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DEPARTMENT OF SUPPLY CHAIN & INFORMATION SYSTEMS

AN INDUSTRY ANALYSIS OF NATURAL GAS AND ITS PLACE IN THE UNITED STATES

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ABSTRACT

The purpose of this industry analysis is to understand the complex nature of the natural gas industry and its current and future market prospects. Industry data regarding chemical properties, supply logistics, global market data, historical regulation and carbon footprint were gathered in order to analyze the current market for United States businesses. Overall, it was concluded that the feasibility of natural gas relies heavily on its expansion of innovative designs to expand capacity within the supply chain. However, natural gas's abundance, combined with its unique chemical properties, production growth and practical applications, make potential growth a significant possibility in today's "carbon-constrained" environment (MIT, 2013). There is clear promise in various economic sectors as a cleaner burning fuel. Overall, current market growth indicates that profitability can be established and expanded for companies willing to undertake the capital investment needed to integrate it into their business strategies and supply chains, yet development of more sustainable long-term goals must be achieved.

TABLE OF CONTENTS

LIST OF FIGURES

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I would like to thank my supervisor Robert Novack and advisor John Spychalski in their guidance and knowledge in this endeavor. They have been both tremendous educators and mentors throughout my academic career. I would also like William and Joan Schreyer, whose commitment to education allowed me the fortune to learn at an institution of the highest order.

Chapter 1: Introduction

The domestic energy landscape has dramatically changed since the turn of the century. United States production levels are at an unprecedented high and exhibit a growth unseen since the 1960s. This last decade of growth has signaled a watershed moment within the world energy landscape and it is forcing businesses to reconsider the market trends and their energy strategy. Without a doubt, current energy independence within the United States is due in large part to the substantial rise in the production of natural gas. In prior years, natural gas was typically unheeded within the global market. However today, many experts believe that natural gas can provide a path towards a more sustainable future because it offers significant environmental benefits as well as an abundant supply. Therefore, the purpose of this study is to investigate the current state of natural gas and its future market potential. By providing a comprehensive industry analysis, businesses will be better equipped to analyze the potential place of natural gas and its sustainable benefits within the supply chain.

With the purpose of providing better general knowledge of natural gas, this study provides a high-level view of industry practices, policies and market data. After briefly introducing the unique composition and historical advancement of natural gas within the United States, this thesis focuses on the four major components of the natural gas industry: supply, market structure and risk, legislation and environmental impact. Industry data was gathered from a multitude of public databases, publications, expert studies and governmental resources to assess the natural gas potential in the United States. As a highly regulated and monitored industry and essential political concern, a majority of the industry data was gathered from various governmental agencies including the Energy Information Administration, Environmental Protection Agency and Department of Energy.

The discussion of supply and market structure begin by analyzing natural gas at different points along the value chain. Beginning at the point of extraction, the study provides analysis of the growing domestic reserves and advancement of unconventional drilling practices and technologies. It underscores how success in extracting unconventional natural gas like shale gas is reshaping the market structure. Subsequent analysis of infrastructure, capacity and financial data provide further insight into its feasibility as a more effective fuel source. Focus on key sectors within the economy including energy generation and transportation, as well global markets and risk help to elaborate unique opportunities and threats to current supply chains.

The second half of the study refocuses around important analysis of future prospects and sustainability concerns regarding the expansion of natural gas. First, it helps to define sustainability, its metrics and its purpose. Using sustainability analytics derived from a series of metrics, models and reports assembled by the Massachusetts Institute of Technology, Pricewaterhouse Coopers and Ernst & Young, the study confirms the idea that natural gas could be a viable short-term alternative to other carbon-based fuels. The study continues into detail about significant natural gas legislation and its current and future prospects on the industry. Such legislative developments continue to grow in importance within the energy sector and help to emphasize some of the key challenges natural gas producers and consumers may face in coming years. Lastly, the study concludes with a brief analysis of the positive aspects of sustainable natural gas innovation within the value chain. By providing information about sustainability and environmental impact, businesses can better analyze the total impact of natural gas investment.

Chapter 2: Understanding Natural Gas

Natural gas has a relatively short and rapidly developing history and unique gaseous properties that make it incredibly unique in today's market. Today, natural gas production has begun to exceed that of other fossil fuels and its potential reserves far exceed that of its crude oil counterpart. In 2013, the United States became the number one hydrocarbon producer in the world for the first time since the 1970s (Goldenberg, 2013). New technologies and extraction techniques have created a wealth of domestic supply and a watershed shift in gas demand both in the United States and abroad. Previously untapped resources like shale gas are driving capital investment in infrastructure in hopes of expanding the commercial frontier. Moreover, new market research and demand has begun to push demand into all areas of business creating a wealth of opportunities. Yet, the limits of capacity and environmental concerns still leave some to criticize if natural gas is the future of energy in the United States. To meet these concerns, it is important to understand what makes natural gas and its challenges so unique.

Properties

Natural gas's unique chemical composition and characteristics are a fundamental reason why both businesses and researchers alike are analyzing its potential as a fuel source. Natural gas, like the other fossil fuels, is a carbon-based gas that formed from decomposing plant and animal matter. Over millions of years, pressure within the Earth's mantle and core buries this matter and force it into a gas as oxygen is removed and heat from the Earth create a molecule called hydrocarbon. Hydrocarbon is the scientific name for the molecule found in the world's fossil fuel deposits and is the primary chemical component burned for energy creation. Hydrocarbons can appear in three different forms: in solid form as coal, in liquid form known as crude oil and in a gaseous form as natural gas. All three forms are considered non-renewable resources because of their lengthy formation. Natural gas contains the simplest and lightest hydrocarbon known as methane (CH_4). While natural gas may contain other hydrocarbons, like those in liquid form like propane and butane, methane remains the most important molecule for natural gas to cleanly burn (Salvador, 2012). Thus, in order to achieve the optimal "dry gas" fuel state, other hydrogen and carbon molecules are extracted in refinement. Because of this lower carbon state, natural gas emits a substantially lower amount of CO_2 emissions making it the cleanest nonrenewable energy source (EIA, 2015).

Thermogenic natural gas, or gas created from this pressurizing process, is the primary form used to create energy and comes in two main forms called "associated gas" and "non-associated gas." Simply put, natural gasses formed from a crude oil deposit or formed as a byproduct of bringing oil to the surface, are referred to as "associated gasses," or gasses formed in association with their liquid counterpart. Conversely, non-associated gasses are gasses formed without the presence of oil. Non-associated gasses are crucial to United States natural gas production accounting for eighty-nine percent of domestic output. This is due primarily to the abundance of various non-associated fields and new technologies that have grown exponentially in the last thirty years. In the last decade alone, advancement in the non-associated gas industry has pushed both the production and capacity frontier to staggering new levels (MIT, 2013).

Historical Advancement

Much of the information about natural gas is relatively new, thus giving staggering opportunities for the global marketplace. The use of natural gas in modern times dates back to the Industrial Revolution in Great Britain around 1785. The first type of manufactured natural gas was a coal-based gas that was used to light the streets and homes of the city of London. While coalbed methane (CBM) is still produced, it is not as widely used due to its higher carbon content and lower recovery yields (MIT, 2013). In 1821, William A. Hart drilled the first natural gas in the United States in Fredonia, New York. Yet, the real start of the industry occurred in 1859 when Edwin Drake dug a sixty-nine foot well and five and half mile pipeline to the town of Titusville, Pennsylvania bringing non-associated natural gas straight to the inhabitants of the town. Thirty years later, natural gas became the staple heat and light source for the modern home and the burgeoning city streets of the United States. Yet, unlike liquid fossil fuels, natural gas faces the unique logistical challenge of transporting and storing something in a gaseous state. As a gas, methane has triple the volume but less density than crude oil making it harder to get to market efficiently. In order to solve this substantial supply chain challenge, infrastructure, in the form of pipelines, had to be created in order to move the gas from the fields to the cities and homes. Pipelines require substantial capital investment, which ultimately dissuaded many businesses from undergoing investment initially and prolonged the development and expansion of the resource. To this day, infrastructure remains a key component of understanding the logistical challenges of the natural gas industry. Large-scale pipeline projects did not begin until the 1950s and 1960s when the United States government and private companies began significantly investing in a pipeline infrastructure to bring natural gas to the mass market. As technology and innovation improve the ability of companies to bring natural gas to market, the capabilities of natural gas will expand into various fields and its role in society will grow (US-DOE, 2013).

Natural gas has come under the microscope in recent years as technology and innovation have finally caught up to its potential. Natural gas production has skyrocketed as horizontal drilling and hydraulic fracking have unearthed new ways to extract the resource from the Earth. From a consumer perspective, its function has expanded from simply lighting streets and heating homes and stoves to touching every sector of the economy including transportation, manufacturing and electricity production. Chemical engineering has designed ways to both liquefy and transport gas sustainably and efficiently. Supply chains now must analyze the market for a more sustainable resource as the geopolitical market is undergoing a watershed shift in energy production. Overall, natural gas's feasibility relies heavily on its expansion of innovative designs to expand capacity within the supply chain and bring it to market. While the market is mature, the history of natural gas is relatively short and has yet to begin. Natural gas's inherent, unique properties have the potential to flourish in a "carbon-constrained" environment giving clear promise to companies willing to undertake the capital investment needed to integrate it into their business strategies and supply chains (MIT, 2013).

Chapter 3 Supply

Proven Reserves

In 2014, the United States recorded proved natural gas reserves totaling 388.8 Trillion cubic feet. This number, up 9.8 percent from the previous year, broke the record number of reserves for the second straight year. That same year the number of proven natural gas reserves overtook crude oil reserves, making it the most abundant fossil fuel in the United States (EIA, 2015). The previous year, natural gas production also grew substantially in both energy sectors as the Energy Information Agency placed the United States ahead of both Russia and Saudi Arabia as the world’s top hydrocarbon producer for the second straight year (Goldenberg, 2013). From a reserve standpoint, the number of proven natural gas reserves United States is estimated to be among the top five highest in the world, with that number growing each year. Three main regions, seen in Figure 1, contains almost seventy percent of the world’s natural gas reserves. For the past thirty years, the regions of Russia, the Middle East and North America have vacillated between being the world’s top producer. In addition, this is also not subject to change as they are also the regions with the highest number of proven reserves.

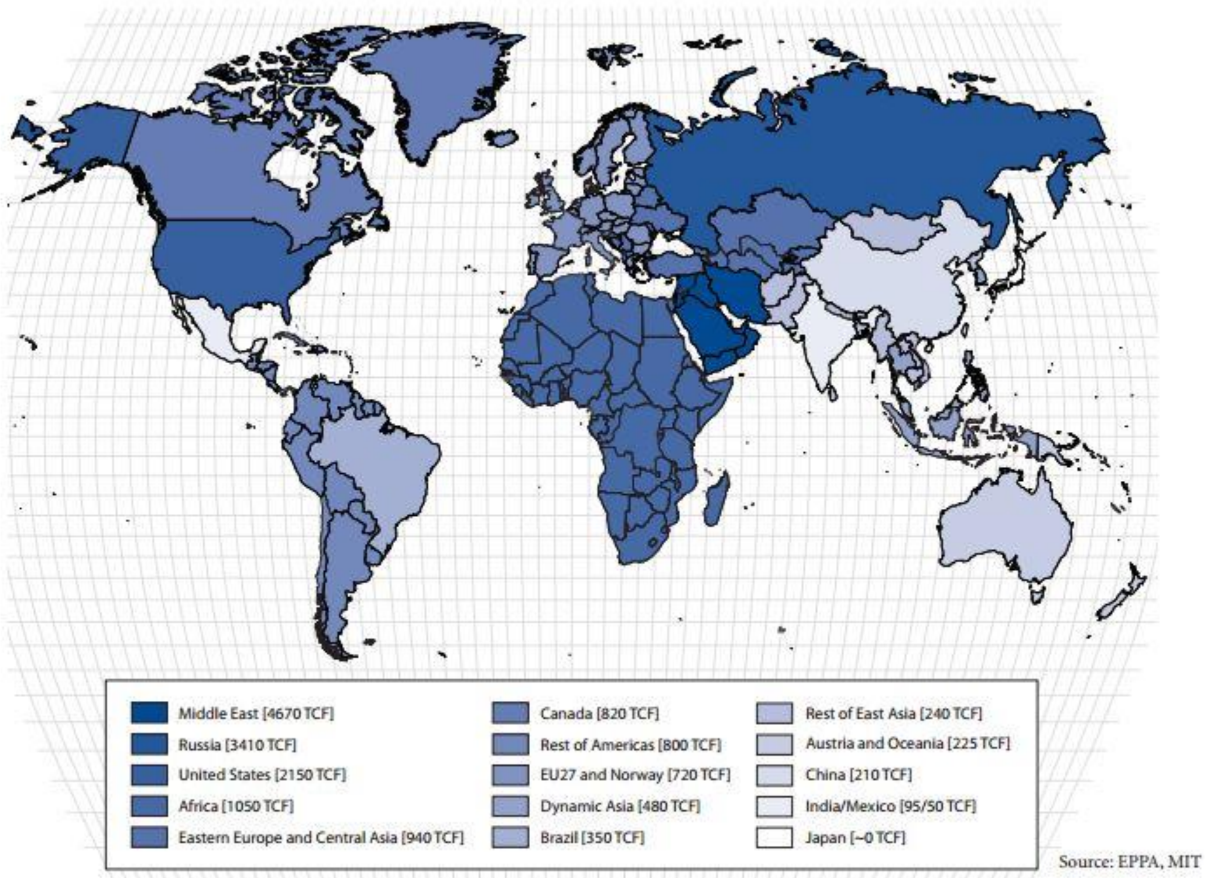


Figure 1: Map of Proven Oil Reserves

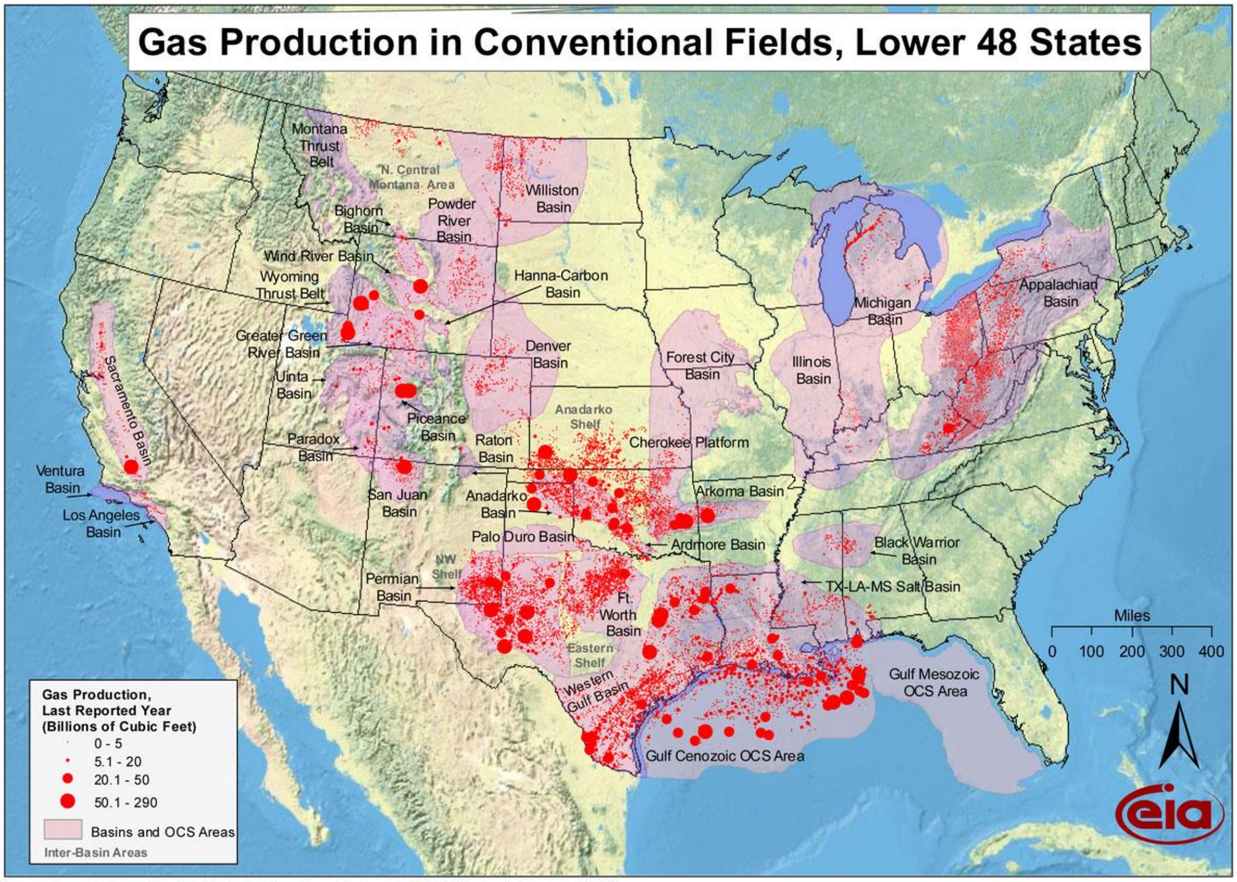
According to the EIA, "proved reserves are estimated volumes of hydrocarbon resources that analysis of geologic and engineering data demonstrates with reasonable certainty are recoverable under existing economic and operating conditions." In other words, proven reserves are yearly estimations of the number of natural gas fields within a particular country. These estimations account for discoveries, appraisal of existing fields, current reserve production and change in technologies and price. A proven reserve, therefore, can have a significant impact on the world energy market because it is an estimated reflection of potential production for upcoming years. Estimations like these are essential for large drilling corporations because the lead times on capital investments could be years or even decades away. It also may help them forecast production capacity and raw material supply decades into the future (EIA, 2015).

Proven reserves are sub-divided into two main categories, conventional and nonconventional reservoirs. Whether or not a reservoir is conventional or not is based on where the gas is located beneath the earth and how it is extracted. Natural gas's unique characteristics as a gas have always made extraction a unique operational challenge. Conventional gas reservoirs are usually found in well-defined subterranean reservoirs with high levels of permeability. Because of the permeability and well-defined location of the deposit, it makes it easy to locate and extract the gas. Conventional wells typically drill straight down vertically and generally require fewer resources. Historically, conventional reservoirs yield better recovery rates (around eighty percent) than unconventional or oil reservoirs. Conversely, unconventional resources are found in accumulations where permeability is much lower and the distribution of gas is deeper and more spread out. This requires different and more complex drilling techniques to reach the gas. Recent developments in technology and extraction methods, like hydraulic fracking, or "fracking" and horizontal drilling have allowed unconventional reservoirs to reach higher production levels than in previous years. Deeper, more complex deposits like shale and tight sandstone gas are the key components related to recent industry growth and will continue to shape the industry in the coming years (MIT, 2013).

Conventional Reservoirs

Historically, conventional reservoirs have been the primary reservoir type utilized globally. The closely compressed deposit structure allows better capture, treatment and transportation of natural gas. Vertical wells come in varying shapes and sizes and are drilled straight downward into the deposit to expand and reach the gas. After drilling, careful lining is placed within the well to keep the gas from escaping and minimize environmental contamination and leakage. Electric charges are then sent down the well to break the rock around it, allowing the gas to move through the tightly compressed rock and up the well. A conventional well, if executed correctly, can yield up to twice the volume recovered than crude oil (MIT, 2013).

Conventional fields, while still classified as non-associated gasses, are located geographically similarly to oil deposits. According to Figure 2, the largest proven reserves for conventional deposits reside in Texas, the Gulf of Mexico (offshore drilling), and Oklahoma. These proven locations have continuously been top hydrocarbon producers, as they contain the most established equipment and labor force and have the most pipeline infrastructure to support natural gas production. While not pictured, Alaska’s pipeline infrastructure and natural resource also contributes large amounts of conventional non-associated gas as the fifth highest total producing region in the United States (EIA, 2015). Alaska works closely with neighboring Canada, utilizing the North American Free Trade Agreement, to move gas throughout the upper northwest. Overall, conventional reserves produce the highest amount of natural gas in the United States and globally by a fair margin. However, from 2000-2009, conventional gas production dropped fourteen percent to forty-one percent of total US production, while shale gas production, an unconventional gas resource, rose thirteen percent to fourteen percent of total production (MIT, 2013). This market trend is very reflective of today’s natural gas environment and these early market indicators exemplified that unconventional reservoirs, particularly shale, would begin rival conventional production and expand total production in the immediate future.



Source: Energy Information Administration based on data from HPDI, IN Geological Survey, USGS
Updated: April 8, 2009

Figure 2: Conventional Fields in the US

Unconventional and the Rise of Shale Gas

Outside of North America, unconventional gas remains significantly underdeveloped due to the current supply of global conventional reserves and limited access to distribution infrastructure and new technology. In the United States, the most produced source of unconventional gas is known as tight gas. Tight gas gets its name from the impermeable dense rock that surrounds the gas deposit. This impermeable sand or rock and the underlying deposits are much older than conventional gas deposits and thus their durability and impermeability make them increasingly hard to break. Currently, tight gas sands in the Southwest, namely Texas, provide the most tight gas in the United States (EIA, 2015). Drilling tight gas requires much stronger drills and considerably more energy and effort to drill effectively and get gas to flow consistently from these underground pockets. Considerably more seismic and analytical data are required to locate and map a location for a tight gas drill, making project lead times longer and costs higher. These powerful drills are directional spread out in order to stimulate the expansive region and loosen the gas from the ground in an effort to cause more gas to flow.

Recently, a process known as hydraulic fracturing, also known as fracking has proven very effective a freeing tight gas deposits. Like other drilling techniques, fracking drills deep into the earth in order to break rock and release gas to the surface. However, because tight gas lies underneath much less permeable rock it needs a bigger break to release the gas. In hydraulic fracturing, a high-pressure water and chemical mixture is also released to break the rock. Often times, this is done horizontally deep within the earth to increase the effectiveness of the chemical mixture. This second process, shown in Figure 3, is called horizontal drilling because it extend the well horizontally at great depth to reach the deeper gas deposits far beneath the surface. Many times, these older “shale” deposits are drilled right after a conventional well has dried. Thus, hydraulic fracturing has allowed companies to dig deeper and farther, raising some environmental concerns as it is relatively new and its environmental effects not completely documented. These two processes most importantly have revolutionized natural gas production by expanding the capability frontier for unconventional deposits. The United States can now produce more natural gas than ever and redefine where natural gas can be found. In essence, technological advancement has not allowed any more natural gas fields to be created, but rather found by drilling deeper and more effectively.

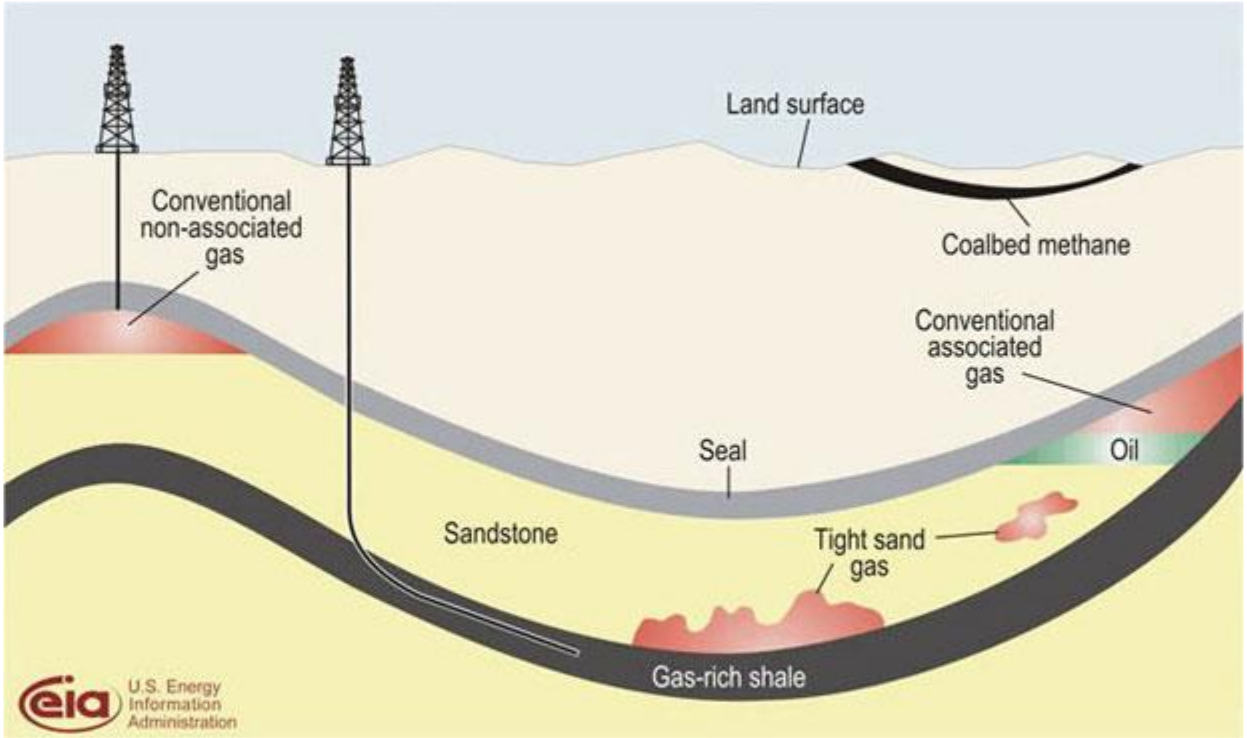
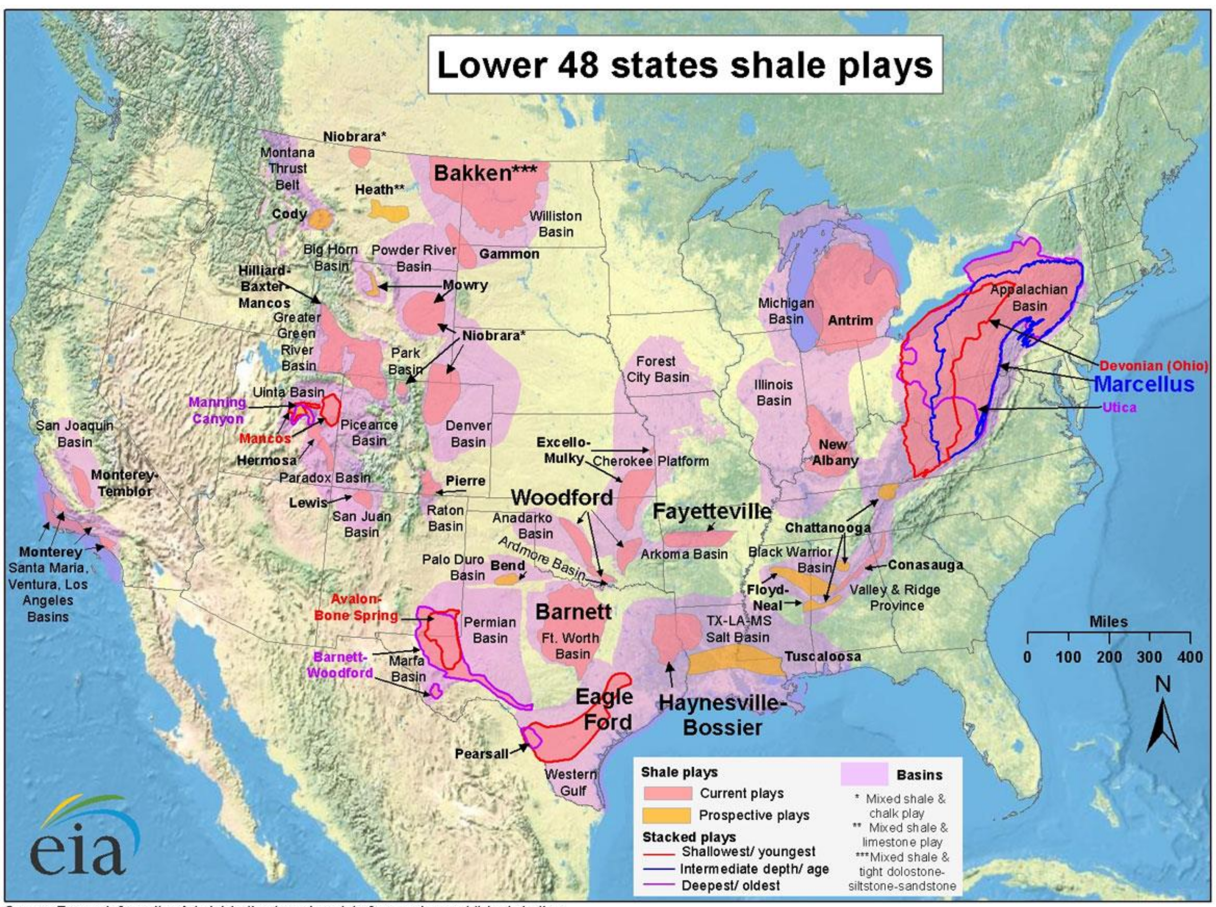


Figure 3: Drilling Techniques and Natural Gas Location

The rise of shale gas is perhaps the most interesting development in natural gas production in the last ten years. While shale has been available since natural gas was first found by William Hart back in 1821, it was not until the advent of hydraulic fracturing and horizontal drilling that it could be utilized in its current state. Shale gas, in comparison to other types, refers to the deep grainy, sedimentary rocks where the gas is found. These carbon laced rocks form large underground organic deposits called “plays” where black shale (which form hydrocarbons) are located (Salvador 2013). Six major shale plays shown in Figure 4 account for almost all of shale gas production in the United States: the Barnett and Eagle Ford Shales in Texas, the Marcellus Shale in West Virginia and Pennsylvania, the Fayetteville Shale in Arkansas, the Woodford Shale in Northern Texas and Oklahoma, and the Haynesville-Bossier in Texas and

Louisiana (EIA, 2015). Most importantly, the number of proven shale reserves in the seven years 2007 and 2014 were slightly higher than the number of proven reserves of all the other types of natural gas combined. Even more impressive, is that shale production grew from one percent to fourteen percent from 2000 to 2009 (MIT, 2013). This nine Surprisingly, while three different shales in Texas gave the state a higher shale production in 2014, the number of discoveries and proven shales in the Marcellus Basin, have made Pennsylvania one of the biggest players in the shale industry as of 2015 (EIA, 2015). Looking forward, its production and importance to the Northeast make it a major region to watch in the next five years.



Source: Energy Information Administration based on data from various published studies.
Updated: May 9, 2011

Figure 4: United States Shale Locations

Two other forms of unconventional natural gas that are produced globally are coalbed methane (CBM) and Methane Hydrates. Overall, their individual production is minimal, yet technology continues to increase their potential. Coalbed methane is captured from coal deposits and was one of the first types of natural gas to be utilized in electric power generation. However, capturing coalbed methane is quite ineffective in large quantities and less environmentally friendly making it a less viable long-term source. Surprisingly, from 2000 to 2009 coalbed methane grew to nine percent of United States production (MIT, 2013). This proves that coalbed methane production will exist as long as there is a need for natural gas. The last form, methane hydrate, is of the most consequence of the other forms of unconventional gas. Conversely, methane hydrate could be a potential long-term resource in many places throughout the world. A methane hydrate is an ice-like form of water and methane that occurs in the permafrost ocean deposits and tar sands close to the Arctic Circle. While none of these reserves have been proven or are included in current estimates, some experts believe that hydrate deposits could exceed 100,000 trillion cubic feet. At this current time, however, recovering this gas is beyond reach. Moving forward, advancing technologies should provide better insight into recoverable resources within the Arctic Circle (MIT, 2013).

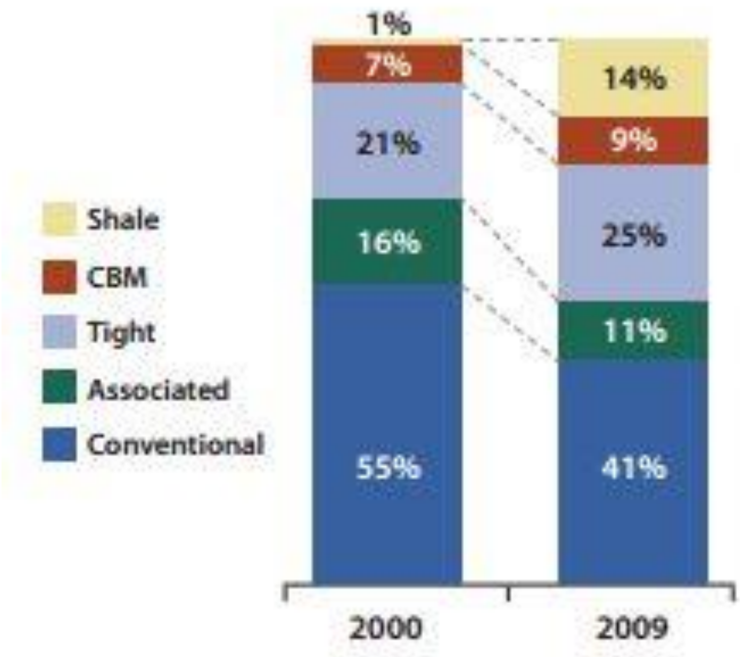


Figure 5: Gas Distribution from 2000-2009

Overall, natural gas production and supply is trending upwards. The Potential Gas Committee published a report recently regarding the United States' potential supply. According to their data, the United States, using new identification and extraction technologies has grown its potential remaining gas resources by seventy-seven percent since 1990 (Byers, 2015). Even more importantly, the rise of unconventional natural gas as shown by Figure 5, exhibit a fundamentally changing market. Such a large change will only increase market viability and consumption of natural gas in the next decade as unconventional resources will become more readily available. If this trend continues, the United States will have considerable leverage over the global market (MIT, 2013).

Chapter 3: Market Economics

Financial Market Structure

Today, the stock price of natural gas is around $1.81 per million British thermal unit (mmBtu), as of March of 2016 (NYSE, 2016). This price marks a remarkable low cost that has been steadily decreasing in the past decade. The inverse relationship between technology and price only opens the possibility of more natural gas penetration within the global and domestic markets. Overall, the industrial production index indicates a significant, continual increase in production within the United States. Overall, the next five years is meant to grow two percent by 2021. This growth is an indication that the overall production is keeping the price of natural gas down, but its use is rebounding from the financial crisis. As a commonly used source of energy, natural gas is in the mature stage of its life cycle, with very few major players within the field. Major energy providers like Halliburton and ExxonMobil compete at the point of extraction, while smaller regional utility firms compete within the industry sector. More importantly, because of its unique production, capacity and storage constraints, the regulation and barriers to entry are very high. Profitability, therefore, is dependent on the economy, the world price per million British thermal unit, and the ability to get it to the market efficiently (IBISWorld, 2016).

Overall, the cost at the point of operation, at the wellhead or even at the export point, is relatively cheap, about $1 to $2/million British thermal unit. The most expensive part of natural gas production undoubtedly is the cost associated with transportation. Because of the unique qualities with being a gas, the total landed cost is ultimately higher than its crude oil and coal counterparts. Businesses are also very dependent on the global consumption market, which is highly volatile. Thus, pushing economies of scale and keeping costs low are primary business concerns. Capital and infrastructure, in the form of thousands of miles of gas pipelines, and railways and trucking routes must be developed in order to get gas to market. This can result in a 50-250 percent increase in price depending on various logistical factors including tariffs, freight and intermodal costs and geographic location. Thus, shown by Figure 6, transportation cost can drive the breakeven price higher for unconventional forms of natural gas that have not yet set up the right economies of scale (MIT, 2013).

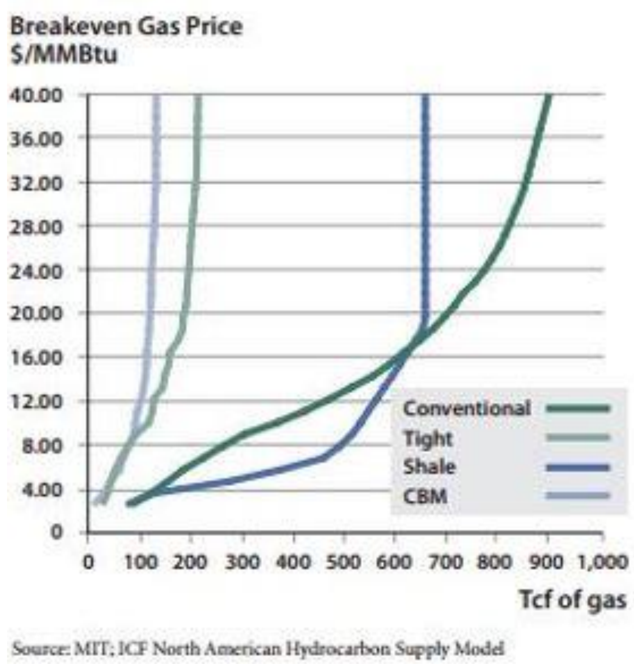
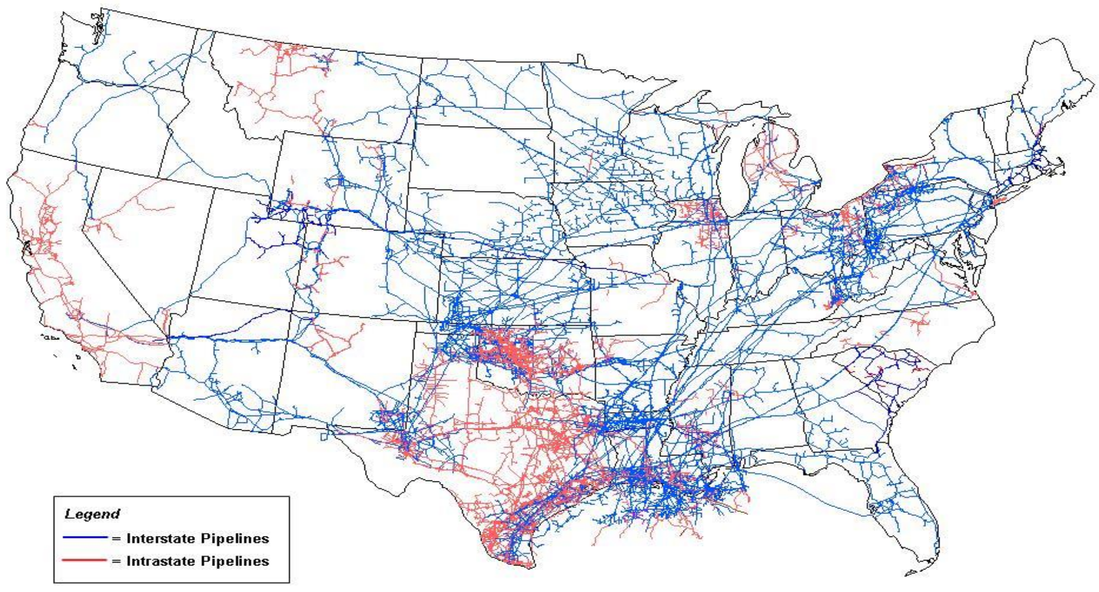


Figure 6 ; Breakeven Point for Natural Gas in 2007

The pipeline infrastructure and capacity that has been so critical to the development of the natural gas industry, has ultimately been a major reason for its slower economic development. Unlike crude oil, natural gas's dependence on infrastructure has led to a localized market as opposed to a global one (MIT, 2013). The United States currently has 210 different pipeline systems connecting 305,000 miles of transmission pipelines shown in Figure 8, which is the highest of any country in the world. Pipeline systems are divided into three different types: gathering systems, interstate systems and distribution systems. All three contribute by connecting conventional and unconventional extraction sites to the 16,000 different delivery and receipt points within the United States. To keep gas flowing forward at all times, 1,400 different compressor stations continuously move gas from well sites. At the end of the system, gas is distributed into one of the 24 market hubs, stored in one of the 400 underground facilities or pushed through one of the 49 import and export pipes to neighboring countries (EIA, 2015; MIT, 2013; Schenk 2015).



Source: Energy Information Administration, Office of Oil & Gas, Natural Gas Division, Gas Transportation Information System

Figure 7: United States Pipeline Network

While the United States ranks first in total natural gas production, the pipeline infrastructure is in dire need of improvement. As new sites are found and utilized, new pipelines have to be constructed in order to bring gas to market. Moreover, numerous pipelines were built during the first natural gas boom in the 1950s, 1960s and 1970s. In the United States pipeline system, over twenty-five percent of the pipelines in the United States are fifty years old or older (MIT, 2013). Business and governments thus have indicated a need for more capital investment in the coming future. As total market demand, both domestic and abroad, continues to grow, the infrastructure providing gas is being adapted to fulfill higher consumption. From 2005-2008, over eighty billion cubic feet of pipeline infrastructure were added in the United States. Over the next twenty years, it is projected that companies will spend an estimated $210 billion in infrastructure especially within developing areas like the Marcellus shale basin. These improvements can help to alleviate some of the major concerns around infrastructure, yet the current low price per million British thermal unit makes such projects harder to justify. Most pipelines have been constructed going east to west to meet growing demand (MIT, 2013). The Rocky Mountain Express was the biggest pipeline constructed in the last ten years, adding 1.8 Billion cubic feet to the pipeline system (EIA, 2015). However, adding capacity does not completely solve the logistical challenges associated with gas production. Old infrastructure is both a capacity restraint and a sustainability concern. From a capability perspective, pipelines are only as effective as the point of production is. If a well begins to wane production early, the capital invested might not yield a justifiable return on investment. Pipelines have limited storage capability, must constantly be running and do not have a backhaul like trailers making optimization capabilities a significant challenge. In addition, maintenance and regulation are only going to increase operating costs as incidents like the Deepwater Horizon Oil Spill will only reinforce a need to further invest in the hydrocarbon infrastructure.

Natural Gas Markets

While the United States has an abundance of natural gas resources, numerous other regions like Russia and Saudi Arabia also have an abundance of the resource. The global supply in its current state is about 150 times what production was in 2009 and fluctuates around 16,200 trillion cubic feet. This projection sees resources becoming scarce about a century from now. The MIT Sloan Energy Initiative also concludes that 9,000 trillion cubic feet of this projection could be extracted at around $4/million British thermal unit, which is a very affordable price. These facts lead to the conclusion that the position of natural gas in the global market is likely to grow (MIT, 2013).

The demand for carbon-based fuels and all fuels in general, continues to grow as populations and emerging nations continue to develop into mature economies. Yet, natural gas more than any other resource, has the highest growth potential due to its position within the economy. Currently, natural gas is the only hydrocarbon that touches all sections of the economy. Many supply chains today are based upon petroleum and oil consumption, yet natural gas could prove to be a competitive advantage moving forward because of this market advantage. Much of global demand will depend on the development of usable infrastructure for emerging markets to utilize it the way the United States does shown in Figure 8. Without it, natural gas will not grow at the current predicted rate.

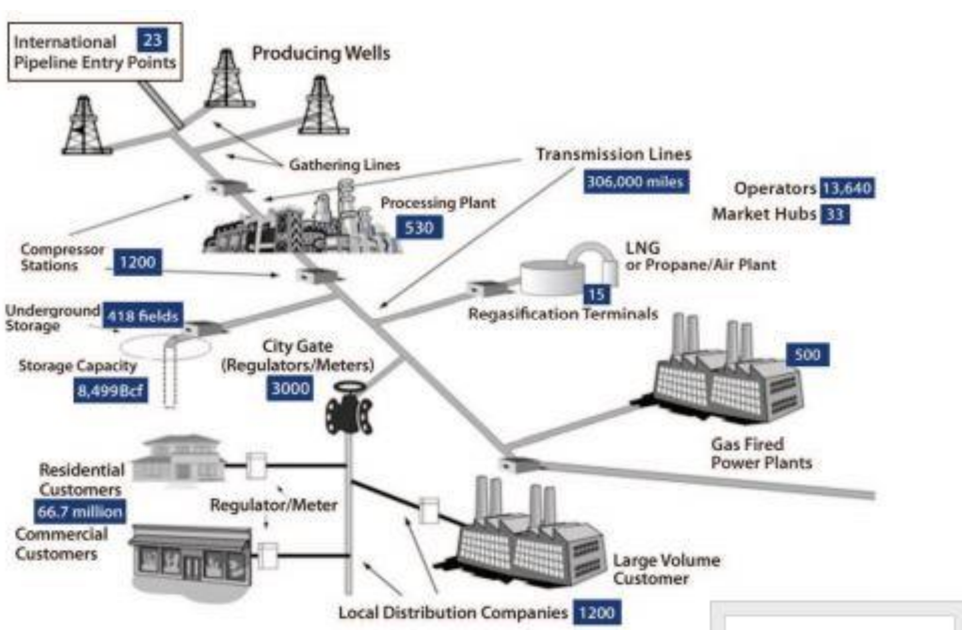


Figure 8: Diagram of the United State Natural Distribution Route

Within industry, natural gas is a critical raw material for hundreds of businesses when designing or manufacturing their products. Some products, such as pharmaceuticals or plastics, contain natural gas as an essential ingredient. In other products, such as glass or steel, it is a vital heat source in order to mold the products into usable shapes. In 2009, the industrial industry used 7.4 trillion cubic feet of natural gas. Eighty-one percent went to six key industries: chemicals (twenty-nine percent), petroleum & coal products (fourteen percent), primary metals (eleven percent), food (eleven percent), nonmetallic mineral products (eight percent) and paper (eight percent). Thus, some businesses cost models can be entirely based upon the economic price of a barrel of oil or BTU of natural gas. Natural gas's place within the industrial sector is a large opportunity for companies to take advantage of cleaner burning, more economical hydrocarbon. Yet overall, its use comparatively declined during the recession. Fortunately, this parallels a renewed focus on cost reduction and overall efficiency rather than a declination of overall use. For example, when prices rise, natural gas use decreases as companies look to cut back on an expensive resource. This price elasticity signals efficiencies in operations and innovation and will foster innovations in industrial and process heating manufacturing (MIT, 2013).

Electric power generated from natural gas is the fastest growing and most important sector in which natural gas is used. In 2009, twenty- three percent of the total power generated came from natural gas producing plants. These plants also represented forty percent of the total generating capacity in the United States. There is increasing opportunity in this sector that coincides with an increasing ability to utilize capacity and storage of natural gas. The ability to extract natural gas from the ground quicker and more efficiently has pushed the overall cost of production down, while also allowing lead times to be better forecasted and optimized. This optimization is heavily reliant on the maturing pipeline infrastructure. Without this infrastructure, moving gas from the deposit to the trucking or rail location would cause the range of use to be more limited. Another large driver is the increasingly stringent policies regarding

CO2 emissions. As the cleanest burning hydrocarbon, natural gas has made coal based electric generation obsolete. According to MIT's study, the most effective way at reducing C02 emissions in the power sector is through this evolution. Currently, there is an underutilization of natural gas electric plants due to a construction boom in the 1990s meaning that natural gas already has the capacity to be a bigger player in the industry. At the low cost of less than $20/ton, the power sector could reduce CO2 production by twenty percent and reduce the amount of other noxious chemicals (MIT, 2013). Companies like ExxonMobil have significantly invested within this sector of the market because of its growth. According to ExxonMobil, global electricity demand is expected to grow by sixty-five by 2040. In reaction to such demand, ExxonMobil recently bought XTO Energy for $41 billion and entered to joint ventures in both Qatar and Australia in anticipation such growth (Exxon 2016; Dorsey 2016).

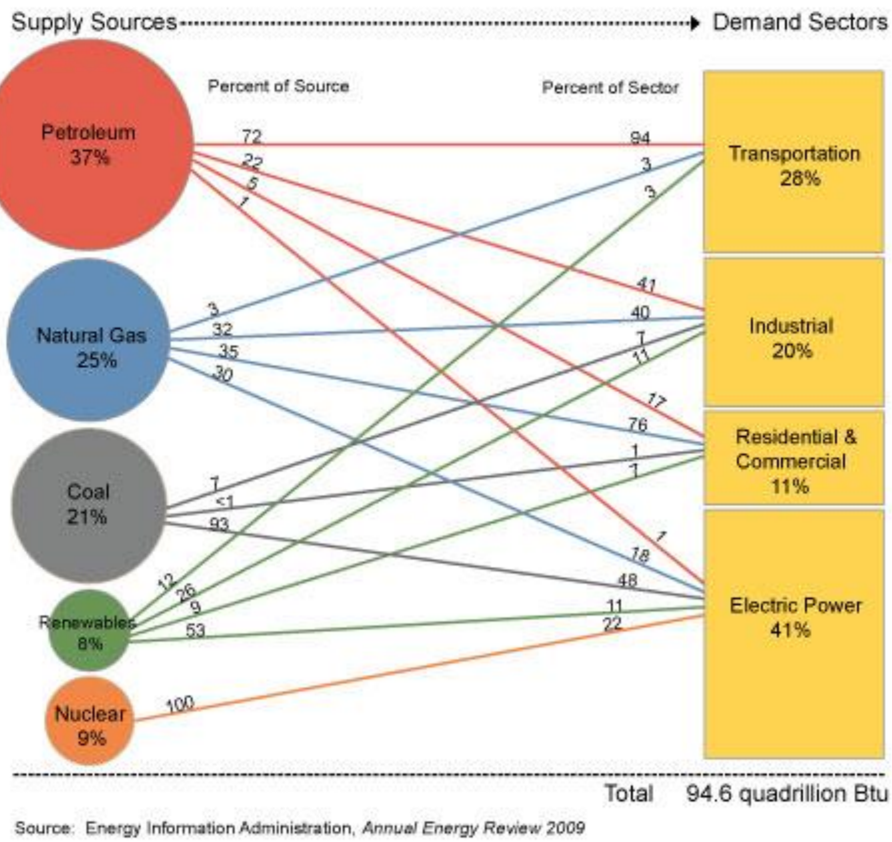


Figure 9: 2009 United States Energy Breakdown

Similar to electricity production, the residential sector also is a source of opportunity in reducing CO2, and optimizing efficient use. According to Figure 9, thirty-five percent of natural gas consumption in 2009 is used by the residential/commercial sector to heat many residential homes and businesses, especially in the colder regions of the United States. The residential/commercial sector is regarded as the most practical for the use of natural gas, as lighting, water heating, appliances, heat and electronics can all be powered by this one resource. Yet overall, this sector is slightly more volatile than the others are because sales are largely associated with weather conditions. In 2013, for example, residential use decreased about twenty-one percent compared to other economic sectors. Volatility in the market makes it difficult for companies to ensure consistent growth within this sector. Buildings and contractors are beginning to use various technologies to incorporate the burgeoning resource into construction. For example, new heat pumps that can act as both a heater and an air conditioner have optimized electricity and natural gas in mild weathered areas. Innovations like this further natural gas's place within the home and business utility and will continue to play a major role within the market (MIT, 2013).

The newest and least developed use of natural gas is within the transportation sector. In order to expand the role of gas in this sector, the two core logistical challenges must be met: storage and capacity. Petroleum dominates the transportation industry because of the ability to store, package and distribute a liquefied resource. However, as the ample supply of gas continues to grow and the price continues to dip, interest in two forms of natural gas called compressed natural gas (CNG) and liquefied natural gas (LNG) has grown. As of 2009, 94% of the transportation uses petroleum, while only 2.6 percent use natural gas. Transportation also generates a third of the United States total emissions. A fact that the United States government has been targeting in its efforts to better help the environment. These two economic and environmental drivers could make natural gas more viable in the future (MIT, 2013).

Today, there are about eleven million natural gas powered vehicles (NGVs) on the road worldwide. Of those eleven million vehicles, 99.9 percent are CNG vehicles comprising of one percent of the total world vehicle population. The current market breakdown for NGV's is ninety-five percent light cars and trucks, three percent busses and two percent heavy-duty trucks. Most markets that use NGVs do so because of governmental support and therefore are located in places like Brazil, Pakistan and Argentina. Within the United States, there are only about 100,000 light-duty CNG vehicles (MIT, 2013).

CNG vehicles are the most widely used form of natural gas transportation in today's market. A chief reason for CNG use is because CNG engines are quite similar to those that use petroleum. Using a spark-ignition, CNG vehicles store natural gas in large high-pressure tanks to achieve the correct amount of density needed to power the vehicles. CNG tanks are much larger than gas tanks achieving a range only about twenty five percent that of gasoline. Thus, significant investment must be made to both the vehicle and fuel infrastructure. A benefit of CNG vehicles is that their CO_2 emissions during usage are about seventy-five that of gasoline. Yet, this number is strictly during usage and does not factor the full sustainable cost of ownership neglecting the CO_2 emissions produced during the production and distribution (MIT, 2013).

The current market for CNG relies on short, range heavy-duty vehicles. Urban busses, delivery trucks, and government vehicles have significant opportunity to utilize natural gas efforts because their high mileage operations can achieve significant fuel cost savings. At the current market price, CNG is substantially cheaper than gasoline (around fifty percent). However, the vehicles must be equipped with the needed modifications in order to use this resource requiring higher upfront costs. Fleet operations thus could see beneficial economies by ordering in bulk and bringing payback time down. Fleet operations (i.e. busses and garbage trucks) would also see benefit in the delivery of natural gas to its area of operations, whereas a typical consumer would find it much harder to get economies of scale. According to MIT's Future Energy Initiative, the payback time for short range, heavy-duty vehicles is around three years or less making it a viable economic option moving forward for businesses. Consumers wishing to buy CNG cars will have a much more difficult time. Currently, the Honda GX is the only factory made CNG vehicle in the United States and has an incremental cost of $7,000, not to mention the logistical challenges of purchasing the CNG itself when fuel depletes. The United States lacks the aftermarket conversion structure that Asian and European countries have in place to make CNG vehicles viable for the common consumer. Regulation and certifications from agencies like EPA have made it difficult to bring these cars to market. This legislative challenge will remain important if CNG vehicles hope to achieve any market penetration on the consumer market (MIT, 2013).

Liquefied natural gas poses the most unique market potential for natural gas of all its applications. Undoubtedly, the most pressing need for natural gas sustainability is to reduce CO2 emissions within the transportation industry and overall carbon footprint. It is widely believed that LNG could provide an interesting alternative to diesel and petroleum based operations. LNG is created by treating natural gas at a facility in which freezable components, like water and CO2 are removed from the gas. After removal, the composition is frozen at -162 degrees Celsius to leave mostly (if not all) methane. This new form is $1/600^{th}$ the volume of the original state of natural gas but must be maintained at this low temperature in order to be transported or stored. In order to use LNG, a truck or vessel must have a very large double-walled tank maintained at a temperature at -162 degrees Celsius. Over time, the liquid within the tank warms and the pressure releases. This process usually lasts about a week requiring LNG vehicles to refill a fair amount when compared to other fuel sources (MIT, 2013).

While the challenges for production and maintenance have hindered the development of LNG on a global scale, there are numerous obtainable benefits from the energy source. First, on a per tank basis, LNG provides two and half times the energy that CNG can provide and sixty percent of what diesel can provide. This makes it beneficial to explore its potential in the high stakes, constantly changing transportation industry. Margins are low, and regulation is only increasing, making fuel exploration unavoidable for all logistics providers (MIT, 2013). Greenhouse gas emissions for LNG are higher than CNG because of the liquefaction process, but still provides a ten to fifteen percent decrease versus diesel fuel. Sooner rather than later, legislation will push the breakeven point more in favor of CO2 reduction making natural gas even more attractive. Drayage vehicles in Long Beach and Los Angeles have shown that LNG applications are available in the market (MIT, 2013). However, LNG's major market opportunity is as a potential replacement for long-haul trucks and bunker fuel for overseas and maritime operations (Loveland, 2014).

Overall, LNG trucks is an area of opportunity for logistics providers moving forward. However, three serious supply chain challenges have made it hard for LNG to be a practical solution for the trucking industry. The primary issue relates to fixed cost. In an industry where the level of a competition is great, higher fixed costs lead to necessary price increases. If a freight provider invested in a fleet of LNG trucks, their fixed cost would increase at about $70,000 per truck. Furthermore, the salvage value of such assets is much lower than standard diesel tractors. Higher net loss makes it hard to justify such an investment in the current market. Secondly, variable costs may also increase, as there is no concrete LNG fuel infrastructure in place for long haul routes. Flexibility, therefore, would be significantly constrained until the market catches up with the technology. Lastly, reliability and service level could be compromised. Service and maintenance issues regarding LNG tanks could be much harder to remedy if there is no concrete system in place to rectify issues with cryogenic tanks. Ultimately, service level could decrease because of the immaturity of the supply chain. According to the American Trucking Association, the trucking industry is still a long way off from implementing LNG trucks on a regular basis despite high potential in the industry (MIT, 2013).

Poten & Partners recently published a study discussing LNG citing that, "The relative low price of natural gas and LNG compared to current high residual bunker and distillate fuel prices in the U.S and Europe has added to the attractiveness of LNG as an alternative marine fuel" (Adamchak, 2015). One massive market trend is impending regulation regarding emissions. While the specifics will be discussed in the next chapter, it should be noted that environmental regulation is a large catalyst for cleaner burning fuels. For example, the International Maritime Organization called for sulphur reductions on a global basis effective by 2020. Thus, there has been large investment and exploration in the development of bi-fuel and tri-fuel energy sources. These chemical mixtures of hydrocarbons are created by synthesizing natural gas with diesel and other carbons to form cleaner burning solutions like methanol, ethanol and dimethyl ether as shown in Figure 10. These prospects are intriguing because they can change according to the fueling infrastructure (i.e. tankers and carriers or high-performance Indy 500 cars) and actually produce higher efficiency and lower CO_2 (MIT, 2013).

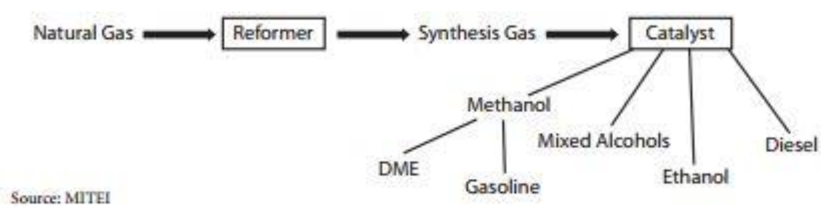


Figure 10: Gas Synthesis Diagram

In the case of maritime transport, many experts see the impending sulphur regulations and the low price of natural gas as an opportunity to reevaluate their supply chains and gain competitive advantage. While bunker fuel is incredibly cheap, natural gas has already begun limited market penetration with fifty LNG powered ships in use or on order. If natural gas is to continue its penetration, which is less than one percent, LNG infrastructure including liquefaction plants and refueling hubs will have to become more commonplace at major ports within the United States. Globally, LNG has had greater success with Chinese ports and European ports like Antwerp building sophisticated LNG infrastructure. In addition, TOTE Inc. just built the first LNG powered containership in San Diego investing $350 million in the project exhibiting the high capital needed to move to LNG powered ships. The maritime industry is the prototype for other industries looking to capitalize on the gas boom. LNG vessels are expected to grow to almost 1,800 by 2020. More importantly, such expansion is also expected to lead to greater savings and efficiencies, which will undoubtedly permeate to other industries (Loveland, 2014; Murphy, 2016).

Global Market and Risk

It is important to analyze the macroeconomic risks of natural gas as an alternative energy source. To start, the world price controls the liquidity of the market stronger than other consumer products. Macroeconomic conditions like the relatively low price of oil and gas on the market can stagnate growth in its development. In the short term, long-term projects and infrastructure projects with long lead times (like the LNG vessel projects) are still subject to significant market risk and could be delayed or cancelled. Political regulation can redefine the industry instantly and change cost models in a matter of weeks. The energy industry as a whole is one in which revenue streams are highly volatile, and consumer and investor confidence in the long term are essential for steady growth. Competition domestically and globally is regional in nature and competes heavily against the market rather than between businesses to businesses. Consequently, risk must be hedged geopolitically and economically to ensure a continually profitable business model (MIT 2013). Natural gas's regional nature qualifies a closer look at the three global markets to determine whether gas is a worthy investment (IBISWorld, 2016).

The United States market is the most mature of all three major global markets. It has the longest history of natural gas use, and the largest, most advanced infrastructure in the world. As a result, regulation is also the most developed within the United States. The Natural Gas Act of 1938 began the construction of America's robust, yet now outdated, pipeline network. Growth of the industry grew heavily into the 1970s under a long-term contract market, but slowed due to a belief that domestic consumption would soon surpass supply. Culminating in the Natural Gas Policy Act of 1978, price controls and ceilings were removed making the market fully transparent and much more flexible with regard to the market. Overall, the North American market is predictable and most importantly, remains self-sufficient for the most part. The North American Free Trade Agreement (NAFTA) exports gas between the United States and Canada and down to Mexico. While the United States still imports large amounts of oil and gas, its overall energy dependence has decreased due to better production. In addition, production has also spurred exports to places in Asia, like Japan and China. This has created a more integrated market and a more "liquid" energy market for North America (MIT, 2013).

The European market developed much later than in North America, operating on small quantities from the Soviet Union, Netherlands and Africa for much of the 20th century. Its development was even further hindered by a poor decision to tie the price of natural gas to the crude oil price during the Organization of the Petroleum Exporting Countries (OPEC) oil embargo. Europe's pipeline infrastructure never properly developed and thus the market still operates on imports from Russia and North Africa. Countries like Spain also utilize LNG imports because of their unfortunate position in relation to the Russian pipeline. These elongated supply chains and feeble infrastructure create an energy scarcity that significantly affect public policy and energy utilization. Energy diversification in Europe is not only a competitive advantage; it is a national security priority. Prior to the development of the European Union, regulation created significant issues from country to country, and pressed the need to have a more flexible energy policy. In 1998, the EU sought to create an internal natural gas market that led to mild developments of a spot market. However, Europe continues to struggle with energy dependence and will need to investigate energy solutions (MIT, 2013).

The third market, industrialized Asia, does not have conventional natural gas resources in proximity making them increasingly dependent on LNG imports from the Middle East, North America, Southeast Asia and Australia. China specifically, imports high amounts of LNG and has lowered the price internally to establish a price advantage for LNG within the domestic market. As the market dictates, the scarcity of supply places high premiums on natural gas as a resource. The market structure hence is still in an infant form and relies on contracts to ensure a continual supply to meet demand. Yet, like Europe, Asia struggles to optimize natural gas because it pegged to the price of oil. The reason this curtails optimization is that oil does not signal natural gas delivery, price and consumption, which are three key components for efficient use. In order to remedy this, Asia, like Europe, will have to develop a more flexible value chain and establish a spot market for natural gas to better allocate development contracts (MIT, 2013).

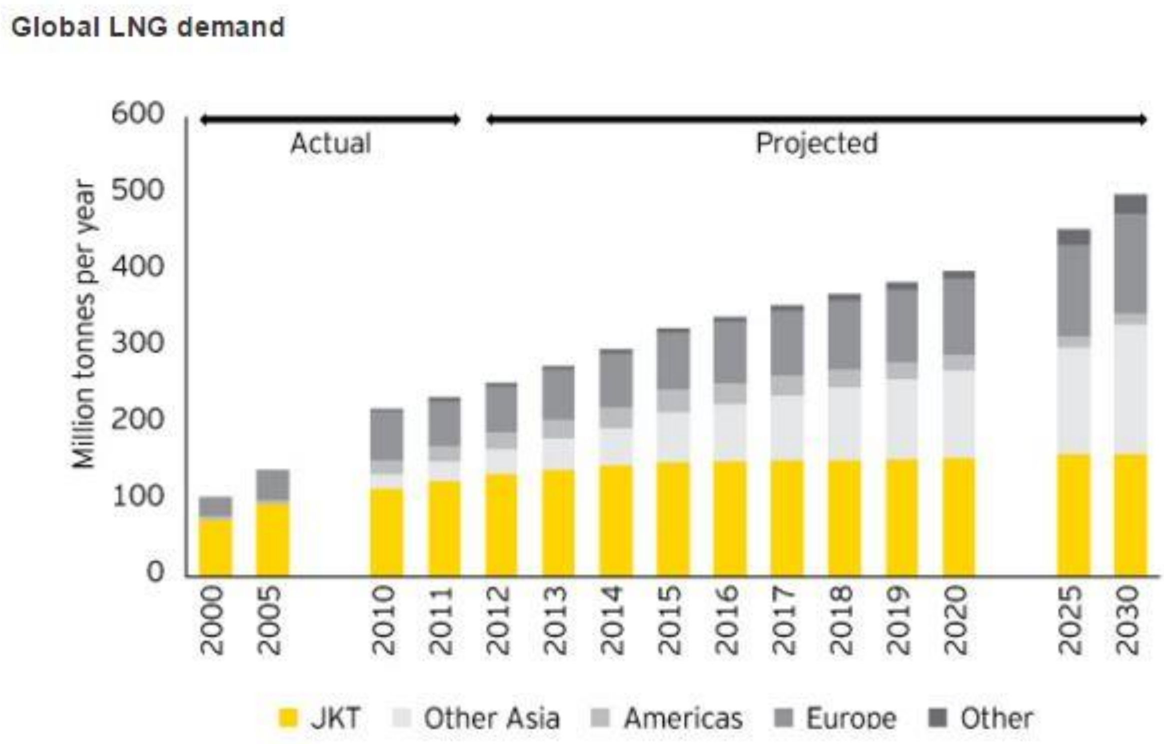


Figure 11: Projected Global LNG Demand

Overall, the macroeconomic environment of energy is increasingly complex as emerging markets continue to grow. Shown by Figure 11, forms of natural gas like LNG are poised to grow in the global market. In doing so, countries will need to provide more liquid environments for energy in order to better optimize capacity. Taxes, tariffs and subsidies can increase operational fees and hinder development because of the relatively ample supply. In order for natural gas to grow it will need to continue to reduce production costs to provide incentive to switch from crude oil and petroleum (Byers, 2015).

Chapter 4: Sustainability

How Is Sustainability Measured

The most pressing issue around natural gas, and around all hydrocarbons for that matter, is whether or not they are sustainable. Being sustainable means optimizing energy output in the most energy efficient way. Of the hydrocarbons, empirical evidence has shown that natural gas is the most sustainable. Yet, from a practical standpoint it has more challenges because of its chemical composition. Global and domestic regulation is putting greater emphasis on the carbon footprint. A business's carbon footprint entails its carbon emission from end to end within the supply chain. In order to analyze this, metrics regarding emissions need to be defined and measured. Furthermore, an understanding of different parts of the value chain and their effect on emissions will be of paramount concern in the near future (Berners-Lee, 2010).

The key metrics that the energy industry is beginning to use to measure sustainability include greenhouse gasses (GHGs), CO2 emissions, and carbon footprint. In the energy industry, especially with regard to hydrocarbons, greenhouse gasses play a major role in the production and profitability for the industry. Governmental caps on emissions are becoming more stringent pushing the industry to adapt more to policy. In 2014, the oil and gas industry totaled direct emissions of 3.2 billion metric tons of carbon dioxide equivalent (CO2e), which was about half of the total GHG emissions within the United States (Berners-Lee, 2010). This information, directly from the EPA, comes from 8,080 facilities in nine different industries. Power plants accounted for 2.1 billion metric tons and petroleum and natural gas systems attributed 236 million metric tons, respectively. GHGs encompass all of the different pollutants that are released into the atmosphere including methane (CH_4), nitrous oxide (N_2O) and sulfate (SF_4). However, CO_2 emissions remains the key metric under surveillance because it accounts for almost all of GHG emissions. For example, Figure 12 illustrates that CO_2 accounted for 91.5 percent of GHG emissions in 2014, an eight percent increase from the previous year. While CO_2 emissions primarily come from power generation, methane conversely comes from the gas and oil systems themselves in production, refineries and in distribution. This accounts for a much smaller portion of emissions at about seven percent. Potency can also play a role into the impact of greenhouse emissions. Analysis of methane and nitrous oxide has revealed a serious concern about even these smaller produced GHGs. Methane is twenty five times more potent than carbon dioxide and nitrous oxide is 300 times as potent. The worst of all, refrigerant gases, can be up to several thousand times more potent. This impact must be studied in a slightly different way to account for a total picture into carbon usage (Schenk, 2016; Berners-Lee, 2010).

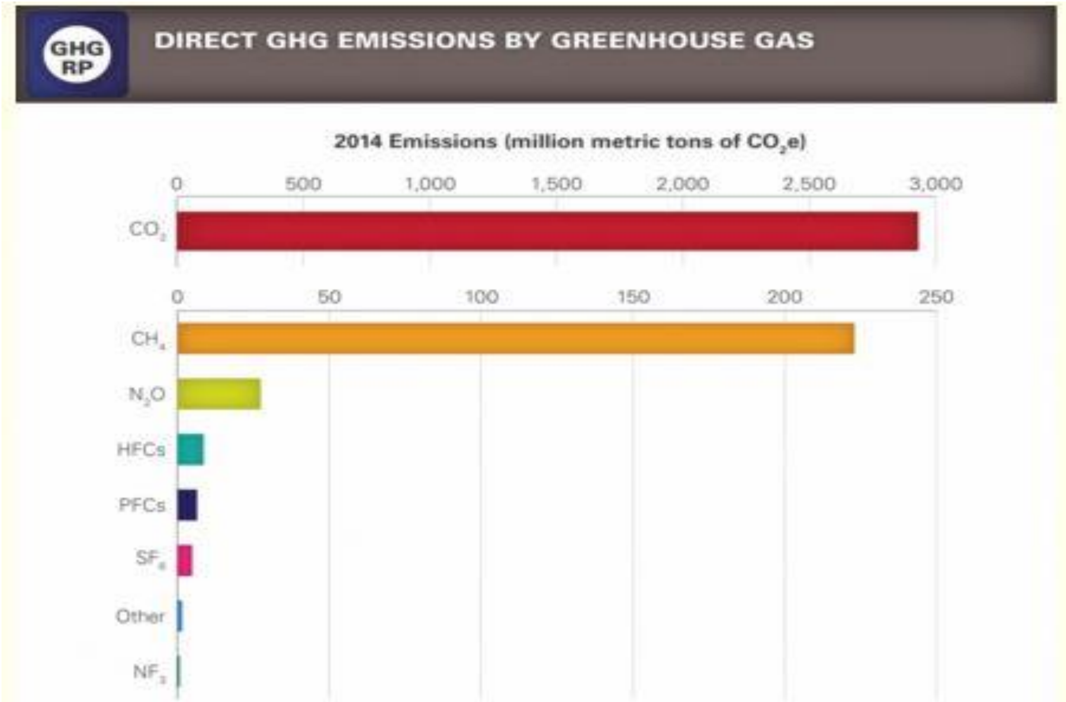


Figure 12: 2014 GHG Emission Breakdown

The metric that has been derived in an attempt to account for total environmental impact of someone or something is known as a carbon footprint. While there are other sustainability metrics, and the carbon footprint is by no means a perfect metric, it is beneficial that a carbon footprint resembles the structure of a calculated total cost of ownership and total landed cost within the supply chain. For example, the carbon footprint of producing a car includes its emissions during use but also how it was produced and brought to market. It includes the emissions emitted during the production process and even as far back in the value chain as the extraction of raw materials. This total emission perspective makes it nearly impossible to give an exact carbon impact but it provides insight as to trends and benchmarking opportunities. Most importantly, it is a way to account for indirect emissions within the supply chain (Berners-Lee, 2010).

Why Sustainability?

Social and economic drivers pressure businesses to consider inefficiencies in their supply chain and ways to add value for their customers. Additionally, in today's current market, trends have shown that sustainability is becoming an obligatory part of the supply chain as a whole. Regulation and competitive advantage are the key catalysts driving innovation within the natural gas industry. The more the industry grows, the more competitive and complex (with regards to the market) the industry becomes. Moving forward, companies must all take steps forward with regard to the environment in order to stay competitive in the market (IBISWorld, 2016).

Chapter 5: Regulation

Regulation and government legislation is the primary reason for sustainable initiatives within the energy sector. The domestic energy market is a highly regulated industry and will be even more regulated in coming years. Better information regarding climate change and environmental impact has pushed greenhouse gas emissions into the forefront in society and in the consumer market. Each of the following pieces of legislation significantly affected the way natural gas is produced, distributed and utilized within the United States and each serves as major example of how regulation has shaped the gas industry.

Clean Air Act

The Clean Air Act of 1970 established a precedent of greenhouse gas legislation within the United States at the federal level. It was one of the first environmental acts in the United States to regulate greenhouse gas emissions in an attempt to control air pollution. Its general purpose was to set goals and standards for air purity within the United States. Targeting businesses and industries like transportation, the clean air act pushed states to pass implantation plans to track and reduce emissions. In 1990, the Clean Air Act was significantly amended to combat four major environmental concerns: acid rain, urban air pollution, toxic emissions, and stratospheric ozone depletion. Concerning natural gas and business, this act made businesses within the energy sector environmentally conscious and accountable for emissions thus increasing the value of more sustainable practices. It also fortified the notion that sustainable initiatives had economic value, in this case a projected $2 trillion in savings by the year 2020 (EPA, 1990).

Energy Policy Act

In August of 2005, President George W. Bush signed a bill called the Energy Policy Act of 2005. The Energy Policy Act was particularly important for the domestic energy market because it permitted the United States government to provide significant tax breaks and loan incentives throughout the energy industry. At the time, the United States dependence on foreign fossil fuels was a major national concern and a top priority of the Bush administration. The act effectively bolstered all facets of United States energy production. Although much of the benefits and focus was on nuclear power, the fossil fuel industry also benefitted greatly. The act reduced taxes by $2.8 billion for fossil fuel production allowing companies to produce more at lower rates and spur domestic production. Next, it also targeted the transportation industry by requiring a higher amount of biofuel be added to gasoline each year. A statute of this nature, plus a $1.3 billion tax break for the alternative fuel industry, made liquefied natural gas a more economical prospect and a possible future alternative. Lastly, the act included a substantial omission regarding natural gas extraction, which provided substantial leverage for the industry. The Energy Policy Act exempted fluids used in hydraulic fracturing from protections within the Clean Air Act, Clean Water Act and the Safe Drinking Water Act. This exemption, known as the “Halliburton loophole,” does not requires companies from disclosing chemicals used in the hydraulic fracturing process. Today, this policy remains in effect and is often criticized by environmental advocates and legislators alike. The Fracturing Responsibility and Awareness of Chemicals Act is an example of legislative resistance to such privileges regarding the natural gas industry (NRDC, 2015). However, FRAC has yet to be passed and the fracking and shale industry still face large amounts of criticism (FERC, 2015; EPA, 2015).

Clean Power Plan

The Clean Power Plan is an ambitious power plan aimed at reducing emissions from power plants and the electric production industry within the United States. With the goal of reducing emissions thirty-two by 2030, the Clean Power Plan aims to create a partnership between states and the EPA to monitor and asses emission output regularly by establishing metrics for the electric generating units (EGUs). Each year, the EPA will monitor EGUs on an industry-wide and state basis. The states thus will have to coordinate and optimize efficiencies in order meet federal standards regarding greenhouse gas emissions. Some states have begun to optimize through emissions trading, or the ability to lower one state's standards to raise another because of the interconnected energy network. This energy strategy could potentially reinforce natural gas's importance in the market as a more sustainable and clean energy source. Moreover, it could lead to further investment in interstate infrastructure networks and pipelines expanding the potential markets for gas based energy (EPA, 2015).

Kyoto Protocol and Paris Agreement

From an international perspective, the Kyoto Protocol is one of the first significant international forms of legislation regarding sustainability and climate change. The binding international agreement primarily focuses on reducing GHG emissions on a global scale in an effort to curb global warming. Initially, twenty-eight members, many of them part of the European Union, ratified the document and committed to the first reduction period. Overall, the agreement sought to curb the carbon emissions of developed countries who had been industrialized for the longest period. Developing economies therefore had an inherent advantage in this agreement. The initial proposition did not include developing, yet enormous, economies of China, Brazil, India and Russia. This served as a point of contention for many vital carbon-based countries including the United States to refuse to commit to the agreement. While the Clinton administration signed the agreement in 1998, it was never ratified by Congress or put into effect by the Bush administration. Without the United States, the overall effect of the Kyoto Protocol was minimal at best. However, precedence and later amendments, like the Doha Amendments of 2012, incorporated countries China and paved the way for further internationally accountable legislation. Currently, the most promising form of climate legislation is the Paris Agreement of 2015. This agreement has a unique bottom to top structure that holds nations accountable by setting targets nationally as opposed to internationally. The purpose primarily is to prevent a further rise in global temperature, to provide financial assistance for sustainable practices in developing countries and reduce overall emissions without threatening food production. There are criticisms that such a system lacks appropriate enforcement or binding terms without an established governing body. Currently, every country has approved the wording of the overall agreement and President Obama has already pledged $500 million towards the "Green Climate Fund" in support of the plan. The signature period for countries and for the Paris Agreement begins in April of 2016 and will only take effect if fifty-five countries that produce at least fifty-five percent of GHG emissions ratify and accept the agreement (UNFCC, 2014; Davenport, 2015).

Regulatory Bodies and Safety

Because natural gas is a heavily regulated industry, it requires a substantial federal body to oversee it. The Federal Energy Regulatory Commission (FERC), the modern equivalent of the Federal Power Commission, oversees rates and economies related to interstate energy production, transportation and distribution. The pipeline infrastructure and its rates, the electric power rates, the LNG terminals, and licensing all falls underneath the jurisdiction of FERC. Because of this, the federal government is heavily involved in the natural gas industry working in both conjunction and sometimes opposition to major companies within the industry. For example, FERC is actively working with Canadian officials to build a profitable Alaskan pipeline for the United States market. On the opposite side, it also seeks to prosecute companies or entities attempting to manipulate rates within the market (MIT, 2013; Revkin, 2016).

In the past decade, a primary environmental concern that FERC, the Department of Transportation and businesses have had to address is the issue of pipeline and infrastructure safety and environmental contaminations. Leakage, water contamination or exploding pipelines are just some of the serious safety concerns regarding natural gas. Leakage remains an incredibly high environmental concern because it impacts ecosystems, water supply, property and potentially life. When natural gas is leaked, two potential risks can severely affect the area around them (MIT, 2013).The first is carbon monoxide. Carbon monoxide poisoning can pollute water supplies and can causes death among those who are exposed for too long. As a gas, a leak may not be seen but rather smelled or inhaled making risk of detection more difficult (PUCO, 2016). The other potential risk, an explosion, can be caused when too much gas is confined to one area and pressure and flammability ignites the gas. Such explosions are rare but can be extremely dangerous and hazardous. While these risks are quite pronounced, there are more subtle risks to natural gas. Many environmental concerns come from the premise that an undiagnosed leak or difficulty of capping such a leak make natural gas a risky investment for the environment. Hydraulic fracturing has the potential to be and to certain extent already is a problematic environmental concern for property owners and citizens located in close proximity to shale and unconventional natural gas drilling sites (MIT, 2013). As a drilling company drills deeper and further outward in the earth’s crust (using undisclosed chemicals), the potential risk for exposing uncaptured natural gas into the environment or water supply increases. However, distribution pipelines account for eighty-six percent of serious pipeline incidents compared to gathering pipeline systems at the point of extraction, which only account for one percent of incidents. Therefore corrosion in the distribution network, third party collisions (i.e. hitting an unseen pipe), or construction defects are all more probable causes of unwarranted leakage. Corrosion specifically is a paramount risk since according to the DOT, twenty-five percent of natural gas pipelines are over fifty years old. Distribution pipes are also smaller and more complex as a system as they are located closer to urban centers and crowded areas (MIT, 2013).

Recently, governing bodies are becoming more aware of pipeline safety. In 2003, the DOT implemented a rule for operators to test pipeline safety. However, in 2010, ten people were killed in a gas explosion in California. Tragedy therein signifies that natural gas is not without its risks and the infrastructure it relies on is heavily tied to its safety within society. Legislation and regulation continually force innovation and maintenance on an expansive domestic and global network. This incurs a cost. Between the DOT and the industry as a whole from 2002-2013, $72 million was spent on technology for pipeline safety. This number is likely to grow as production and investment increases. Therefore, sustainability is a mandatory variable cost ultimately affects the bottom line on an annual basis (MIT, 2013).

Chapter 6: Sustainable Advantage in the Supply Chain

Like most components of the value chain, cost and financial motivations play crucial roles within the formation of a sustainable supply chain. In recent years, sustainable supply chains have become not only a mandatory regulatory or goodwill initiative but also a financially pragmatic solution to the growing complexities of today's supply chain. Globalization has made the need for differentiation and competitive advantage imperative for profitability in the global market and an essential part of adding dollars to the bottom line. Investor relations, the ability to meet demand, increased operational efficiencies and lower cost and goodwill are all substantial benefits for sustainable investment for natural gas and all industries.

First, sustainability provides a significant financial advantage. In 2012, Pricewaterhouse Cooper published a market report regarding financial investment in sustainable projects. Some of the key findings included significant investor interest regarding the sustainability of value-added projects, demand and middle class especially within emerging markets is likely to expand the role of sustainability, and sustainable companies tend to do better financially (PwC, 2012). Nearly one out of eight dollars, under professional management in the United States, is part of sustainable investing. The enormity of recent investment is based on the predilection of investors that sustainability adds both value and dollars to the bottom line. Thus, sustainable companies tend to see more investment if they are attempting to be "green" or "sustainable". Moreover, in 2011, 285 institutional investors urged governments to accept binding international treaties on climate change realizing the interconnection between economies and the environment. Commodity prices are likely to rise, they argue, due to the expanding middle class of emerging markets and their energy, water and food demands. Gas demand, the study says, will increase seventy one percent by 2036. Investors contend that sustainable companies will best be able to meet these growing challenges (PwC, 2012). Finally, according to a new Harvard Business School report, companies that engage in sustainable projects, especially for growing commodity networks like energy, "tend to have better stock performance, lower volatility, and greater return on assets (ROA) and return on equity (ROE)" (PwC, 2012) Sustainability allows companies to better engage within the entire supply chain from extraction to the end user. For natural gas giants, like ExxonMobil and Halliburton, utilizing this information allows them to better optimize efficiencies in distribution and achieving better understanding consumption patterns in a variety of sectors. Overall, natural gas companies will need to utilize effective financial investment and smart use of capital concerning sustainability to best optimize growth (ExxonMobil, 2016)).

The most important competitive advantage for natural gas and the energy industry is that energy sustainability provides a significant operational advantage. From bottom line cost to overall production, sustainability provides a key opportunity for the industry. According to the MIT Sloan Energy Initiative, natural gas has significant opportunity for better efficiencies because unlike oil, "the total cost of delivering gas to international markets is strongly influenced by transportation costs" (MIT, 2013). Transportation, whether through pipelines or through motor carriers, remains a high variable cost. This cost can be lowered by optimizing pumping and extraction technologies around the pipeline infrastructure. At the point of extraction, reducing well emissions and placing extra detection and capture technologies currently has a payback period of three to eight months according to the MIT study. One example is in the Bakken oil fields in North Dakota. In July of 2014, the Bakken gas fields were failing to capture thirty percent of the one billion cubic feet of gas produced each day. This loss, attributed to the lack of infrastructure, amounted to almost $50 million a month. In order to become more efficient, companies like General Electric are pairing with service providers to construct methane capturing storage sites that convert methane into reusable CNG. These sites, built in conjunction with extraction wells, can be used to power the drills and wells of the site thus becoming more sustainable. According to GE, this "last mile" logistics process can have potential savings up to fifty percent when compared to diesel fueling (Dodge 2015).

Other natural gas companies are also making significant strides in energy sustainability by looking at their own energy consumption when producing energy at the source. ExxonMobil's Global Energy Management Systems track and benchmark emissions data all across their upstream processes from refinement to production. A prime example of a potential carbon footprint metric, this data was used to implement projects like Cogeneration, which was designed to capture heat when electricity was produced. This captured heat is used as energy in other parts of the value chain like in chemical processing and helped some plants achieve up to eighty percent efficiency. Currently, Exxon has more than thirty Cogeneration sites bolstering both investor confidence and bottom line benefits (ExxonMobil, 2016).

The last advantage is related to the market idea of goodwill. Businesses and consumers are recognizing the importance of being sustainable and the risk of neglecting the environment. The Deepwater Horizon Oil Spill, also known as the BP Oil Spill, caused catastrophic environmental damage that it still being felt in 2016. Ten oil workers died among the countless animals and marine life that also were killed. From an economic perspective, this meltdown caused BP's stock price to drop fifty-five percent on top of the court and damage damages that continues to grow in the tens of billions of dollars. The natural gas and energy industry have more responsibility than most industries to stay sustainable. While consumer goodwill does not necessarily affect companies at the retail level, it remains a vital component of overall business strategy and financial performance (Chamberlin 2014; NYSE 2016)

Conclusion

Due to substantial changes in the past decade, natural gas has reshaped both its short term and long-term viability. Primarily, the growing abundance of the domestic natural gas supply has made it a cheap and available resource. Technological improvements, such as hydraulic fracturing and horizontal drilling, have greatly expanded the United States ability to drill deeper and utilize unconventional forms of natural gas. The shale gas boom and expansion of production has already changed how it is utilized within the market. Electric power generation, for example, continues to expand over other carbon-based fuels such as coal. The ability of natural gas to burn cleaner and reduce CO2 make it economical in the short term for business. More importantly, impending legislation and continued growth make its long-term prospects also more viable. Sustainability, and the ability to measure it, remain critical to be able to justify a switch to natural gas. If there is continued research into infrastructure, CNG and LNG transportation applications and sustainable practices, natural gas could continue to see meteoric growth in the next decade. Eventually, even natural gas will need to be replaced. However, what natural gas can provide in terms of sustainability make it a viable solution in the short term while society waits for the creation of a truly sustainable fuel source. Continued advancement of natural gas will help bring industry down the path towards a more sustainable future.

Appendix

Notes:

U.S. Natural Gas Marketed Production (Million Cubic Feet)

Decade	Year-0	Year-1	Year-2	Year-3	Year-4	Year-5	Year-6	Year-7	Year-8	Year-9
1900's	128,000	180,000	206,000	239,000	257,000	320,000	389,000	407,000	402,000	481,000
1910's	509,000	513,000	562,000	582,000	592,000	629,000	753,000	795,000	721,000	746,000
1920's	812,000	674,000	776,000	1,025,000	1,162,000	1,210,000	1,336,000	1,471,000	1,596,000	1,952,000
1930's	1,978,911	1,721,902	1,593,798	1,596,673	1,815,796	1,968,963	2,225,477	2,473,483	2,358,201	2,538,383
1940's	2,733,819	2,893,525	3,145,694	3,515,531	3,815,024	4,042,002	4,152,762	4,582,173	5,148,020	5,419,736
1950's	6,282,060	7,457,359	8,013,457	8,396,916	8,742,546	9,405,351	10,081,923	10,680,258	11,030,248	12,046,115
1960's	12,771,038	13,254,025	13,876,622	14,746,663	15,546,592	16,039,753	17,206,628	18,171,325	19,322,400	20,698,240
1970's	21,920,642	22,493,012	22,531,698	22,647,549	21,600,522	20,108,661	19,952,438	20,025,463	19,974,033	20,471,260
1980's	20,179,724	19,955,823	18,582,001	16,884,095	18,304,340	17,270,223	16,858,675	17,432,901	17,918,465	18,095,147
1990's	18,593,792	18,532,439	18,711,808	18,981,915	19,709,525	19,506,474	19,812,241	19,866,093	19,961,348	19,804,848
2000's	20,197,511	20,570,295	19,884,780	19,974,360	19,517,491	18,927,095	19,409,674	20,196,346	21,112,053	21,647,936
2010's	22,381,873	24,036,352	25,283,278	25,562,232	27,336,644	28,809,310				

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Transportation & Distribution Intern May 2015 – Aug. 2015
- Led a Transportation Analysis Project to identify savings opportunities regarding domestic carriers
- Devised a unique strategy for validating savings opportunities leading to over $50,000 in savings opportunities
- Developed, presented and executed a SharePoint workflow process reducing freight payment cycle time by 25%
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VWR International LLC, Operations Management Bridgeport, NJ
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- Redesigned a Distribution Center Inspection Program leading to a 2% decrease in shipping errors.
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Delta Sigma Phi Fraternity State College, PA
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