid_mine.cfm (accessed 04 Feb 2014).
- United States Environmental Protection Agency. "Regulation of Hydraulic Fracturing Under the Safe Drinking Water Act." 2014. http://water.epa.gov/type/groundwater/uic/class2/hydraulicfracturing/wells_hydroreg.cfm (accessed 04 Feb 2014).
- Water Defense. "About Us." 2014. <http://waterdefense.org/content/about-us> (accessed 14 Jan 2014).
- WGC, News. "View From The Top." *WGC News*, 8th June, 2012.
- The White House. "Remarks by the President in State of the Union Address." 2012. <http://www.whitehouse.gov/the-press-office/2012/01/24/remarks-president-state-union-address> (accessed 1 Feb 2014).
- The White House. "President Barack Obama's State of the Union Address." 2014. <http://www.whitehouse.gov/the-press-office/2014/01/28/president-barack-obamas-state-union-address> (accessed Jan 30 2014).
- Wolske, Kim and Andrew Hoffman. "Hydraulic Fracturing in the State of Michigan-Public Perceptions Technical Report." (2013).
- Wood, Jonathan. "The Global Anti-Fracking Movement: What It Wants, How It Operates And What's Next." *Control Risks* (2012) Accessed 20th Jan 2014. ControlRisks.com.

Chapter Nine

- Baker Hughes. *Baker Hughes LiteProp Ultra lightweight Proppants. Baker Hughes LiteProp Ultralightweight Proppants*. Baker Hughes, 2012. Pg. 2-7. http://c14503045.r45.cf2.rackcdn.com/v1/7a03f342882fdbcb86adc6d18f54a4eb7/34847-liteprop_brochure-us.pdf.
- Baker Hughes. "VaporFrac Fracturing Fluid." 2014. <http://www.bakerhughes.com/products-and-services/pressure-pumping/hydraulic-fracturing/vaporfrac-fracturing-fluid>.
- Brown, D. "Hydro Fracturing gets 'Green Tech' Treatment." August, 2012, <https://www.aapg.org/explorer/2012/08aug/hydrofrac0812.cfm>.
- Bullis, Kevin. "One Way to Solve Fracking's Dirty Problem." *MIT Technology Review*, September 24, 2013. <http://www.technologyreview.com/news/519416/one-way-to-solve-frackings-dirty-problem/>.
- Bullis, Kevin. "Can Fracking Be Cleaned Up?." *MIT Technology Review*, June 5, 2012. <http://www.technologyreview.com/news/428076/can-fracking-be-cleaned-up/>.
- Business Wire. "*Preferred Sands Recognized for Its Industry-Leading Environmental Stewardship*." October 30, 2013. <http://www.marketwatch.com/story/preferred-sands-recognized-for-its-industry-leading-environmental-stewardship-2013-10-30>.
- Denney, Dennis. *Technology Applications*. 2010. Pg. 20. http://www.slb.com/~media/Files/stimulation/industry_articles/201007_jpt_channel_fracturing.pdf.
- Dow Chemical Company. "*Preferred Sands Launches New Proprietary Technology for Hydraulic Fracturing Proppants*." February 19, 2013. <http://www.dow.com/news/press-releases/article/?id=6172>.
- Environmental Leader. "GE to Build \$110m Fracking Research Center." Environmental Leader." 2013. <http://www.environmentalleader.com/2013/04/04/ge-to-build-110m-fracking-research-center/>.

- Fuel Fix. "Industry giant GE aims to improve fracturing." 2013.
<http://fuelfix.com/blog/2013/05/27/industry-giant-ge-aims-to-improve-fracking/>.
- GasFrac. "GASFRAC - Home." 2014. <http://www.gasfrac.com>.
- Goodman, Matt. "Waterless Fracking Method Targets Natural Gas Industry's Gaze." January 12, 2012. <http://dfw.cbslocal.com/2012/01/12/waterless-fracking-method-target-for-natural-gas-industrys-gaze/>.
- Gurule, Kendall. "Nitrogen gas tracking." *Frackwire* July 9, 2013. <http://frackwire.com/nitrogen-gas-fracking/>.
- Halliburton. "CleanStim® Hydraulic Fracturing Fluid System." 2014.
<http://www.halliburton.com/en-US/ps/stimulation/fracturing/cleanstim-hydraulic-fracturing-fluid-system.page#>.
- Halliburton. "Cleanstream® Ultraviolet Light Bacteria Control Process." 2014.
<http://www.halliburton.com/en-US/ps/stimulation/fracturing/water-based-gel-systems/cleanstream-%20ultraviolet-light-bacteria-control-process.page>.
- Halliburton. "RapidFrac™ Multistage Fracturing System - Halliburton." 2014.
<http://www.halliburton.com/en-US/ps/service-tools/well-completions/horizontal-completions/rapidfrac-multistage-fracturing-system.page#>.
- Halliburton. "Halliburton's CleanWave(TM) Water Treatment Technology Takes Spotlight Award at Offshore Technology Conference." 2011.
<http://ir.halliburton.com/phoenix.zhtml?c=67605&p=irol-newsArticle&ID=1558040&highlight=>.
- Halliburton. *El Paso Corporation completed first natural gas well using all four CleanSuite™ technologies*. Halliburton, 2012.
http://www.halliburton.com/public/common/Case_Histories/H09138.pdf.
- Halliburton. *Williams halved pumping time and improved initial performance with new RapidFrac™ system*. Halliburton, 2011.
http://www.halliburton.com/public/cps/contents/Case_Histories/web/H08703.pdf.
- Halliburton. *MonoProp™ Low Density Proppant for High-Porosity Fractures*. Halliburton, 2008. http://www.halliburton.com/public/pe/contents/Data_Sheets/web/H/H06228.pdf.
- Harrington, Kent. "GASFRAC Takes the Water out of Fracking." *ChEnected* May 29, 2012, 2012. <http://chenected.aiche.org/energy/gasfrac-takes-the-water-out-of-fracking/>.
- Mcnally, Scott. "Waterless Fracking?." *Scientific American* October 10, 2012.
<http://blogs.scientificamerican.com/plugged-in/2012/10/10/guest-post-waterless-fracking/>.
- Preferred Sands. "Preferred RCS Proppants." 2014.
<http://www.preferredsands.com/preferredrcs/proppants.html>.
- Rigzone. "BlackBrush Extends GASFRAC Contract for Waterless Frac Process." March 13, 2012. http://www.rigzone.com/news/article.asp?a_id=116000.
- Schlumberger. "Case Study: Channel Fracturing Increases Production by 37% for Petrohawk in the Eagle Ford Shale." 2011.
http://www.slb.com/resources/case_studies/stimulation/hiway_fracturing_eagle_ford_shale.aspx.
- Schlumberger. "Case Study: HiWAY Technique Increases Condensate Production by 43% in the Eagle Ford Shale." 2011.
http://www.slb.com/resources/case_studies/stimulation/hiway_increases_eagle_ford_cs.aspx.
- Schlumberger. "HiWAY Flow-Channel Hydraulic Fracturing Technique." 2014.
http://www.slb.com/services/completions/stimulation/sandstone/hiway_channel_fracturing.aspx?t=2.
- Siegel, RP. "Is There Really Such A Thing As Green Fracking?." *Triple Pundit* October 23, 2012. <http://www.triplepundit.com/2012/10/really-green-fracking/>.

Chapter Ten

- Ahmed, Nafeez. "US Army colonel: world is sleepwalking to a global energy crisis." 17th Jan, 2014. <http://www.theguardian.com/environment/earth-insight/2014/jan/17/peak-oil-oilandgascompanies> (accessed Feb 1, 2014).
- BBC News. "Total to invest \$21m in UK shale gas." 13th, Jan 2014. <http://www.bbc.co.uk/news/uk-25695813> (accessed 20 Jan 2014).
- Ebinger, Charles. "The U.S. Unconventional Hydrocarbon Renaissance and Impact on Japan." Washington, DC: Anderson Court Reporting, 2014.
- EIA. "Annual Energy Outlook 2014 Early Release." 2013. http://www.eia.gov/forecasts/aeo/er/early_production.cfm (accessed 16 Jan 2014).
- EIA. "Brazil - Analysis - U.S. Energy Information Administration (EIA)." 2013. <http://www.eia.gov/countries/cab.cfm?fips=BR> (accessed 17 Jan 2014).
- EIA. "Canada - Analysis - U.S. Energy Information Administration (EIA)." 2012. <http://www.eia.gov/countries/cab.cfm?fips=CA> (accessed 21 Jan 2014).
- EIA. "Company Level Imports." 2013. <http://www.eia.gov/petroleum/imports/companylevel/> (accessed 20 Jan 2014).
- EIA. "France - U.S. Energy Information Administration (EIA)." 2013. <http://www.eia.gov/countries/country-data.cfm?fips=FR#pet> (accessed 21 Jan 2014).
- EIA. "How dependent is the United States on foreign oil? - FAQ - U.S. Energy Information Administration (EIA)." 2013. <http://www.eia.gov/tools/faqs/faq.cfm?id=32&t=6> (accessed 16 Jan 2014).
- EIA. "Japan - Analysis - U.S. Energy Information Administration (EIA)." 2013. <http://www.eia.gov/countries/cab.cfm?fips=ja> (accessed 16 Jan 2014).
- EIA. "Korea, South - Analysis - U.S. Energy Information Administration (EIA)." 2013. <http://www.eia.gov/countries/cab.cfm?fips=KS> (accessed 16 Jan 2014).
- EIA. "Mexico - Analysis - U.S. Energy Information Administration (EIA)." 2012. <http://www.eia.gov/countries/cab.cfm?fips=MX> (accessed 27 Feb 2014).
- EIA. "United Kingdom - Analysis - U.S. Energy Information Administration (EIA)." 2013. <http://www.eia.gov/countries/cab.cfm?fips=UK> (accessed 16 Jan 2014).
- Environmental and Energy Study Institute. "*Fact Sheet: DoD's Energy Efficiency and Renewable Energy Initiatives.*" Washington, DC: Environmental and Energy Study Institute, 2011.
- Faulkner, Chris. "Energy Independence Day is Just Around the Corner." *USA Today*, 2013.
- Harvey, Christine and Loder, Asjylyn. "Fracking Boom Pushes U.S. Oil Output to 25-Year High." 11th, Dec 2013. <http://www.bloomberg.com/news/2013-12-11/fracking-boom-pushes-u-s-oil-output-to-25-year-high.html> (accessed 17 Jan 2014).
- Harvey, Fiona. "Vince Cable: Shale gas won't be a reality in UK for at least a decade." 4th, Feb 2014. <http://www.businessgreen.com/bg/news/2326699/vince-cable-shale-gas-wont-be-a-reality-in-uk-for-at-least-a-decade> (accessed 5 Feb 2014).
- Huber, Albert and Bowe, Peter. "The Keystone Pipeline Would Create Thousands Of Jobs." 7th Feb, 2014. <http://www.forbes.com/sites/realspin/2014/02/07/the-keystone-pipeline-would-create-thousands-of-jobs/> (accessed 8 Feb 2014).
- IEA. "*Oil & Gas Security - Emergency Response of IEA Countries.*" France: International Energy Agency, 2012.
- Itoh, Shoichi. "Energy Security in Northeast Asia: A Pivotal Moment for the U.S.-Japan Alliance." March, 2013. <http://www.brookings.edu/research/opinions/2013/03/12-energy-security-itoh> (accessed 17 Jan 2014).
- Jaffe, Amy. "The Americas, Not the Middle East, Will Be the World Capital of Energy." 15th Aug, 2011. http://www.foreignpolicy.com/articles/2011/08/15/the_americas_not_the_middle_east_will_be_the_world_capital_of_energy (accessed 17 Jan 2014).

- Karbuз, Sohbet. "How Much Energy Does the U.S. Military Consume? – An Update." 5th, August 2013. <http://www.dailyenergyreport.com/how-much-energy-does-the-u-s-military-consume-an-update/> (accessed 17 Jan 2014).
- Knowledge@Wharton. "Renewable Energy for Japan: A Post-Fukushima Quest - Knowledge@Wharton." 2013. <http://knowledge.wharton.upenn.edu/article/renewable-energy-japan-post-fukushima-quest/> (accessed 18 Jan 2014).
- Krauss, Clifford. "Energy Secretary Calls Oil Export Ban Dated." 14th Dec, 2013. http://www.nytimes.com/2013/12/14/business/energy-environment/energy-secretary-voices-concern-over-dated-oil-export-restrictions.html?_r=2& (accessed 21 Jan 2014).
- Meisen, Peter and Chanal, Margaux. "*How is 100% Renewable Energy Possible in South Korea by 2020.*" Global Energy Network Institute, 2012.
- Montgomery, Scott L. *The powers that be*. Chicago: University of Chicago Press, 2010.
- NEB. "Energy Reports - Canada's Energy Future 2013 - Energy Supply and Demand Projections to 2035 - An Energy Market Assessment." 2013. http://www.neb-one.gc.ca/clf-nsi/nrngynfntn/nrgyrprt/nrgyftr/2013/nrgftr2013-eng.html#s4_1 (accessed 1 Feb 2014).
- OGJ. "The 1973 Oil Embargo: Its History, Motives, and Consequences." 2005. <http://www.ogj.com/articles/print/volume-103/issue-17/general-interest/the-1973-oil-embargo-its-history-motives-and-consequences.html> (accessed 18 Jan 2014).
- OGJ. "The Oil Weapon: Past, Present, and Future." 2005. <http://www.ogj.com/articles/print/volume-103/issue-17/general-interest/the-oil-weapon-past-present-and-future.html> (accessed 18 Jan 2014).
- Philips, Matthew. "U.S. Makes More Oil than It Takes." 14th, Nov 2013. <http://www.businessweek.com/articles/2013-11-14/u-dot-s-dot-makes-more-oil-than-it-takes> (accessed 21 Jan 2014).
- PwC. "Shale Oil: The Next Energy Revolution." 2014. <http://www.pwc.co.uk/oil-gas/publications/shale-oil-the-next-energy-revolution.jhtml> (accessed 20 Jan 2014).
- PwC. "*Shale Oil: The Next Energy Revolution.*" UK: PWC, 2013.
- Republique Francaise. "*National Action Plan for the Promotion of Renewable Energies 2009-2020.*" Republique Francaise. 2009.
- Robertson, Helen. "*Petroleum Economist - Shale Boom to US Economy.*" 2013.
- The Economist Intelligence Unit. "*Diminishing Dependence: Shrinking US Oil Imports.*" The Economist, 2013.
- The Economist. "Energy to Spare." 17th Nov, 2012. <http://www.economist.com/news/business/21566694-america-track-produce-all-energy-it-needs-home-energy-spare> (accessed 19 Jan 2014).
- Think Progress. "The U.S. Military Leads the Charge on Renewables, Efficiency and Energy Security." 2011. <http://thinkprogress.org/climate/2011/06/14/244716/military-renewables-efficiency-and-energy-security/> (accessed 27 Feb 2014).
- Thompson, Loren. "What Happens When America No Longer Needs Middle East Oil?." 3rd December, 2012, <http://www.forbes.com/sites/lorenthompson/2012/12/03/what-happens-when-america-no-longer-needs-middle-east-oil/> (accessed 19 Jan 2014).
- U.S. Department of State. "South Korea." 2014. <http://www.state.gov/r/pa/ei/bgn/2800.htm> (accessed 2 Feb 2014).
- Williamson, Lucy. "South Korea's drive for renewable energy." 1st Dec, 2011, <http://www.bbc.co.uk/news/business-15984399> (accessed 28 Feb 2014).

Chapter Eleven

- Abdulghaffar, Mahmood. "Will the U.S. Fifth Fleet Relocate from Bahrain?" 29th July, 2013, <http://muftah.org/will-the-u-s-fifth-fleet-relocate-from-bahrain/> (accessed 26 Feb 2014).

- Arango, Tim and Clifford Krauss. "China Is Reaping Biggest Benefits of Iraq Oil Boom." 2nd June, 2013, <http://www.nytimes.com/2013/06/03/world/middleeast/china-reaps-biggest-benefits-of-iraq-oil-boom.html?pagewanted=all> (accessed 2 Feb 2014).
- Bremmer, Ian and Kenneth Hersh. "When America Stops Importing Energy." 22nd May, 2013, <http://www.nytimes.com/2013/05/23/opinion/global/when-america-stops-importing-energy.html> (accessed 24 Jan 2014).
- Brennan, Elliot. "Shale Gas: The Key in the US' Asia Pivot?" 8th March, 2013, <http://www.chinausfocus.com/energy-environment/shale-gas-the-key-in-the-us-asia-pivot/> (accessed 3 Feb 2014).
- Calmes, Jackie and Steven Lee Meyers. "U.S. and China Move Closer on North Korea, but Not on Cyberespionage." 8th June, 2013, http://www.nytimes.com/2013/06/09/world/asia/obama-and-xi-try-building-a-new-model-for-china-us-ties.html?pagewanted=all&action=click&module=Search®ion=searchResults%230&version=&url=http%3A%2F%2Fquery.nytimes.com%2Fsearch%2Fsite%2Fsearch%2F%3Fac tion%3Dclick%26region%3DMasthead%26pgtype%3DHomepage%26module%3DSearchSubmit%26contentCollection%3DHomepage%26t%3Dqry947%23%2Fus+china+climate+calmes&_r=0 (accessed 4 Feb 2014).
- Cardwell, Diane. "Unplugging Bottlenecks in Oil and Gas Deliveries." 8th October, 2013, <http://www.nytimes.com/2013/10/09/business/energy-environment/unplugging-bottlenecks-in-oil-and-gas-deliveries.html?action=click&module=Search®ion=searchResults%230&version=&url=http%3A%2F%2Fquery.nytimes.com%2Fsearch%2Fsite%2Fsearch%2F%23%2Fenergy%2Bindependence%2Bcardwell%2F> (accessed 6 Feb 2014).
- Clayton, Blake. "The Case for Allowing U.S. Crude Oil Exports." *Council on Foreign Relations* (2013) Accessed 4 Feb 2014. <http://www.cfr.org/oil/case-allowing-us-crude-oil-exports/p31005#>.
- Donilon, Tom. "American Power: Farewell to Declinism." *Foreign Affairs* (2013) Accessed 3 Feb 2014. <http://www.foreignaffairs.com/articles/139509/tom-donilon/energy-and-american-power>.
- Downs, Erica. "China-Middle East Energy Relations." *Brookings* (2013) Accessed 29 Jan. 2014. <http://www.brookings.edu/research/testimony/2013/06/06-china-middle-east-energy-downs>.
- Downs, Erica. "Implications of the U.S. Shale Energy Revolution for China." *Brookings* (2013) Accessed 29 Jan 2014. <http://www.brookings.edu/blogs/up-front/posts/2013/11/07-shale-energy-revolution-china-downs#>.
- Eia.gov. "AEO Table Browser - Energy Information Administration." 2014. <http://www.eia.gov/oiaf/aeo/tablebrowser/#release=AEO2014ER&subject=0-AEO2014ER&table=1-AEO2014ER®ion=0-0&cases=full2013-d102312a,ref2014er-d102413a> (accessed 20 Jan 2014).
- Eia.gov. "China - Analysis - U.S. Energy Information Administration (EIA)." 2013. <http://www.eia.gov/countries/cab.cfm?fips=CH> (accessed 14 Feb 2014).
- Eia.gov. "Russia - Analysis - U.S. Energy Information Administration (EIA)." 2014. <http://www.eia.gov/countries/cab.cfm?fips=RS> (accessed 18 Feb 2014).
- Eia.gov. "Saudi Arabia - U.S. Energy Information Administration (EIA)." 2013. <http://www.eia.gov/countries/country-data.cfm?fips=SA> (accessed 2 Feb 2014).
- Eia.gov. "Total Crude Oil and Products Exports by Destination." 2014. http://www.eia.gov/dnav/pet/pet_move_expc_a_EP00_EEX_mbb1_m.htm (accessed 6 Feb 2014).

- Eia.gov. "U.S. Energy Information Administration (EIA) - Source." 2013.
http://www.eia.gov/forecasts/archive/aeo13/source_oil_all.cfm#tightoil (accessed 20 Jan 2014).
- Eia.gov. "U.S. Total Crude Oil and Products Imports." 2014.
http://www.eia.gov/dnav/pet/pet_move_impcus_a2_nus_ep00_im0_mbbbl_m.htm
 (accessed 23 Jan 2014).
- Eia.gov. "Venezuela - Analysis - U.S. Energy Information Administration (EIA)." 2014.
<http://www.eia.gov/countries/cab.cfm?fips=VE> (accessed 10 Feb 2014).
- Forero, Juan. "Venezuela Cautions U.S. It May Curtail Oil Exports." 27th Feb., 2006,
http://www.nytimes.com/2006/02/27/international/americas/27venez.html?_r=0
 (accessed 5 Feb 2014).
- Globalenergyinitiative.org. "Global Energy Developments to Watch in 2014." 2014.
<http://globalenergyinitiative.org/world/117-global-energy-developments-2014.html>
 (accessed 12 Feb 2014).
- Gustafson, Thane. "Russian Oil Industry at a Crossroads as Infrastructure Ages." 4th December, 2012, <http://www.nytimes.com/2012/12/05/business/global/russian-oil-industry-at-a-crossroads-as-infrastructure-ages.html?pagewanted=all> (accessed 16 Feb 2014).
- Hall, Wynton. "Govt Offering \$378,000 to Teach Chinese Firms U.S. Shale Gas 'Technologies'." 17th December, 2012, <http://www.breitbart.com/Big-Peace/2012/12/17/Govt-Offering-378-000-To-Teach-Chinese-Firms-U-S-Shale-Gas-Technologies> (accessed 13 Feb 2014).
- Haykel, Bernard. "Is there a crisis in US-Saudi relations?" 26th Nov., 2013,
<http://america.aljazeera.com/opinions/2013/11/relations-us-saudiarabia.html> (accessed 8 Feb 2014).
- Hunt, Katie. "China Faces Steep Climb to Exploit Its Shale Riches." 30th Sept., 2013,
<http://www.nytimes.com/2013/10/01/business/energy-environment/china-faces-steep-climb-to-exploit-its-shale-riches.html> (accessed 2 Feb 2014).
- Inter Press Service. "U.S. Moving Toward Controversial New Role in Global Energy Market - Inter Press Service." 2013. <http://www.ipsnews.net/2013/06/u-s-moving-toward-controversial-new-role-in-global-energy-market/> (accessed 22 Feb 2014).
- Kramer, Andrew. "Flow Starts in Gas Pipeline From Russia to Germany." 6th September, 2011,
http://www.nytimes.com/2011/09/07/business/global/flow-starts-in-gas-pipeline-from-russia-to-germany.html?action=click&module=Search®ion=searchResults%230&version=&url=http%3A%2F%2Fquery.nytimes.com%2Fsearch%2Fsite%2Fsearch%2F%3Dclick%26region%3DMasthead%26pgtype%3DHomepage%26module%3DSearchSubmit%26contentCollection%3DHomepage%26t%3Dqry652%23%2Frussia+pipelines&_r=0
 (accessed 28 Feb 2014).
- Kramer, Andrew. "Russia Cuts Off Gas Deliveries to Ukraine." 1st January, 2009,
<http://www.nytimes.com/2009/01/02/world/europe/02gazprom.html?action=click&module=Search®ion=searchResults%230&version=&url=http%3A%2F%2Fquery.nytimes.com%2Fsearch%2Fsite%2Fsearch%2F%23%2Frussia%2Bukraine%2Benergy%2Bkramer%2F>
 (accessed 13 Feb 2014).
- Krauss, Clifford. "Dwindling Production Has Led to Lesser Role for Venezuela as Major Oil Power." 8th March, 2013,
http://www.nytimes.com/2013/03/09/world/americas/venezuelas-role-as-oil-power-diminished.html?_r=0 (accessed 5 Feb 2014).
- Myers Jaffe, Amy and Edward Morse. "Liquefied Natural Profits: The United States and the Remaking of the Global Energy Economy." *Foreign Affairs* (2013) Accessed 6 Feb 2014.
<http://www.foreignaffairs.com/articles/139932/amy-myers-jaffe-and-edward-l-morse/liquefied-natural-profits>.

- Parker, Ashley. "Romney Unveils Plan for Energy Independence." 23rd August, 2013, <http://thecaucus.blogs.nytimes.com/2012/08/23/romney-unveils-plan-for-energy-independence/?action=click&module=Search®ion=searchResults%230&version=&url=http%3A%2F%2Fquery.nytimes.com%2Fsearch%2Fsitesearch%2F%23%2Fenergy%2Bindependence%2Bparker%2F> (accessed 3 Feb 2014).
- Russia Today. "Oil to remain dominant on energy market – OPEC." 29th October, 2013, <http://rt.com/search/shortnews/term/Oil+to+remain+dominant+on+energy+market+-+OPEC/> (accessed 13 Feb 2014).
- Russia Today. "Russia pivots towards industry, not reliant on oil-Medvedev." 10th Dec., 2013, <http://rt.com/business/medvedev-oil-russia-industry-996/> (accessed 1 Feb 2014).
- State.gov. "Unconventional Gas Technical Engagement Program (UGTEP)." 2014. <http://www.state.gov/s/ciea/ugtep/index.htm> (accessed 27 Feb 2014).
- The White House. "Joint Fact Sheet on Strengthening U.S.-China Economic Relations." December 5, 2013.
- U.S. Department of State. "Facts on U.S.-Russian Energy, Energy-Efficiency Cooperation." June 18, 2012.
- U.S. Department of State. "State's Jacobson on U.S. Priorities in Western Hemisphere." September 27, 2013.
- U.S. Department of State. "China-U.S. Joint Statement on Climate Change." April 13, 2013.
- U.S. Department of State. "National Security Advisor Donilon on Global Energy Policy." April 24, 2013.
- U.S. Department of State. "Gulf Cooperation Council to Strengthen Economic Ties with U.S." October 1, 2012.
- U.S. Department of State. "Facts on 91 Outcomes from U.S.-China Strategic Track." July 12, 2013.
- U.S. Department of State. "World Shale Oil & Gas." September 5, 2013.

Chapter Twelve

- Baker Hughes. *Baker Hughes LiteProp Ultra lightweight Proppants. Baker Hughes LiteProp Ultralightweight Proppants.* Baker Hughes, 2012. Pg. 2-7. http://c14503045.r45.cf2.rackcdn.com/v1/7a03f342882fdbcb86adc6d18f54a4eb7/34847-liteprop_brochure-us.pdf.
- Baker Hughes. "VaporFrac Fracturing Fluid." 2014. <http://www.bakerhughes.com/products-and-services/pressure-pumping/hydraulic-fracturing/vaporfrac-fracturing-fluid>.
- Brown, D. "Hydro Fracturing gets 'Green Tech' Treatment." August, 2012, <https://www.aapg.org/explorer/2012/08aug/hydrofrac0812.cfm>.
- Bullis, Kevin. "One Way to Solve Fracking's Dirty Problem." *MIT Technology Review*, September 24, 2013. <http://www.technologyreview.com/news/519416/one-way-to-solve-frackings-dirty-problem/>.
- Bullis, Kevin. "Can Fracking Be Cleaned Up?." *MIT Technology Review*, June 5, 2012. <http://www.technologyreview.com/news/428076/can-fracking-be-cleaned-up/>.
- Business Wire. "Preferred Sands Recognized for Its Industry-Leading Environmental Stewardship." October 30, 2013. <http://www.marketwatch.com/story/preferred-sands-recognized-for-its-industry-leading-environmental-stewardship-2013-10-30>.
- Denney, Dennis. *Technology Applications.* 2010. Pg. 20. http://www.slb.com/~media/Files/stimulation/industry_articles/201007_jpt_channel_fracturing.pdf.
- Dow Chemical Company. "Preferred Sands Launches New Proprietary Technology for Hydraulic Fracturing Proppants." February 19, 2013. <http://www.dow.com/news/press-releases/article/?id=6172>.

Environmental Leader. "GE to Build \$110m Fracking Research Center." Environmental Leader." 2013. <http://www.environmentalleader.com/2013/04/04/ge-to-build-110m-fracking-research-center/>.

Fuel Fix. "Industry giant GE aims to improve fracturing." 2013. <http://fuelfix.com/blog/2013/05/27/industry-giant-ge-aims-to-improve-fracking/>.

GasFrac. "GASFRAC - Home." 2014. <http://www.gasfrac.com>.

Goodman, Matt. "Waterless Fracking Method Targets Natural Gas Industry's Gaze." January 12, 2012. <http://dfw.cbslocal.com/2012/01/12/waterless-fracking-method-target-for-natural-gas-industrys-gaze/>.

Gurule, Kendall. "Nitrogen gas tracking." *Frackwire* July 9, 2013. <http://frackwire.com/nitrogen-gas-fracking/>.

Halliburton. "CleanStim® Hydraulic Fracturing Fluid System." 2014. <http://www.halliburton.com/en-US/ps/stimulation/fracturing/cleanstim-hydraulic-fracturing-fluid-system.page#>.

Halliburton. "Cleanstream® Ultraviolet Light Bacteria Control Process." 2014. <http://www.halliburton.com/en-US/ps/stimulation/fracturing/water-based-gel-systems/cleanstream-%20ultraviolet-light-bacteria-control-process.page>.

Halliburton. "RapidFrac™ Multistage Fracturing System - Halliburton." 2014. <http://www.halliburton.com/en-US/ps/service-tools/well-completions/horizontal-completions/rapidfrac-multistage-fracturing-system.page#>.

Halliburton. "Halliburton's CleanWave(TM) Water Treatment Technology Takes Spotlight Award at Offshore Technology Conference." 2011. <http://ir.halliburton.com/phoenix.zhtml?c=67605&p=irol-newsArticle&ID=1558040&highlight=>.

Halliburton. *El Paso Corporation completed first natural gas well using all four CleanSuite™ technologies*. Halliburton, 2012. http://www.halliburton.com/public/common/Case_Histories/H09138.pdf.

Halliburton. *Williams halved pumping time and improved initial performance with new RapidFrac™ system*. Halliburton, 2011. http://www.halliburton.com/public/cps/contents/Case_Histories/web/H08703.pdf.

Halliburton. *MonoProp™ Low Density Proppant for High-Porosity Fractures*. Halliburton, 2008. http://www.halliburton.com/public/pe/contents/Data_Sheets/web/H/H06228.pdf.

Harrington, Kent. "GASFRAC Takes the Water out of Fracking." *ChEnected* May 29, 2012, 2012. <http://chenected.aiche.org/energy/gasfrac-takes-the-water-out-of-fracking/>.

Mcnally, Scott. "Waterless Fracking?." *Scientific American* October 10, 2012. <http://blogs.scientificamerican.com/plugged-in/2012/10/10/guest-post-waterless-fracking/>.

Preferred Sands. "Preferred RCS Proppants." 2014. <http://www.preferredsands.com/preferredrcs/proppants.html>.

Rigzone. "*BlackBrush Extends GASFRAC Contract for Waterless Frac Process*." March 13, 2012. http://www.rigzone.com/news/article.asp?a_id=116000.

Schlumberger. "Case Study: Channel Fracturing Increases Production by 37% for Petrohawk in the Eagle Ford Shale." 2011. http://www.slb.com/resources/case_studies/stimulation/hiway_fracturing_eagle_ford_shale.aspx.

Schlumberger. "Case Study: HiWAY Technique Increases Condensate Production by 43% in the Eagle Ford Shale." 2011. http://www.slb.com/resources/case_studies/stimulation/hiway_increases_eagle_ford_cs.aspx.

Schlumberger. "HiWAY Flow-Channel Hydraulic Fracturing Technique." 2014. http://www.slb.com/services/completions/stimulation/sandstone/hiway_channel_fracturing.aspx?t=2.

Siegel, RP. "Is There Really Such A Thing As Green Fracking?." *Triple Pundit* October 23, 2012. <http://www.triplepundit.com/2012/10/really-green-fracking/>.

Chapter Thirteen

AEO2014 Early Release Overview. AEO2014 Early Release Overview. Energy Information Association, 2014. [http://www.eia.gov/forecasts/aeo/er/pdf/0383er\(2014\).pdf](http://www.eia.gov/forecasts/aeo/er/pdf/0383er(2014).pdf). (accessed 22 Feb 2014).

afdc.energy.gov. "Alternative Fuels Data Center: Alternative Fueling Station Counts by State." 2014. http://www.afdc.energy.gov/fuels/stations_counts.html (accessed 23 Feb 2014).

Corporate Average Fuel Economy Standards. Corporate Average Fuel Economy Standards. Volpe The National Transportation Systems Center, 2014. http://www.volpe.dot.gov/sites/volpe.dot.gov/files/docs/CAFE_infographic_v3.pdf. (accessed 22 Feb 2014).

Department of Energy FY 2014 Congressional Budget Request: Budget Highlights. Department of Energy FY 2014 Congressional Budget Request: Budget Highlights. 2014. http://energy.gov/sites/prod/files/2013/04/f0/FY14_DOE_Budget_Highlights_Final.pdf. (accessed 22 Feb 2014).

Department of Energy FY 2010 Congressional Budget Request: Budget Highlights. Department of Energy FY 2010 Congressional Budget Request: Budget Highlights. 2014. <http://energy.gov/sites/prod/files/FY10Highlights.pdf>. (accessed 22 Feb 2014).

dieselnet.com. "Emission Standards: USA: Cars Fuel Economy (1978-2011)." 2014. <https://www.dieselnet.com/standards/us/fe.php> (accessed 21 Feb 2014).

eia.gov "How dependent is the United States on foreign oil? – FAQ – U.S. Energy Information Administration (EIA)." 2014. <http://www.eia.gov/tools/faqs/faq.cfm?id=32&t=6> (accessed 28 Feb 2014).

eia.gov. "Short-Term Energy Outlook - U.S. Energy Information Administration (EIA)." 2014. http://www.eia.gov/forecasts/steo/report/global_oil.cfm (accessed 22 Feb 2014).

eia.gov. "United States - U.S. Energy Information Administration (EIA)." 2014. <http://www.eia.gov/countries/country-data.cfm?fips=US#pet> (accessed 23 Feb 2014).

eia.gov. "What was the highest U.S. average retail price of regular gasoline? – FAQ – U.S. Energy Information Administration (EIA)." 2014. <http://www.eia.gov/tools/faqs/faq.cfm?id=247&t=1> (accessed 28 Feb 2014).

energy.gov. "The eGallon: How Much Cheaper Is It to Drive on Electricity?" 2014. <http://energy.gov/articles/egallon-how-much-cheaper-it-drive-electricity> (accessed 22 Feb 2014).

EV Everywhere Grand Challenge: Road to Success. EV Everywhere Grand Challenge: Road to Success. Argonne National Laboratory, 2014. http://www1.eere.energy.gov/vehiclesandfuels/electric_vehicles/pdfs/everywhere_road_to_success.pdf. (accessed 22 Feb 2014).

"Hybrid Car Statistics." 2014. http://www.evscroll.com/Hybrid_Car_Statistics.html (accessed 22 Feb 2014).

Gerken, J. The Huffington Post. "Obama To Talk Up Benefits Of Fuel-Efficient Trucks." 2014. http://www.huffingtonpost.com/2014/02/18/obama-fuel-efficiency-standards_n_4807697.html (accessed 21 Feb 2014).

Global Comparison of Light-Duty Vehicle Fuel Economy/GHG Emissions Standards. Global Comparison of Light-Duty Vehicle Fuel Economy/GHG Emissions Standards. The International Council on Clean Transportation (ICCT), 2014. http://www.theicct.org/sites/default/files/info-tools/ICCT_PVStd_Aug2013_v0.pdf. (accessed 23 Feb 2014).

- Hartman, K. Ncsl.org. "State Electric Vehicle Incentives and Information." 2014.
<http://www.ncsl.org/research/energy/state-electric-vehicle-incentives-state-chart.aspx#wa>
 (accessed 23 Feb 2014).
- Lahood, S. R. Whitehouse.gov. "Historic Fuel Efficiency Standards for Cars and Light Trucks | The White House." 2014. <http://www.whitehouse.gov/blog/2012/08/28/historic-fuel-efficiency-standards-cars-and-light-trucks> (accessed 22 Feb 2014).
- Leahy, M. and Bruel, H. eia.gov. "U.S. crude oil production growth contributes to global oil price stability in 2013 - Today in Energy - U.S. Energy Information Administration (EIA)." 2014. http://www.eia.gov/todayinenergy/detail.cfm?id=14531#tabs_SpotPriceSlider-1 (accessed 23 Feb 2014).
- Loiseau, J. DailyFinance.com. "Pump vs. Plug: Do You Really Save Money Driving an Electric Car? - DailyFinance." 2014. <http://www.dailyfinance.com/2013/06/24/gas-vs-electric-cars-cost-comparison/> (accessed 22 Feb 2014).
- Plumer, B. Washington Post. "Is public transit habit-forming?." 2014.
http://www.washingtonpost.com/blogs/wonkblog/post/is-public-transportation-habit-forming/2012/05/18/gIQAFw1WYU_blog.html (accessed 23 Feb 2014).
- statisticbrain.com. "Gas Station Statistics | Statistic Brain." 2014.
<http://www.statisticbrain.com/gas-station-statistics/> (accessed 23 Feb 2014).
- sustainabledevelopment.un.org. "Congestion Charge System in London ∴ Sustainable Development Knowledge Platform." 2014.
<http://sustainabledevelopment.un.org/index.php?page=view&type=99&nr=29&menu=1449>
 (accessed 23 Feb 2014).
- Utech, D. Whitehouse.gov. "Driving Toward Greater Energy Security | The White House." 2014.
<http://www.whitehouse.gov/blog/2013/11/13/driving-toward-greater-energy-security>
 (accessed 22 Feb 2014).
- Vehicle Technologies Office: Fact #814: January 27, 2014 More Choices when Buying Vehicles that Use Advanced Technology and Alternative Fuels." 2014.
http://www1.eere.energy.gov/vehiclesandfuels/facts/2014_fotw814.html (accessed 22 Feb 2014).