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Understanding the Marcellus Shale Supply Chain

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Pitt Business Working Papers

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Pitt Business Working Papers - 2012

Understanding the Marcellus Shale Supply Chain

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Abstract:

Understanding the Marcellus Shale Supply Chain examines the overall supply chain as it currently exists for the Marcellus Shale development, principally located in and around Pennsylvania. This study seeks to fill a critical information gap on the nature of the supply chain, derived from the drilling and extraction of natural gas from Marcellus Shale geologic deposits. The study first looks at the macroeconomics of the natural gas market, the major components of the supply chain, and an analysis of supplier characteristics, resources, and best practices. Our analysis is based on extensive field research and interviews, as well as information gathering from a number of publicly available sources.

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1 Executive Summary

This project examines the overall supply chain for the Marcellus Shale development, principally located in and around Pennsylvania. This study seeks to fill a critical information gap on the nature of the supply chain, derived from the drilling and extraction of natural gas from Marcellus Shale deposits. The study first looks at the macroeconomics of the natural gas market, the major components of the supply chain, and an analysis of supplier characteristics, resources, and best practices. Shaun Seydor, Associate Director at the Institute for Entrepreneurial Excellence at the Katz Graduate School of Business, and Pitt Business Adjunct Professor Oda Bolden, led a Pitt student group of researchers in this analysis of the supply chain. Partnering with industry experts through interview, insight, and learning, the students were able to uncover many critical elements of the supply chain itself, as well as opportunities and support programs for supplier entry and education.

Our goal with this study is to provide a realistic picture of the current supply chain for natural gas drilling in Pennsylvania, primarily to provide information to small businesses and manufacturers. Section 2 provides a brief background to the Marcellus Shale industry and the critical issues that must be considered in the supply chain. Section 3 looks at the demand side of the natural gas industry, to first quantify and understand the components of the macroeconomic cycle. Section 4 addresses each major section of the supply chain, covering from exploration to natural gas marketing. Next, Section 5 looks at supply chain needs, including industries, selection practices, and supplier support. Section 6 wraps up by summarizing critical takeaways for the Marcellus Shale supply chain.

2 Industry Overview

The United States oil and gas business has increasingly concentrated on shale in recent years. With technology improvements, including horizontal drilling and hydraulic fracturing techniques, economic recovery of huge natural gas deposits in shale rock formations has become commonplace in the last decade. The Marcellus Shale formation, located in Pennsylvania, New York, Ohio, and West Virginia, is one of the largest such shale formations in the world, covering more than 95,000 square miles. The heart, or so called 'fairway', of this play resides within Pennsylvania, stretching from the Southwest to the Northeast, covering nearly two-thirds of the Commonwealth. With such a world-class opportunity present and available, in the form of economic viability, fiscal recovery and sustainability, and immense job creation and infrastructure improvement, careful consideration of all issues is being pursued in this high-stakes discussion. According to a report by IHS Global Insight, "shale gas, by September 2011, had reached 34% of total US natural gas production. By 2015, that share will grow to 43% and will more than double, reaching 60%, by 2035. Also, nearly $1.9 trillion in shale gas capital investments are expected between 2010 and 2035. In addition, during 2010, the shale gas industry supported 600,000 jobs; this will grow to nearly 870,000 in 2015 and to over 1.6 million by 2035" (IHS, 2011). Many supply chain opportunities exist due to both direct and indirect economic effects of Marcellus Shale exploration, and those opportunities represent the focus of this research.

Pennsylvania lies within the vast majority of the Marcellus Shale geologic formation and includes its most abundant and resource-rich areas. Recently, the U.S. Geological Survey (USGS) has raised its estimate of natural gas resources in the giant Marcellus Shale gas formation, concluding that the undiscovered technically recoverable natural gas resources could range "from 43 Tcf to 144.1 Tcf, representing probabilities of 95% and 5% respectively. Its mean estimate represents a probability of 50%" (O'Neil, 2011). Such estimates can contribute to the formation of numerous employment and supply chain opportunities. With this abundance of local gas reserves, many ancillary industries may be developed too, including plastics, glass, fertilizer, natural gas vehicles and fueling station infrastructure, natural gas power plants, and many others. This is no more evident than in the recent announcement that Royal Dutch Shell will analyze construction of an ethane cracker plant in Monaca, PA, at an estimated cost of more than $1 billion and creating thousands of construction jobs and hundreds of permanent jobs (Gough, 2012). The Marcellus Shale has the ability to revolutionize scores of markets in Pennsylvania.

There are wide-ranging estimates of potential job creation by several different resources. By 2020, the Marcellus Shale natural gas industry will have created or supported 212,000 Pennsylvania jobs, according to a Penn State projection (Toland, 2010). This notion is also shared by others within the industry. Development of Marcellus Shale natural gas could create 280,000 jobs and add $6 billion of federal, state, and local tax revenues over the next decade, according to a study commissioned by the American Petroleum Institute (Snow, 2010). Forecasted job growth will occur through three different channels: directly in the oil and gas industry; indirectly from a chain of outlays in supporting industries; and economic growth from property owners' royalties and new tax revenues and consumer spending by newly employed individuals and their families (Snow, 2010).

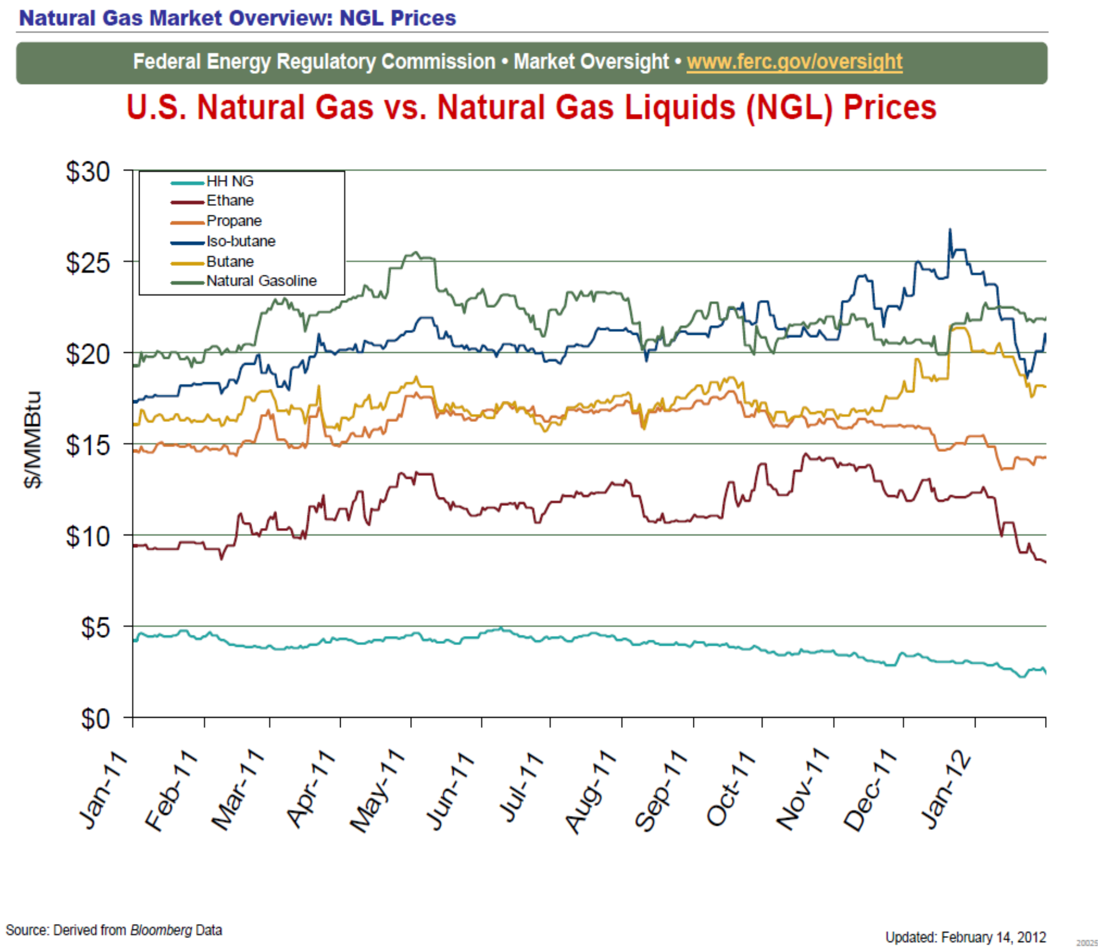
An example of these economics in action: The natural gas industry motivated Dura-Bond Industries Inc. to break ground on a $12 million facility at U.S. Steel's former Duquesne Works, President Wayne Norris said. The company coats pipe for U.S. Steel, and needed the additional capacity to keep up with growth in the sector. "It used to be that pipe made here was not consumed here. It was a declining business, but the Marcellus Shale changed all that "(Gordon, 2012). There are changes happening on the industrial front as well. The Pennsylvania Public Utility Commission (PUC) is working to provide incentives to companies in the state supplying the natural gas industry and is evaluating railroad needs to support the industry (Gordon, 2012). The

Marcellus Shale has spillover effects in other industries, most notably construction. Recently, MarkWest Energy Partners, L.P. announced expansion plans for the Marcellus and Utica Shales that include more than 600 million cubic feet per day of additional processing capacity and 140,000 barrels per day of incremental fractionation capacity (Energy Weekly, 2012).

One fact that must be addressed, however, is that the entire industry is under varying future expectations, due to the decline in natural gas commodity prices. Natural gas prices have recently been at the lowest point in years. According to numbers by the United States Energy Information Administration (USEIA), U.S. storage facilities are holding 60% more gas than normal. This glut of natural gas supply has forced prices to drop by 59% from last summer's peak of $4.85. Gas prices in North America are expected to remain below recent levels and will remain well below petroleum prices (Bewley, 2011). Despite low natural gas prices, investment continues in shale gas exploration and production because the lower risk in these properties is offset by the lower product prices.

Because Southwestern Pennsylvania has "wet gas", meaning there are other hydrocarbons present in addition to the methane-based natural gas, such as ethane, propane, butane, and others, there is opportunity to process these compounds out and sell them on the commodities markets. So in essence, this elevates the break-even point for Marcellus Shale drilling operations in this region. When natural gas prices are depressed, these additional revenue streams provide for a more attractive investment and a stronger return, as is the case today. The following chart describes commodity prices for the various NGLs present in portions of the Marcellus Shale formation.

Figure 1: Natural Gas vs. Natural Gas Liquids (FERC, 2012)



Natural gas prices are expected to steadily rise as demand increases through traditional, emerging, and new markets. Nonetheless, reduced natural gas prices have caused a shift of focus from "dry gas" fields, located in the eastern Marcellus Shale to "wet gas" fields located in west. As macroeconomic factors such as the commodity price of natural gas, supply chain development, demand/supply side changes, and regulatory consistency are addressed, the number of Marcellus Shale wells is expected to continually rise in the coming years. This can be assessed through open permits, 5,751 of which were issued in 2011 (DEP, 2012): In the first few months of 2012, 1,160 permits were issued, signaling a consistent trend (DEP, 2012).

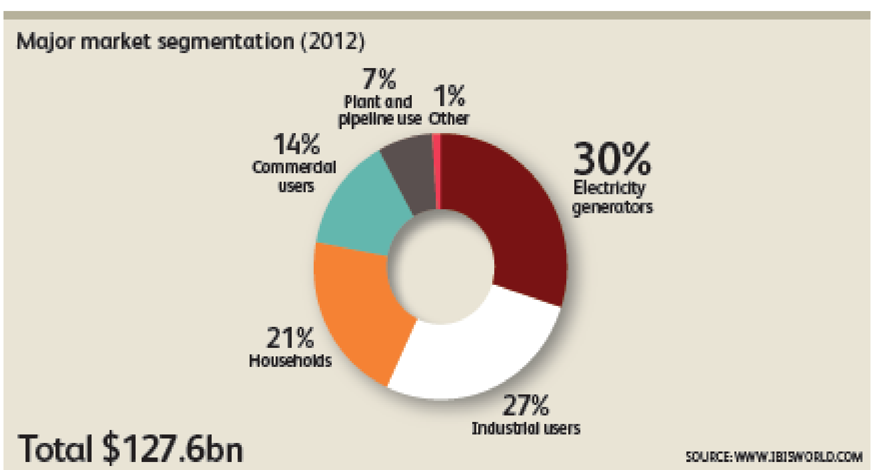
3 Macroeconomic Uses of Natural Gas

According to the USEIA, natural gas customers are defined as follows (USEIA, 2012):

- **Electricity Generation** – Natural gas used for power generation to sell electricity to the public.
- **Industrial –** Natural gas used for heat, power, or chemical feedstock at manufacturing facilities or in mining or other mineral extractions, as well as in agriculture, forestry, fisheries and construction.
- **Commercial –** Natural gas used in non-manufacturing establishments or agencies primarily engaged in the sale of goods or services, including hotels, restaurants, wholesale and retail stores, and other service enterprises.
- **Residential –** Natural gas used in private dwellings, including apartments, for heating, air conditioning, cooking, water heating and other household uses.

As shown in below, the largest customer segment in 2012 is electricity generators (30%) followed by industrial users (27%), households (21%), and commercial users (14%).

Figure 2: Natural Gas Market Segmentation (Molavi, 2012)



Total demand and concentration of the market among the major customers in the tri-state region of Pennsylvania, Ohio, and West Virginia, are seen in the next table*:*

Table 1: Domestic and Regional Natural Gas Demand by Market Segment (EIA, 2012)

Segment	2010 US Demand (MMcf)	2010 Tri-State Demand (MMcf)	Tri-State Percent of US Demand
Electricity Generators	6,668,325	81,905	1.2%
Industrial Users	6,517,477	474,746	7.3%
Commercial Users	3,101,675	322,963	10.4%
Residential Users	4,787,320	534,366	11.2%
TOTAL	**21,074,797**	**1,413,980**	**6.7%**

3.1 Electricity Generation

The largest market for consumption of natural gas is power generation. According to reports, 21% of all electricity generated in the United States relies on natural gas as a feedstock, and 30% of all natural gas consumed domestically is consumed by power generation users (Molavi, 2012). As electricity usage trends upward, demand for natural gas in this sector is expected to increase. The USEIA forecasts that demand for electricity will increase by roughly 1% per year through 2035, requiring an additional 223 gigawatts of capacity by 2035. Other fuel sources for electricity generation, such as coal, will continue to supplement natural gas use; however, the quantity and relative proportion of natural gas use in power generation is predicted to grow as illustrated below, highlighting the additions to new capacities, by feedstock.

According to the USEIA, natural gas-fired electricity generation accounted for 16% of all generation in 2002 and will increase to 24% of of total for all generation by 2035. The two main drivers for natural gas use in electricity generation are the retirement of aging nuclear, coal, and petroleum-powered genreation plants and increased overall demand for electricity mostly attributed to residential and commercial markets. The growing use of natural gas for power generation can be partly attributed to the low capital cost and greater operational flexibility of natural gas-fired combined cycle generation plants. Additionally, increasingly stringent carbon emission regulations have provided an incentive for electric generation companies to consider natural gas capabilities because emissions can be reduced by 50% when compared to coal-fired generation.

Consumption in the tri-state region of Pennsylvania, Ohio, and West Virginia accounts for only 1.2% of the electricity generated by natural gas in the United States (see ***Table 1***). Regionally, 88.8% of natural gas demand for power generation is concentrated in the top five consumers and/or distributors.

Table 2: Top five Regional Consumers / Distributors of Natural Gas for Electricity Generation in 2010 (EIA, 2012)

Company	**Consumption (MMcf)**	**Percent of Tri-State Consumption**
PPL Interstate Energy Company	29,073	35.5%
UGI Utilities	21,374	26.1%
Philadelphia Gas Works	10,262	12.5%
Dominion Transmission Incorporated	6,869	8.4%
PECO Energy Company	5,167	6.3%
TOTAL	**72,745**	**88.8%**

3.2 Industrial Users

Industrial users are the second largest consumer of natural gas behind electricity generators. Currently, industrial usage accounts for 27% of all natural gas usage within the U.S. The USEIA predicts that industrial usage of natural gas will grow by 0.9% per year over the next 20 years. The level of growth is adversely impacted by a shift in domestic manufacturing from energy-intensive manufacturing industries to less energy-intensive manufacturing industries. Increased energy efficiency of equipment and processes used in the industrial sector also contributes to the marginal growth forecast in the industrial sector.

Demand for natural gas in the industrial sector reflects the overall economy. As the United States economy improves or contracts, industrial demand for natural gas will follow suit. Manufacturing firms will increase output during an upswing in the economy, which in turn requires more fuel to support increased production. Short-term natural gas demand in the industrial sector can swing significantly depending on production schedules; however several factors have driven increased long-term natural gas usage by industrial consumers, including consolidation within the industrial sector, electricity restructuring, industrial carbon emissions regulation, and technology advancement.

The price advantage that natural gas provides to industry has contributed to the rise of natural gas usage. Natural gas has provided domestic manufacturers with a competitive advantage over manufacturers in Europe and Asia who do not have the same access to low-cost production fuels. Low natural gas prices have made some companies that produce chemicals and fertilizer rethink their production locations and consider building new plants in the U.S.

Consumption in the tri-state region of Pennsylvania, Ohio, and West Virginia accounts for 7.3% of the natural gas consumed by industrial customers in the United States (see

Table 1). Regionally, 50.6% of natural gas demand for industrial use is concentrated in the top five consumers and/or distributors.

Table 3: Top Five Regional Industrial Consumers / Distributors of Natural Gas in 2010 (EIA, 2012)

Company	**Consumption (MMcf)**	**Percent of Tri-State Consumption**
East Ohio Gas Company – Dominion East	86,131	18.1%
Columbia Gas Distribution Company	72,168	15.2%
UGI Utilities	30,382	6.4%
Panhandle Eastern Pipeline Company	27,669	5.8%
PECO Energy Company	23,901	5.0%
TOTAL	**240,251**	**50.6%**

3.3 Commercial & Residential Users

Commercial use of natural gas primarily consists of space heating for businesses, but there is also demand in the form of hot water or other heating. A continued growth area is natural gas use in the food service industry, which now offers multifunctional natural gas appliances in the form of hot and cold storage areas, gas-fired fryers, griddles and ovens. From a residential perspective, just over half of domestic households (62 million homes) heat their homes using natural gas. Other residential natural gas applications include cooking, clothes drying, and water heating for both personal and recreational use.

Demand in the residential and commercial sectors shift significantly throughout the year, predominantly due to increased demand for heating in the winter months. However, this effect is partially offset through demand for cooling in the summer months. Using electricity to power air conditioners has been prevalent since the 1950s; however recent technological advances, improved efficiency, and depressed gas prices have caused resurgence in the popularity of gas-powered units. Such units are initially more expensive, but are more efficient, require less maintenance and have an expected working life of as much as 20 years.

As shown in below, the demand for natural gas in the residential and commercial segments is expected to continue to grow over the next five years. However, the strength of the economy will have a material impact on the strength of that growth, predominantly due to demand generated through construction of new property. Partially offsetting the expected volume growth is the anticipated increase in competition and lower prices from the continued deregulation of utility markets across the U.S. over the short-term.

Table 4: Demand and Expected Growth of Natural Gas Use in Residential and Commercial Markets (EIA, 2012)

	Residential	**Commercial**
US Market Size Value	$26.8bn	$17.85bn
US Market Size Volume	21%	14%
US Annual Growth	0.225%	1.1%
US 5 Yr Growth	1.8%	9.1%

Consumption in the tri-state region of Pennsylvania, Ohio, and West Virginia accounts for 11.2% of the natural gas consumed by residential customers and 10.4% of natural gas consumed by commercial customers in the U.S. (see ***Table 1***). Regionally, demand is highly concentrated within the top two customers for both segments, and the top five customers account for over 60% of demand for each segment. As deregulation continues in utility markets, it is expected that the spread across the top five customers will reduce.

Table 5: Top Five Regional Residential Consumers / Distributors of Natural Gas in 2010 (EIA, 2012)

Company	**Consumption (MMcf)**	**Percent of Tri-State Consumption**
Columbia Gas Distribution Company	138,750	26.0%
East Ohio Gas Company - Dominion East	107,286	20.1%
Peco Energy Company	37,739	7.1%
Philadelphia Gas Works	35,864	6.7%
Duke Energy Ohio	31,333	5.9%
TOTAL	**350,971**	**65.7%**

Table 6: Top Five Regional Commercial Consumers / Distributors of Natural Gas in 2010 (EIA, 2012)

Company	**Consumption (MMcf)**	**Percent of Tri-State Consumption**
Columbia Gas Distribution Company	83,141	25.7%
East Ohio Gas Company - Dominion East	49,257	15.3%
Duke Energy Ohio	24,734	7.7%
UGI Utilities	22,879	7.1%
PECO Energy Company	21,012	6.5%
TOTAL	**201,024**	**62.2%**

3.4 Natural Gas Vehicles

Natural gas usage in the transportation sector is still minimal, accounting for 3% of the total demand in the U.S (Naturalgas.org, 2012). Even though the demand in the transportation sector is not significant today, this segment warrants discussion due to the enormous potential for future growth. Industry data shows that vehicular natural gas nearly doubled between 2003 and 2009 (NGVAmerica, 2012). The benefits of natural gas powered vehicles include: decreased environmental emissions because of the clean burning performance of natural gas; improved safety because natural gas dissipates in the event of an accident instead of pooling as do liquid fuels; and decreased dependence on foreign oil because natural gas is domestically available in abundance.

The largest barrier to increased natural gas usage in the transportation sector is the limited refueling infrastructure. Large fleets of vehicles that drive many miles each day and that are centrally maintained and fueled are best suited for natural gas use. In 2011, the top three users in vehicular natural gas were transit buses (62%), waste collection and transfer vehicles (12%), and airport natural gas vehicle fleets (9%) (Naturalgas.org, 2012). The infrastructure needed for more widespread use of natural gas vehicles is expected to expand as more fleets and individual users switch to natural gas vehicles.

The primary driver behind natural gas powered vehicles is the environmental benefit of significantly reduced emissions. Replacing a typical older in-use vehicle with a new natural gas powered vehicle provides exhaust emission reduction ranges as follows: carbon monoxide - 70% to 90%; non-methane organic gas - 50% to 75%; nitrogen oxides - 75% to 95%; and carbon dioxide - 20% to 30% (Naturalgas.org, 2012). Federal and state environmental regulations are expected to become increasingly stringent, especially in regions that experience poor air quality, such as the state of California. In Pennsylvania, incentives such as tax credits and grants are being offered for projects related to alternative fuels. In the Pennsylvania, Ohio and West Virginia region, 99% of natural gas demand for vehicle fuel is concentrated in the top two consumers.

Table 7: Top Four Regional Consumers of Natural Gas for Vehicle Fuel in 2010 (EIA, 2012)

Company	**Consumption (MMcf)**	**Percent of Tri-State Consumption**
East Ohio Gas Company – Dominion East	72	66.1%
PECO Energy Company	36	33.0%
Philadelphia Gas Works	0.8	<1%
UGI Utilities	0.4	<1%
TOTAL	**109**	**88.8%**

3.5 Customer Growth Opportunities

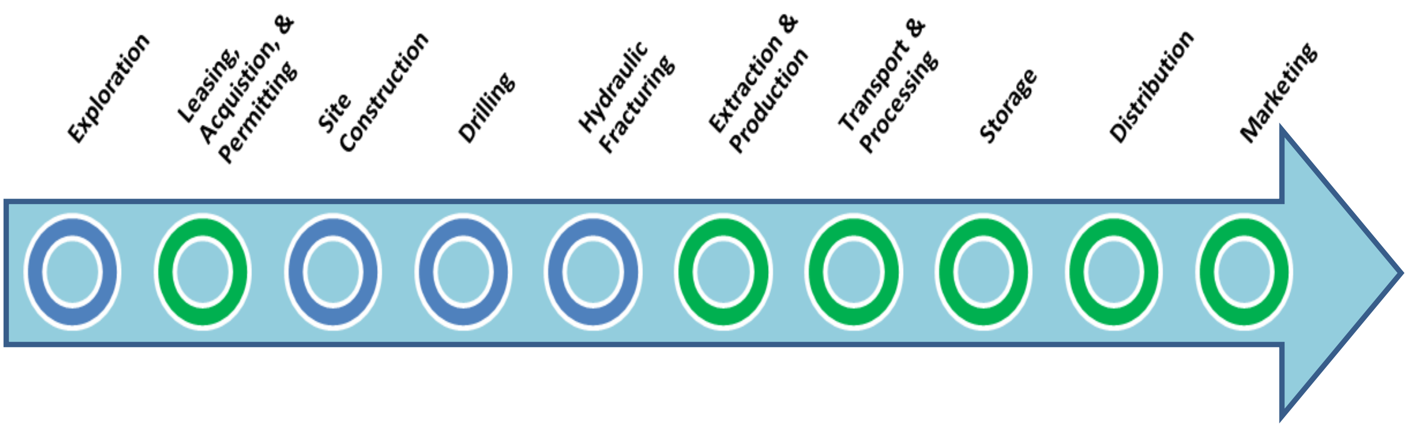
Exports of natural gas represented 1.14 trillion cubic feet (Tcf) in 2010, of which 96% went to Canada and Mexico and the majority of the remaining 4% went to Japan in the form of liquefied natural gas (LNG). Growth in exports is expected over the next five years with an emerging market in Europe, as it potentially diversifies its sources due to current heavy reliance on Russian imports and efforts to offset the decline in indigenous production. This would represent an arbitrage opportunity to mitigate low gas prices in North America.

Global demand for LNG has been increasing at an annual rate of 6% over the last decade and there are currently 25 LNG-importing countries, with developing countries considering the merits of new LNG terminals. In order for the local tri-state area to benefit, changes to current infrastructure would be required. Pipelines for transportation of natural gas across North America currently flow east due to historical availability of product in the west. With demand increasing in the west and as shale gas availability increases, there may be a need and subsequent opportunity to transport gas both south and west.

4 The Marcellus Shale Supply Chain

In a 2011 Pitt Business Working paper, Professor Bill Hefley and his team addressed the direct value chain of one single Marcellus Shale well, located in Southwestern Pennsylvania (Hefley, et al., 2011). This section attempts to expand upon that analysis, to characterize the full supply chain for the Marcellus Shale industry, encompassing the scope of the original Working Paper and including additional sections for analysis. The following diagram depicts the areas of analysis, with blue circles denoting the prior work's scope and the green circles denoting the expansion of analysis for this paper (extraction & production, transport & processing, storage, distribution, and marketing). This section will go beyond the phases associated with drilling one well, to include extraction and production, transport, storage, distribution, and marketing of natural gas.

Figure 3: The Marcellus Shale Supply Chain



4.1 Leasing, Acquisition, & Permitting

The first phase in the supply chain is exploration for a potential drilling location. Once this has been completed, primarily through a geologic evaluation, and a potential drilling site has been identified, the next step entails leasing, acquisition and permitting of the selected site. The Marcellus Shale natural gas well operator must enter into a mineral lease agreement with the landowner before obtaining the necessary permits for drilling. The operator must also post a bond as collateral that all pre-drilling, drilling, and post-drilling activities are carried out in accordance with drilling regulations. The permit application process is extensive and requires that the well operators include details about the well's location and its proximity to nearby environmentally sensitive areas (watersheds, coal seams, biodiversity hotspots). The DEP reviews the application, makes a determination, and approves or denies the drilling of the well, based on the agency's standards. Once the operator's permit application has been approved, the site can be constructed and drilling can begin.

4.2 Drilling

As a high profile phase in the supply chain for a Marcellus Shale wellhead, drilling requires extensive site work prior to the start of operations. Typical site set-up includes mud ponds, drilling rig, brine storage tanks, security fencing, an onsite office, and restroom accommodations, among many others. In addition, the process of drilling the first well includes sinking steel pipes surrounded by concrete to protect ground water from contamination. Each step along this phase requires specific products and services.

A mud pond is the preferred method of disposing the sediment and water recovered from drilling. A mud pond is typically a trench dug during site construction that is lined with plastic. The pond is constructed to allow disposal of the water and cuttings from the drilling operations. The cuttings and other heavy matter tends to settle at the bottom of the mud pond during treatment of the water.

A conductor hole is predrilled and driven into the ground with a pile driver prior to erecting the drill rig. Conductor pipes prevent soft rock from caving in near the surface, and conduct drilling mud from the bottom of the hole to the surface after drilling starts. After drilling is completed, a protective casing and cementing is required prior to moving to the next phase of production. Storage tanks hold the "mud" transported to the site and used in drilling. Depending on the fluid needs of the well, the number of tanks can be increased. Like mud ponds, storage tanks must meet minimum standards.

Setting up the drill rig is one of the major components of the drilling phase. Two types of drilling are done, vertical and horizontal, with predominantly more wells including a horizontal section in Pennsylvania. Both portable and reusable rigging is available through manufacturers and through drilling companies.

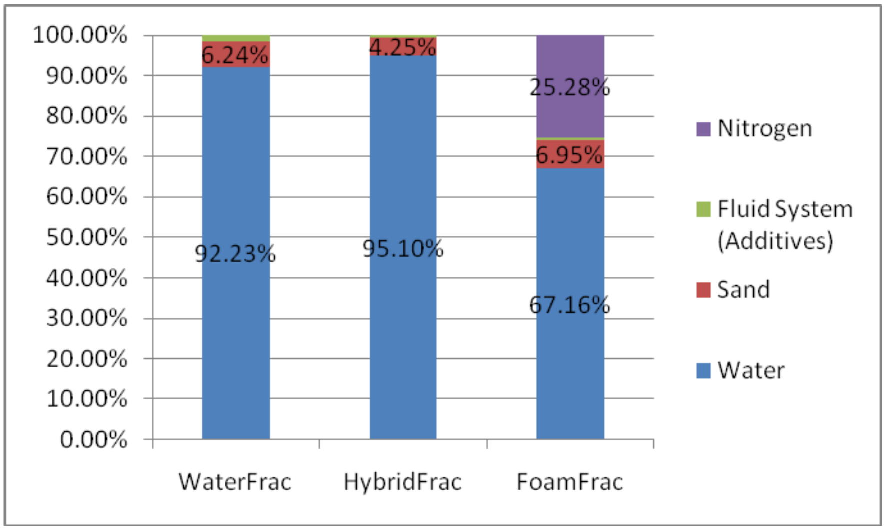
Most rotary drill bits, an important element to the operation, are roller-cone bits consisting of the cutting and circulating sections. The circulating section allows the passage of drilling fluid or mud using hydraulic force of the fluids to improve drilling rates. Drill bits also come with small industrial diamonds embedded in it on the cutting surface. Additional components may be needed for the drilling site, including a blow-out preventer to ensure against accidents, a mud pump to circulate the mud on a drilling rig, power generators, and air compressors. Power generators are specified for the amount of electricity expected to be used on site. Air compressors are used to blow compressed air down the drill pipe and out through the drill bit which blows the cuttings up to the surface into a water bath. The cuttings are separated from any fluids and washed into the mud pond. These activities create a demand for industrial size power generators and air compressors.

4.3 Hydraulic Fracturing

Hydraulic Fracturing, commonly called "fracking," involves injecting a mixture of water, sand, and chemicals at high pressure deep underground to break up shale-rock formations and make it easier to extract oil and natural gas. To avoid misperception, most oil and gas companies have disclosed their fracking fluid composition. Generally, the fracking fluid consists of approximately 90% water, 9.5% sand, and 0.5% chemicals. Natural gas liquids (NGLs) are liquid hydrocarbons carried in suspension in the natural gas stream. The size of the hydrocarbon molecules found in an oil and gas reservoir varies significantly within the reservoir, and from well to well. The smallest molecule, methane (CH_4) is typically what is known as common natural gas. However heavier and more complex molecules can remain in suspension, even after the natural gas stream reaches atmospheric temperatures and pressures. These heavier hydrocarbons – such as ethane, propane, butane, and others – all have added value to the producer if found in significant volumes within the gas stream.

The product description in this value chain phase will mainly focus on these three components. Halliburton, one of the fracking service providers, has disclosed three fluid formulas used specifically in Pennsylvania in different types of formations – WaterFrac, HybidFrac, and FoamFrac (Halliburton, 2012). Below are the compositions of those three formulas:

Figure 4: Hydraulic Fracturing Fluid Possible Compositions (Halliburton, 2012)



Water

Water makes up the largest percentage of fracking fluid (92.23% in WaterFrac, 95.10% in HybridFrac, and 67.16% in FoamFrac). The operators of the wells are normally responsible to provide this amount of water to be mixed with sands and chemicals. Each drill site requires between 3 and 5 million gallons of water per frack. Pennsylvania uses about 8-10 million gallons of water per day for Marcellus Shale drilling, which represents approximately 0.1% of the 9.5 billion gallons of water the state uses daily (Explore Shale, 2012). Roughly 65% of the water used comes from rivers, creeks, and lakes in Pennsylvania. The other 35% is purchased by drilling companies from municipalities. Water may be transported to the drill site by truck or through temporary pipelines installed both above and below ground.

Variably, between 20% and 40% of the water used in fracking a gas well returns to the surface as flowback, and later as produced water. In addition to the fracking fluid added by the drilling companies, this water picks up other contaminants from deep in the earth. These fluids contain sodium and calcium salts, barium, oil, strontium, iron, numerous heavy metals, soap, radiation and other components. In other parts of the United States, gas drilling operations dispose of their wastewater deep in the ground, by utilizing deep injection wells. However, the geology around the Marcellus Shale does not lend itself to accepting deep injections on a broad scale. To overcome this problem, there are some wastewater companies and facilities now within or proposed to be around the Marcellus Shale drilling operations.

Sand

Sand is the second largest component in fracking fluid (6.24% in WaterFrac, 4.25% in HybridFrac, and 6.95% in FoamFrac). This sand is normally provided by fracking services companies as part of their services to the drilling companies. The fracking sands keep the fissure open once the mixture fractures the shale rock deposit. The sand is very dense and specific in shape, giving it strength against crushing. Both of these qualities keep the fracture in the rock bed open thousands of feet below the surface. Some of the sand sources for Marcellus Shale drilling are:

- Northern Sand or Brady Sand, which comes from Santrol of Fairmount Minerals and transloaded from Wexford Lake Sand in Yuma, Michigan. It is a high silica content, 40 – 70 mesh.
- Ottawa sand, generally 95% or greater SiO2 and very spherical in shape, can vary in size from 12 to 270 on the Tyler mesh scale. The quarries this sand comes from are located in the northeastern part of the U.S. and Canada.
- Texas or brown sand, which has higher silica content, generally around 99% SiO2, but is not spherical in shape. The irregularity of the shape does allow for this type of sand to be more permeable than Ottawa sand. The size of sand that can be purchased for fracking is from 8 to 100 on the Tyler mesh scale. These deposits are located in the southern part of the U.S., mostly in Texas.

For many well operators, the specific kind of sand used is dictated by the region where they operate, due to the cost of transporting sand over long distances.

Chemicals / Additives

The chemicals or additives placed in the water have several functions, including reducing friction, allowing pumping of fracturing fluids to occur at a higher rate and at a lower pressure. All of these chemicals represent less than 1% of the fracking fluid, but because most are of a hazardous nature, they require special handling, storage, recycling and disposal. Fracking services companies, such as Halliburton, BJ Services, Schlumberger, CalFrac, and FracTech, provide the chemicals to the operators from supply companies such as Frac-Chem and Par-Chem. The types of chemicals vary from company to company and depend on its unique formulation for certain geologic formations.

There are also miscellaneous products, used in support, of this phase. These include, among others:

- Diesel Fuel for water pumps
- Inserted fracking stage plugs between phases
- Mobile waste water treatment units
- Lining and fencing the water pits
- Pipeline to transport the waters
- Water storage tanks (in addition to the pit)

4.4 Extraction & Production

Once fracturing is completed, the next steps include drilling out the inserted plug between phases, processing flow back, and cleaning out the well. Once flow back is completed and enough water has been removed, the well is turned over to production operations to eventually turn the well online.

After the drilling is completed, a piece of equipment with multiple components, consisting of a casing head and a tubing head, called the "Christmas tree", is installed at the wellhead in preparation for the controlled extraction of the natural gas from the well. The high pressure of the gases and liquids that are being released from the well, require wellheads that can withstand pressures from 2,000 to 20,000 psi. Exposure to the weather and potentially corrosive flow back from the well requires non-corrosive materials and the ability to withstand temperatures from -50°C to 150°C. The wellhead must be durable enough to prevent leaking and blowouts caused by high pressure. Some potential options for treatment of the flow back water include:

New dedicated treatment facilities – Conventional brine plants.

This type of facility treats natural gas wastewater so that it can be discharged to surface water. The equipment in these facilities is designed to remove salts, metals, and oils. Since these facilities are located away from the drilling sites, the cost of transportation to get the water to the facility is very high.

Reuse of water with or without pre-treatment.

Many gas companies have begun to reuse some of the flow back water for other fracking jobs with or without some level of pre-treatment. Relatively clean initial flow back water can be blended without treatment with fresh water and can be reused for drilling again.

Additional fluids may need some pre-treatment, which can be done by either an on-site plant or by treatment in an advanced facility located off-site. An on-site treatment plant consists of a trailer that has a treatment system inside, which can be moved from site to site to perform the treatment of the flow back water to be reused. The challenge in this is to create technology which will allow the on-site plants to handle the large volume of water required for drilling. The positive with this technology is that it reduces truck traffic to the off-site facilities, decreasing transportation expenses. The water can be reused by this method a number of times until it must be fully treated.

Advance facilities – Evaporation and crystallization of salts.

GE, Atela, and other companies are currently developing mobile evaporator units. This technology separates the salt from the water.

Deep injection disposal wells – Underground injection control.

Deep injection wells are a form of waste disposal that pump untreated wastewater down to very deep wells. Pennsylvania currently has seven disposal wells, only one of which is a commercial well. This well already has very limited available capacity. Therefore, some wastewater from Marcellus Shale drilling must be transported by truck to out-of-state locations, namely Ohio. It is important to note that although the deep injection wells are costly and can only be supported by a few locations in Pennsylvania that have suitable geology, their use over transporting the wastewater will ultimately reduce costs for the drilling companies.

Water is an important component in the supply chain, providing opportunities for companies in Pennsylvania to provide advanced wastewater services, improve current wastewater technology, or innovate to create a new technology.

4.5 Transport & Processing

Transport

Pipelines are used as the transportation mechanism to bring natural gas to market. With the increased activity in Marcellus Shale, gas pipeline transportation capacity will need to increase. Pipelines in the Marcellus Shale transport gas from the well sites to collection and processing facilities, as well as transport from these facilities to market. All pipelines are subject to environmental and safety scrutiny. Because of that, there are business opportunities related with inspection equipment such as valves, meters, and leak detection equipment.

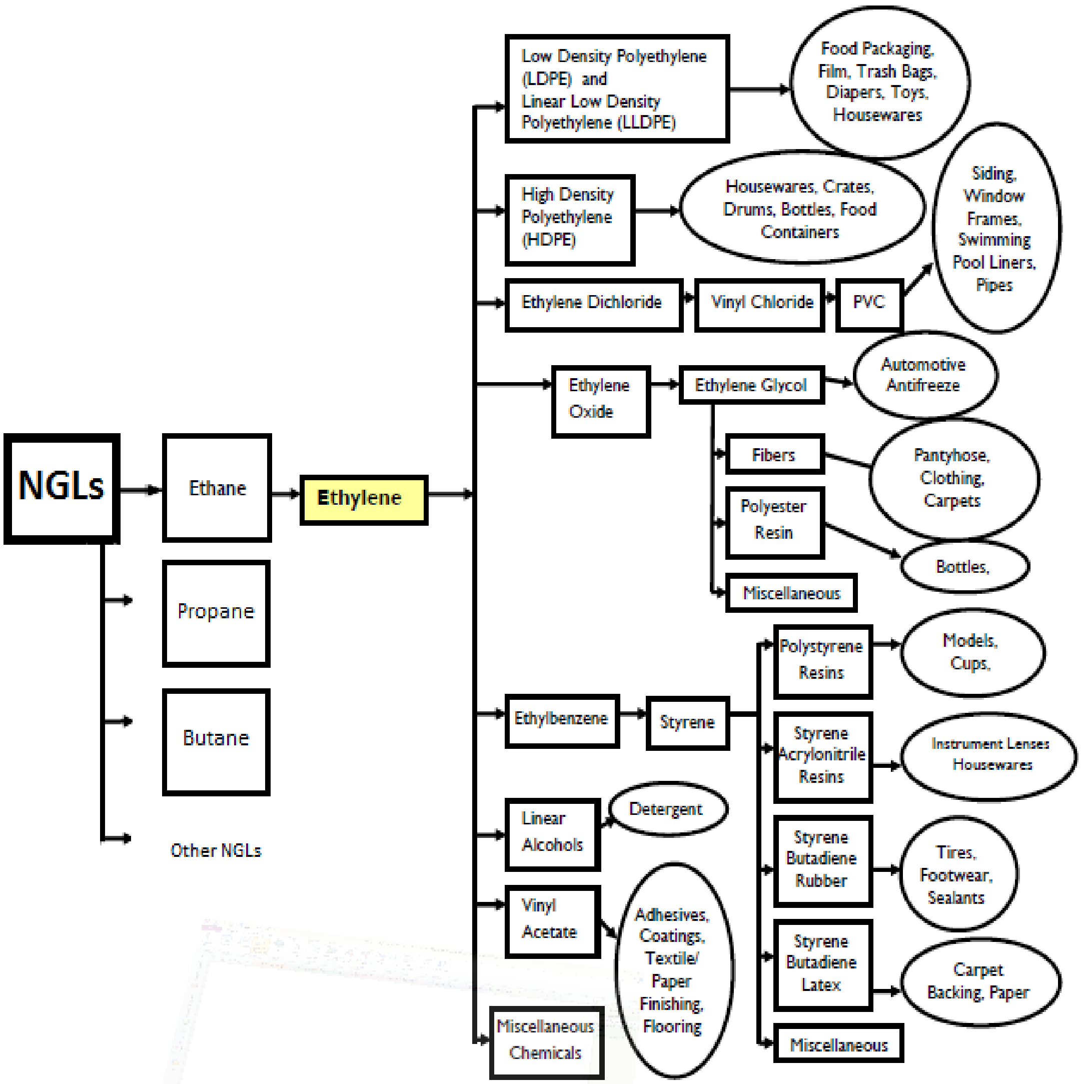
The natural gas that is used in homes is not in the same form as it exists underground. Gas underground comes with compounds and gases, oil, and water which must be removed before being transported over the pipelines. From this natural gas processing, natural gas liquids (NGLs) can be extracted and sold separately.

Processing

The natural gas that is used in homes is not in the same form as it exists underground. Gas underground comes with compounds and gases, oil, and water which must be removed before being transported over the pipelines. From this natural gas processing, NGLs can be extracted and sold separately.

It is generally recognized that ethane is the most abundant of NGLs existing in the Marcellus Shale. The following Figure shows an example of the ethylene supply chain from ethane feedstock through petrochemical intermediates and final end use products. This can be an example of what a proposed Shell ethane cracker plant project's induced supply chain may look like.

Figure 5: A Simplified Ethylene Flow Chart (Adapted from American Chemistry Council, 2011)



The American Chemistry Council analyzed the impact of a hypothetical, but realistic, 25% increase in ethane supply on growth in the petrochemical sector (American Chemistry Council, 2011). It found that the increase would generate:

- 17,000 new knowledge-intensive, high-paying jobs in the U.S. chemical industry.
- 395,000 additional jobs outside the chemical industry.
- $4.4 billion more in federal, state, and local tax revenue, annually ($43.9 billion over 10 years).
- A $32.8 billion increase in U.S. chemical production.
- $16.2 billion in capital investment by the chemical industry to build new petrochemical and derivatives capacity.
- $132.4 billion in U.S. economic output.

Current technology to extract NGLs and transport natural gas has very few roadblocks. Most of the components can be sold in the local markets or used at east coast refineries. The prominent use for ethane is at ethane crackers or ethane refineries to produce ethylene, a compound used to make plastic. As of 2010, no ethane pipelines or crackers operated on the east coast, creating an obstacle for transportation. In the past, due to the shortage of natural gas and lack of ethylene in the U.S., plastic was manufactured overseas. Now with the abundance of Marcellus Shale natural gas, the U.S., and especially Pennsylvania, can explore this growing industry.

In the past year, up to five major companies have announced billion-dollar plus investments either in the new gas producing areas, or in pipeline connections. Last year, Sunoco agreed to move ethane from the Marcellus to Nova Chemical's giant complex at Sarnia, Ontario. Then in January, Enterprise Products Partners confirmed plans to build a 1,230-mile line from Pennsylvania to the Gulf Coast, to begin commercial operations in the first quarter of 2014.

Shell has chosen Pennsylvania for the location of its (proposed) ethane cracker. The company released a statement saying the complex included a steam cracker to turn ethane produced from the Marcellus into ethylene and other petrochemical building blocks. Bayer MaterialScience has expressed interest in siting an ethane cracker in

West Virginia at one of its two manufacturing complexes in the state, according to press reports. With a cracker plant located in the Marcellus region, industry participants can achieve lower costs in managing their respective supply chains. Also, there are some polymer and converter companies in the region. Converters take polymer pellets and form them into either finished plastic products or into component parts that go into other goods, including electronics and automobiles. By several estimates, two-thirds of the plastics converters in North America are within 500 miles of the Marcellus Shale play.

Conditions are conducive to investing billions into ethane crackers at the Marcellus Shale supplied areas, because progress in shale gas development has already reduced natural gas prices. Significant natural gas production could support the operations and infrastructure, making it profitable to use ethane cracker facilities to produce ethylene, as Shell has proposed. The plant, which would be Shell's fifth in the U.S., may be the largest industrial investment in the Southwestern Pennsylvania region for at least a generation. Industry has built new pipelines from the production region (Pennsylvania and West Virginia) to support the demand from the two potential petrochemical markets for Marcellus ethane: Gulf Coast plants (the largest NGL market in North America) and the “northern tier” petrochemical markets of Chicago and Sarnia, Ontario. Companies under this option are expected to build new pipelines to connect with existing ones, which need to be repaired to move the large amount of ethane to the petrochemical market/industry. Industry can then use an ethane cracker facility to create ethylene, to manufacture food packaging, bottles, pipes, carpets, and other products. Pennsylvania has the opportunity to become a part of this innovative solution and help shape this new industry.

4.6 Storage

Natural gas, like most other commodities, can be stored for an indefinite period of time. The exploration, production, and transportation of natural gas take time, and the natural gas that reaches its destination is not always needed right away, so it is injected into underground storage facilities. These storage facilities can be located near market centers that do not have a ready supply of locally produced natural gas.

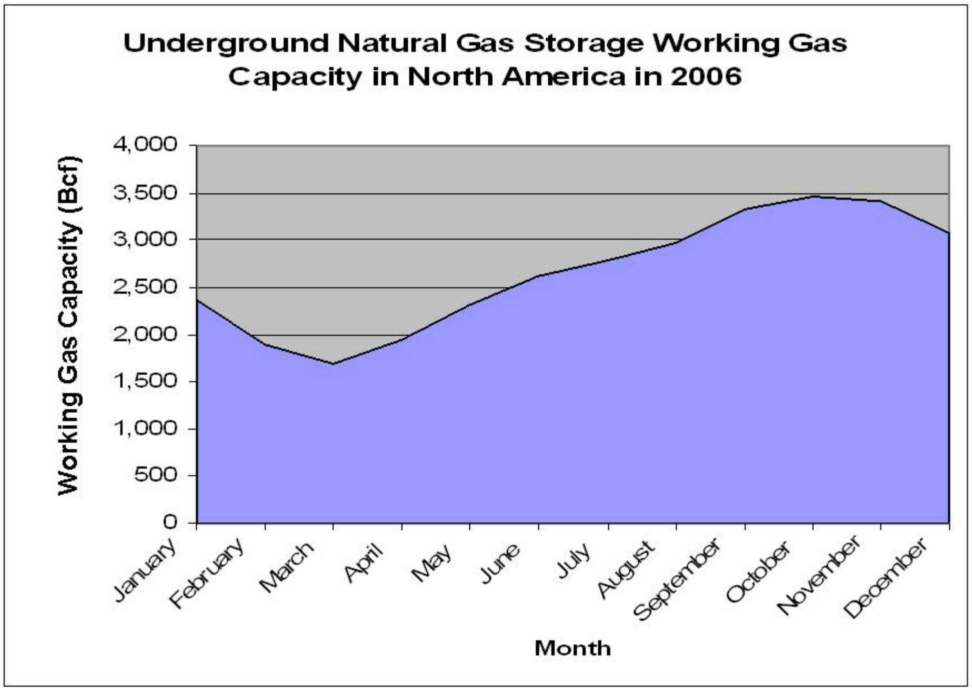
Natural gas is stored for two main reasons: to accommodate fluctuations in demand, and to accommodate fluctuations in prices. The most common types of underground storage are: Depleted Gas Reservoir, Aquifer Reservoir, and Salt Formation.

Storage facilities are most concentrated in the Northeastern U.S., but can be found nationwide. In Pennsylvania, a network pipelines transport natural gas from areas of active production to a variety of end users. Some areas of Pennsylvania store natural gas in deep sandstone formations during periods of surplus so it can be withdrawn later to meet peak demands.

As Marcellus Shale production increases and new pipeline infrastructure is brought on-line, additional underground natural gas storage projects will follow as dictated by the market. As the number of Marcellus wells in production increases, the focus will increasingly shift to pipeline and storage projects. Traditionally, the Northeast has received its shipments of natural gas via pipelines from Western Canada and the Gulf Coast and through a series of LNG import terminals located along the Eastern Seaboard. As production from the Marcellus ramps up over the next several years, assuming the infrastructure will expand to accommodate this new production, the region's reliance on these outside sources should diminish.

Apart from variation in demand, storage is also used in balancing the flow in pipeline systems, leveling production over periods of fluctuating demand, meeting regulatory obligations, and reducing price volatility. The graph on the following page shows a typical capacity of gas storage in North America.

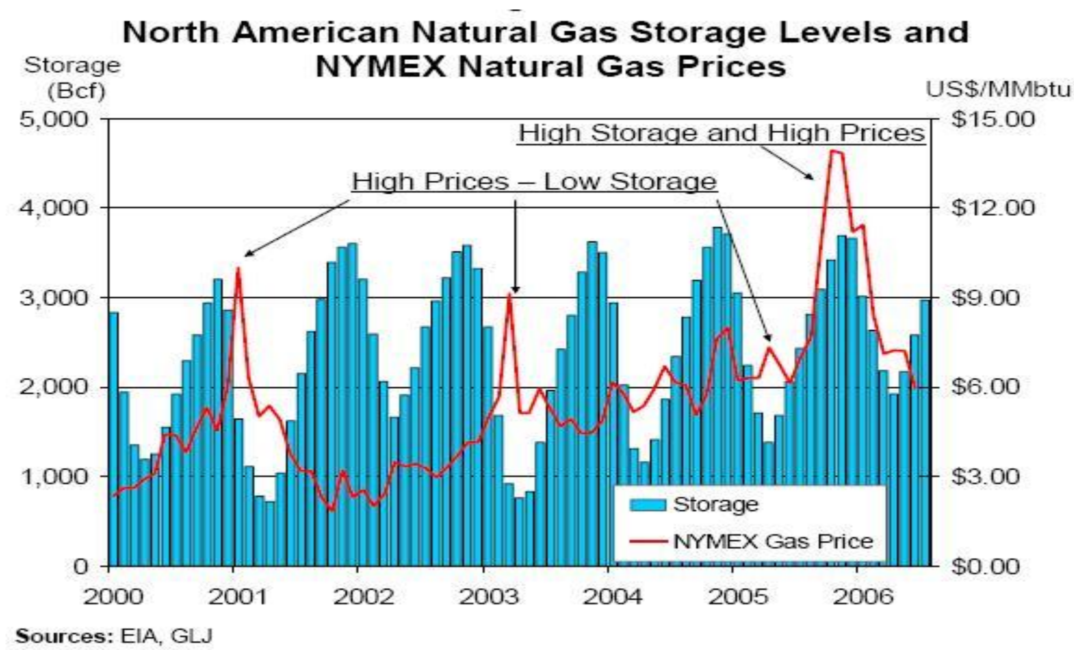
Figure 6: Natural Gas Storage Capacity (USEIA, 2012)



The main reason for the storage tank requirement is variation in demand. As the graph above suggests, the working gas capacity is maximum just before winter and decreases throughout the winter as demand is more than supply. Post-winter the demand is lower than the supply and hence the working capacity increases.

As with all infrastructural investments in the energy sector, developing storage facilities is capital intensive. Additional expenses accumulated during the planning and location of potential storage sites to determine suitability further increases the risk. The capital expenditure to build storage facilities depends on the physical characteristics of the reservoir, ranging from $5 million to $25 million/Bcf of working gas capacity. The wide price range is because of regional differences that dictate the geological requirements. Base gas represents another major cost when building new storage facilities. If the amount of base gas in a reservoir is as high as 80% then it makes a very unattractive investment to develop when gas prices are high. Generally during the last quarter of the year the cost becomes very high, when temporary storage facilities will be required. Cost effective storage facilities would definitely put pressure to reduce the gas prices even when the demand is high.

Figure 7: Natural Gas Storage Levels and Corresponding Prices (USEIA, 2012)



Because of the high cost of building an underground storage facility and seasonal demand of these storage spaces, research has been performed to improve ways to store and transport gas, including hard rock formations such as granite, in areas where such formations exist.

In Sweden a new type of storage facility, called "lined rock cavern," consists of installing a steel tank in a cavern and surrounding it with concrete. Although the development cost of such facility is quite expensive, its ability to cycle gas multiple times compensates for it, similar to salt formation facilities. Hydrates represent another research project sponsored by the U.S. Department of Energy. Hydrates are compounds formed when natural gas is frozen in the presence of water, the advantage being that as much as 181 standard cubic feet of natural gas could be stored in a single cubic foot of hydrate.

With the increase in energy needs and activities around the Marcellus Shale region, there is a constant need to increase storage space. With current underground facilities reaching their peak, more innovative and cost effective technologies to deal with this issue are needed. Although lined rock caverns and hydrates seem promising, more analysis is needed before implementing them in the Marcellus Shale region.

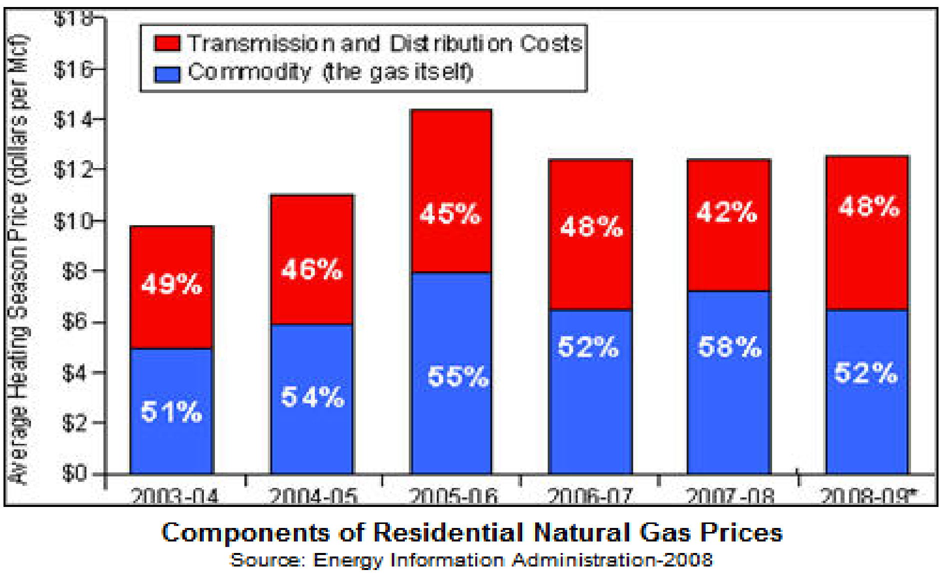
4.7 Distribution

Once the wells have been drilled and the natural gas begins to flow, it must be brought to market. The efficient and effective movement of natural gas from producing regions to consumption regions requires an extensive and elaborate transportation system. In many instances, natural gas produced from a particular well will have to travel a great distance to reach its point of use. There are about 1,200 natural gas distribution companies in the U.S., with ownership of over 1.2 million miles of distribution pipe. While many of these companies maintain monopoly status over their distribution region, many states are currently in the process of offering consumer choice options with respect to their natural gas distribution.

Distribution is the final step in delivering the gas to end-use consumers. While some large industrial and commercial users may receive the gas directly from the interstate or intrastate pipelines, most of the individual users buy the natural gas from their local distribution companies. There are two types of local distribution companies - one is owned by private investors and the other is operated by local governmental departments. Typically, local distribution companies take ownership of the gas at the points where it is delivered from the interstate and intrastate pipelines to the households.

The distribution cost is usually composed half from gas commodity cost and half from transmission cost. Although large pipelines can reduce the unit cost of gas by delivering large amounts of natural gas in the beginning of the transmission, the cost of transmission surges highly when local distribution companies must use much smaller pipes to send the gas to numerous end users in different locations.

Figure 8: Components of Natural Gas Prices (USEIA, 2012)



Transmission Pipes

Mainline transmission pipes can measure anywhere from 6 to 48 inches in diameter, depending on their function. Lateral pipelines, which deliver natural gas to or from the mainline, are typically between 6 and 16 inches in diameter. Most major interstate pipelines are between 24 and 36 inches in diameter. The actual pipeline itself, commonly called “line pipe,” consists of a strong carbon steel material, engineered to meet standards set by the American Petroleum Institute (API). In contrast, some distribution pipe is made of highly advanced plastic, because of the need for flexibility, versatility and the ease of replacement.

Line pipe is also covered with a specialized coating to ensure that it does not corrode from rust or moisture once placed in the ground. There are a number of different coating techniques. In the past, pipes were coated with specialized coal tar enamel. Today, pipes are often protected with what is known as a fusion bond epoxy, which gives the pipe a noticeable light blue color. Also, cathode protection is often used, where an electric current is sent through the pipe to prevent corrosion and rusting.

It is generally estimated that the cost of a new pipe installed to completion is around $1 million to $1.5 million per mile. One 12 inch natural gas pipeline has the capacity to transport 1.7 Bcf of natural gas per day. If the average Marcellus Shale gas well produces 1.7 MMcf of gas per day, one 12 inch high pressure service line could support 1,000 Marcellus Shale gas well drill sites.

Local distribution companies that deliver natural gas are handled by those owned and operated by pipeline companies and public gas systems owned by local government. It has been estimated that over one million miles of natural gas distribution pipelines exist throughout the U.S. Southwestern Pennsylvania distribution lines have a capacity to transfer 7.23 Bcf of natural gas per day.

Compressor Stations

Natural gas is highly pressurized as it travels through an interstate pipeline. To ensure that the natural gas flowing through any one pipeline remains pressurized, compression of this natural gas is required periodically along the pipe. This is accomplished by compressor stations, usually placed at 40 to 100 mile intervals along the pipeline. The natural gas enters the compressor station, where it is compressed by a turbine, motor, or engine.

Turbine compressors gain their energy by using up a small proportion of the natural gas that they compress. The turbine itself serves to operate a centrifugal compressor, a fan that compresses and pumps the natural gas through the pipeline. Some compressor stations are operated by using an electric motor to turn the same type of centrifugal compressor. This type of compression does not require the use of any of the natural gas from the pipe; however it does require a reliable source of electricity nearby. Reciprocating natural gas engines are also used to power some compressor stations. These engines resemble a very large automobile engine, and are powered by natural gas from the pipeline. The combustion of the natural gas powers pistons on the outside of the engine, which serves to compress the natural gas.

In addition to compressing natural gas, compressor stations also usually contain a liquid separator, like those that dehydrate natural gas during processing, using scrubbers and filters to capture any liquids or other unwanted particles from gas in the pipeline. Although natural gas in pipelines is considered dry gas, it is not uncommon for a certain amount of water and hydrocarbons to condense out of the gas stream while in transit. The liquid separators at compressor stations ensure that the natural gas in the pipeline is as pure as possible, and usually filter the gas prior to compression.

Metering Stations

In addition to compressing natural gas to reduce its volume and push it through the pipe, metering stations are placed periodically along interstate natural gas pipelines. These stations allow pipeline companies to monitor the natural gas in their pipes.

These metering stations employ specialized meters to measure the natural gas as it flows through the pipeline, without impeding its movement.

Valves

Interstate pipelines include a great number of valves that work like gateways. Usually open, they allow natural gas to flow freely, or they can be used to stop gas flow along a certain section of pipe. There are many reasons why a pipeline may need to restrict gas flow in certain areas. For example, if a section of pipe requires replacement or maintenance, valves on either end of that section of pipe can be closed to allow engineers and work crews' safe access. These large valves can be placed every 5 to 20 miles along the pipeline, and are subject to regulation by safety codes.

Control Stations and SCADA Systems

Natural gas pipeline companies have customers on both ends of the pipeline - the producers and processors that put gas into the pipeline, and the consumers and local gas utilities that take gas out. In order to manage the natural gas that enters the pipeline, and to ensure that all customers receive timely delivery of their portion of this gas, sophisticated control systems are required to monitor the gas as it travels through all sections of what could be a very lengthy pipeline network. To accomplish this task of monitoring and controlling the natural gas traveling through the pipeline, centralized gas control stations collect, assimilate, and manage data received from monitoring and compressor stations all along the pipe.

Most of the data that is received by a control station is provided by Supervisory Control and Data Acquisition (SCADA) systems. These are essentially sophisticated communications systems that take measurements and collect data along the pipeline and transmit it to the centralized control station. Flow rate through the pipeline, operational status, pressure, and temperature readings may all be used to assess the status of the pipeline at any time. These systems also work in real time, meaning minimal lag time between the measurements taken along the pipeline and their transmission to the control station, where engineers know exactly what is happening along the pipeline at all times. This enables quick reactions to equipment malfunctions, leaks, or any other unusual activity along the pipeline. Some SCADA systems also incorporate the ability to remotely operate certain equipment along the pipeline, allowing engineers in a centralized control center to immediately and easily adjust flow rates in the pipeline.

4.8 Marketing

Any party who engages in the sale of natural gas can be termed a marketer, however they are usually specialized business entities dedicated solely to transacting in the physical and financial energy markets. It is commonplace for natural gas marketers to be active in a number of energy markets, taking advantage of their knowledge of these markets to diversify their business. Many natural gas marketers are also involved in the marketing of electricity, and in certain instances, crude oil.

Marketers can be producers of natural gas, pipeline marketing affiliates, distribution utility marketing affiliates, independent marketers, and large volume users of natural gas. Marketing companies, whether affiliated with another member of the natural gas industry or not, can vary in size and the scope of their operations. Some marketing companies may offer a full range of services, marketing numerous forms of energy and financial products, while others may be more limited in their scope. For instance, most marketing firms affiliated with producers do not sell natural gas from third parties; they are more concerned with selling their own production, and hedging to protect their profit margin from these sales.

There are basically five different classifications of marketing companies: major nationally integrated marketers, producer marketers, small geographically focused marketers, aggregators, and brokers.

The major nationally integrated marketers are the big players, offering a full range of services, and marketing numerous different products. They operate on a nationwide basis, and have large amounts of capital to support their trading and marketing operations. Producer marketers are those entities generally concerned with selling their own natural gas production, or the production of their affiliated natural gas production company. Smaller marketers target particular geographic areas, and specific natural gas markets. Many marketing entities affiliated with local distribution companies are of this type, focusing on marketing gas for the geographic area in which their affiliated distributor operates. Aggregators generally gather small volumes from various sources, combine them, and sell the larger volumes for more favorable prices and terms than would be possible selling the smaller volumes separately. Brokers are a unique class of marketers in that they never actually take ownership of any natural gas themselves. They simply act as facilitators, bringing buyers and sellers of natural gas together.

All marketing companies must have, in addition to the core trading group, significant backroom operations responsible for coordinating everything related to the sale and purchase of physical and financial natural gas, including arranging transportation and storage, posting completed transactions, billing, accounting, and more. Since marketers generally work with very slim profit margins, the efficiency and effectiveness of these backroom operations can make a large impact on the profitability of the entire marketing operation.

In addition to the traders and backroom staff, marketing companies typically have extensive risk management operations, responsible for ensuring that traders do not expose the marketing company to excessive risk. Management is responsible for setting guidelines and risk limitations for the marketing operations, and it is up to the risk management team to ensure that traders comply with these directives. Risk management operations rely on complex statistical, mathematical, and financial theory to ensure that risk exposure is kept under control. Most large losses associated with marketing operations occur when risk management policies are ignored or are not enforced within the company itself.

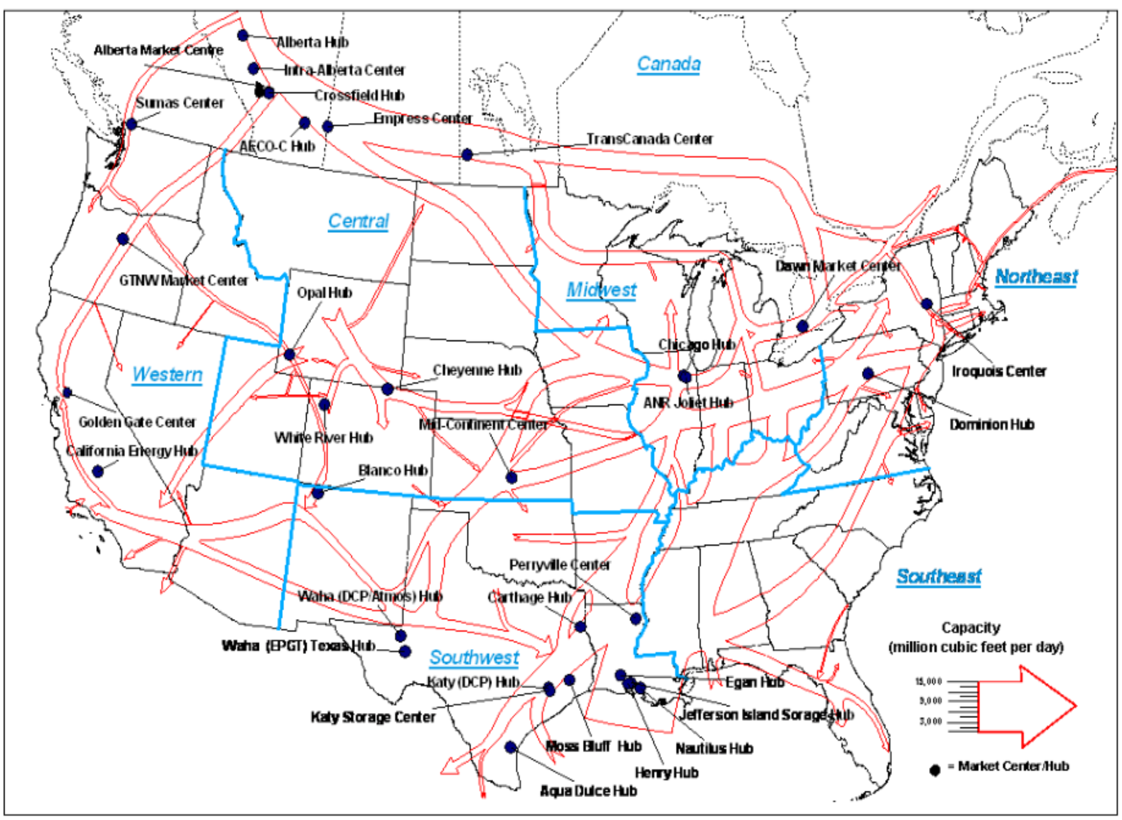
Natural gas marketing coordinates the business of bringing natural gas from the wellhead to end-users. The role of natural gas marketers is quite complex, and does not fit exactly into any one spot in the natural gas supply chain. Marketers may be affiliates of producers, pipelines, and local utilities, or may be separate business entities unaffiliated with any other players in the natural gas industry. Marketers, in whatever form, find buyers for natural gas, ensure secure supplies of natural gas in the market, and provide a pathway for natural gas to reach the end-user. Marketing natural gas can include all of the intermediate steps that a particular purchase requires, including arranging transportation, storage, accounting, or any other step needed to facilitate the sale.

Essentially, marketers are primarily concerned with selling natural gas, either to resellers (other marketers and distribution companies), or end users. On average, most natural gas can have three to four separate owners before it actually reaches the end-user. In addition to buying and selling natural gas, marketers utilize their expertise in financial instruments and markets to both reduce their exposure to risks inherent to commodities, and earn money through speculating as to future market movements. Much non-physical natural gas passes through marketers, and can be much greater than the actual physical volume consumed. This indicates a vibrant, transparent commodity market for natural gas.

Major Natural Gas Market Hubs

Natural gas is priced and traded at different locations throughout the country. These locations, referred to as market hubs, can be found at the intersection of major pipeline systems. There are more than 30 major market hubs in the U.S., the principle of which is known as the Henry Hub, in Louisiana. Henry Hub futures contracts traded on the NYMEX reflect the price of natural gas for physical delivery at this hub. The price at which natural gas trades differs across the major hubs, depending on supply and demand. The difference between the Henry Hub price and another hub is called the location differential. In addition to market hubs, other major pricing locations include citygates, where distribution companies receive gas from a pipeline. Citygates at major metropolitan centers can offer another point at which natural gas is priced.

Figure 9: Natural Gas Hub Locations (USEIA, 2012)



Physical Contracts

Physical trading contracts are negotiated between buyers and sellers. There exist numerous types of physical trading contracts, but most share some standard specifications including identifying the buyer and seller, the price, the amount of natural gas to be sold, the receipt and delivery point, the tenure of the contract, and other terms and conditions, such as payment dates, quality specifications for the natural gas to be sold, and any other specifications agreed to by both parties. Physical contracts are usually negotiated between buyers and sellers over the phone. However, electronic bulletin boards and e-commerce trading sites allow more physical transactions to take place over the Internet.

There are three main types of physical trading contracts: swing contracts, base load contracts, and firm contracts. Swing (or 'interruptible') contracts are usually short-term contracts, and can be as short as one day and are usually not longer than a month. Under this type of contract, both the buyer and seller agree that neither party is obligated to deliver or receive the exact volume specified. These contracts are the most flexible, and are usually put in place when either the supply of gas from the seller, or the demand for gas from the buyer, are unreliable.

Base load contracts are similar to swing contracts. Neither the buyer nor seller is obligated to deliver or receive the exact volume specified. However, it is agreed that both parties will attempt to deliver or receive the specified volume, on a best-efforts basis. In addition, both parties generally agree not to end the agreement due to market price movements. Both of these understandings are not legal obligations; there is no legal recourse for either party if they believe the other party did not make its best effort to fulfill the agreement.

Firm contracts are different from swing and base load contracts in that there is legal recourse available to either party, should the other party fail to meet its obligations under the agreement. This means that both parties are legally obligated to either receive or deliver the amount of gas specified in the contract. These contracts are used primarily when both the supply and demand for the specified amount of natural gas are unlikely to change or drop off.

The daily spot market for natural gas is active, and trading can occur 24 hours a day, seven days a week. However, in the natural gas market, the largest volume of trading occurs in the last week of every month. Known as Bid Week, this is when producers are trying to sell their core production and consumers are trying to buy for their core natural gas needs for the upcoming month. The core natural gas supply or demand is not expected to change; producers know they will have that much natural gas over the next month, and consumers know that they will require that much natural gas over the next month. The average prices set during bid week are commonly the prices used in physical contracts.

The marketing of natural gas is an integral part of the supply chain. Natural gas marketers ensure that a viable market for natural gas exists at all times. Efficient and effective physical and financial markets are the only way to ensure that a fair and equitable commodity price, reflective of the supply and demand for that commodity, is maintained.

5 Supply Chain Needs

This section now shifts focus to the perspective of the individual supplier, through an analysis of industries that are in currently in need, key characteristics that supply chain participants should possess, areas of support available to supply chain entrants, and best practices of successful suppliers.

5.1 Supplier Industries

Industry experts predict that significant growth in the Marcellus Shale industry in the next decade will infuse parallel growth in industries essential for the functioning of the entire business ecosystem. The Marcellus Shale development has several industries that contribute toward keeping the supply chain as effective as possible. Identified industries, from which suppliers are sought, broadly can be described as Business Services, Human Capital, and Construction / Infrastructure Development. Each of these will be examined in further detail.

Business Services

Business Services in the Marcellus Shale value chain are an important intangible commodity. These include legal services, real estate services, brokers, consultants, accounting, tax, and wealth management. Below is a comprehensive list of legal challenges facing the natural gas industry (Babst, 2012). These include:

- Marcellus Shale Well Drilling Permit Requirements
- Land Use and other Local Government Authorizations
- Water Withdrawal Registrations
- Wastewater Management and Disposal Requirements
- Permitting of Impoundment for Fresh Water and Flowback Storage
- Joint Ventures and Joint Development Arrangements
- Pooling and Unitization Agreements
- Marcellus Shale Leasing Disputes

- Stream Crossings and Wetland Disturbances
- Surface and Subsurface Ownership Rights
- Pipeline Right of Way Acquisitions
- Erosion and Sediment Control (E&SC) Plans and Permitting
- Endangered and Threatened Species
- Air Quality and Greenhouse Gases

Some examples of other Business Services include:

- Management, business, and growth consulting firms, both large and small, specializing in the natural gas industry.
- Engineering consulting firms offering services in design, planning, and construction management.
- Environmental consulting firms offering support regarding environmental compliance.
- Real estate management firms helping drilling companies land leasing and right-of way positions, as well as acquiring necessary office, storage, and staging parcels.

Human Capital

Industry experts suggest that Human Capital is one of the greatest assets in the value chain. With the shale gas industry growing, companies are reaching out to attract a broad range of quality personnel. The industry has also been instrumental in creating employment opportunities at a time where high unemployment has become a national issue. The natural gas supply chain requires a highly specialized workforce. It is for this reason that Pennsylvania has experienced an inflow of out-of-state professionals from energy rich states such as Texas (Hefley et al, 2011). As the Marcellus Shale supply chain develops, the demand for skilled professionals will increase even further.

In addition, many universities have adjusted their course and degree offerings in order to produce graduates who are prepared for careers in the industry. Some also offer brief certification programs in coordination with private companies. These programs are becoming increasingly popular as people are eager to join a growing industry. Also, staffing agencies are providing companies with temporary labor, experienced in well site operations and support.

Construction / Infrastructure Development

Construction and infrastructure are the most capital intensive portions within the value chain. There is a significant scope for contractors who can provide the drilling companies with pipelines to transport or construction of a multitude of projects. Representatives from construction companies explained that "shale gas plays have been complete game changers. Simply because of the high volume of the gas, complete infrastructure has to be rebuilt to exploit the resource at a profitable level." Industry sources have also indicated that investments to the magnitude of $15 billion will be made to develop infrastructure by 2020. Since shale gas is located in new formations, pipeline companies have to invest in equipment for gas gathering, compression, gas treatment and storage facilities as well as for new transmission pipelines to move the product to customers.

An analysis of pipeline, storage, and gathering infrastructure conducted by the International Natural Gas Association of America (INGAA) estimated that the nation would invest between $110 billion and $163 billion in new transmission infrastructure and an additional $10 billion to $18 billion in gathering infrastructure by 2030. Much like the development of a well site, pipeline construction is a multistage process requiring the collaboration of several players. A good description of the construction process of a new pipeline includes (Williams Companies, 2012):

1. Pre-construction survey: To ensure legal and environmental compliance and that the new pipeline does not interfere with existing utility lines and agricultural drainages
2. Clearing and grading: Removing vegetation from where the pipeline will be led.
3. Trenching: Soil is excavated to create a ditch where the pipeline will be installed.
4. Pipe stringing and bending: Positioning the individual joints of the pipe.
5. Welding, Pipe coating and weld inspection: Welding the individual joints
6. Lowering pipe in and backfilling: Placing the pipeline into the ditch.
7. Testing with water: Federal regulation requires that the pipeline is tested for leaks.
8. Restoration: Restoring the area once construction has ended.

5.2 Supplier Selection and Development

Supplier Selection

The supplier selection process is very subjective to each individual company, but interviews and conversations with various industry sources suggest certain commonalities. Most suggest that the supplier should possess certain key attributes, ultimately increasing the probability of being selected, to include:

- **Health, Safety, and Environmental (HSE) --** Suppliers are expected to have all the necessary certifications, procedures, and reporting structure in place. Also, fact-based evidence of recent performance history is critical.
- **Financial Solvency --** Financial liquidity, solvency, and reserves are important. These all lend to fiscal adaption to fluctuation of workloads or otherwise.
- **Flexibility and Responsiveness --** The ability to adapt to sudden changes and constant uncertainty is important for a supplier. Since the nature of the industry demands the ability to service 24/7/365, suppliers must be ready and on-call anytime.
- **Transparency --** It is beneficial if suppliers have a certain level of transparency, allowing them to address issues in a straightforward and predictable fashion. This also helps to foster reliability among supply and procurement.
- **Cooperative / Collaborative --** Suppliers must be able to work collaboratively, in a team-based environment, to include actions carried out together through open communication.
- **Trust --** This is an extremely important factor when it comes to the supplier/contractor relation. Companies develop relations in a way that they are able to establish a climate of trust. The human factor is very important.
- **Long-term Perspective --** Contractors typically do not like to switch suppliers, since in many cases, the resulting costs are very high. Suppliers should highlight relationships built for the long-term.

An important factor for suppliers to consider in selection is to demonstrate that they perform, report, and track all necessary components of the relationship. By communicating that the supplier has all checks and balances in order, the contracting company has a certain base comfort level from which to negotiate.

Supplier Development

Suppliers may benefit from having certain certifications and affiliations, effectively enhancing their network. Affiliations are a unique way to familiarize with companies and increasing the contractor network for suppliers. While each represents certain advantages, none are as important to a provider as having a fundamental capability and ability to execute. Following is a brief list of groups that suppliers may find beneficial, relative to the Marcellus Shale:

- **Marcellus Shale Coalition (MSC) --** Founded in 2008, the MSC is an organization committed to the responsible development of natural gas from the Marcellus Shale geological formation and the enhancement of the region's economy. The members of the coalition work with their partners across the region to address issues with regulators, local, county, state and federal government officials and communities about all aspects of producing natural gas from the Marcellus Shale. Website: www.marcelluscoalition.org
- **The Pennsylvania Independent Oil and Gas Association of Pennsylvania (PIOGA) --** PIOGA is the principal nonprofit trade association representing Pennsylvania's independent oil and natural gas producers, marketers, service companies, and related businesses. PIOGA member companies drill and operate the majority of the state's crude oil and natural gas, including the Marcellus Shale. Website: www.pioga.org
- **Association of Energy Service Companies (AESC) --** The AESC was established in 1956 as the Association of Oilwell Servicing Contractors (AOSC). Over the years, the industry and the association evolved to comprise more industry services and products. For more than five decades, the AESC has operated through a network of national committees and local chapters, who address safety, technology, environmental, insurance, governmental, training, oilfield theft, and other issues of common concern. Website: www.aesc.net

- **Independent Petroleum Associates of America (IPAA**) **--** IPAA has represented independent oil and natural gas producers for three-quarters of a century. IPAA represents the thousands of independent oil and natural gas producers and service companies across the United States. IPAA is a national trade association headquartered in Washington, D.C. Website: www.ipaa.org

5.3 Criteria for Supplier Selection and Evaluation

Of all the attributes described in the previous section, the following, through our research, have been determined to be the most important:

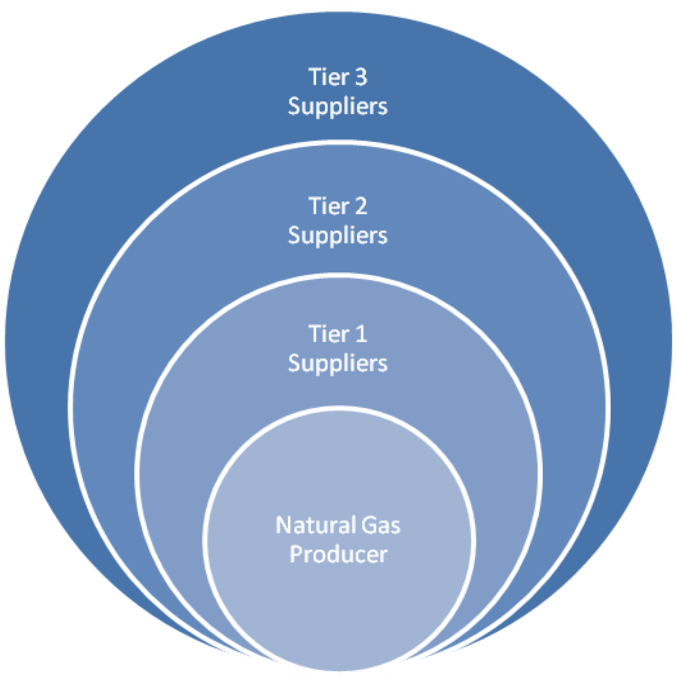
- **Safety (HSE) --** Drilling companies are under intense regulatory scrutiny and choosing a supplier that complies with HSE regulations is crucial.
- **Flexibility and Responsiveness --** The Marcellus Shale market is still very dynamic so drilling companies are looking for suppliers that can support them through increases or decreases in business.
- **Financial Solvency --** Drilling companies want to deal with suppliers who are able to financially withstand instability in the natural gas market, as the emerging opportunity evolves.

Among the major criteria, performance industry experts feel that Safety is clearly the most significant. One anonymous industry consultant said, “Once companies make a decision to utilize a particular component of a supplier, the companies look to get those components as fast and as safe as possible along with transferring as much risk as possible.” Companies also expect the suppliers to qualify financially to receive bids in order to ascertain that the supplier has the financial resources to get into business with the companies. Companies also ask for financial statements from the suppliers, and emphasize a strong balance sheet.

Evaluating supplier performance is an ongoing process and a requirement for companies to ensure that the supply chain stays competitive. This is not to mention that it just makes good business sense. Industry experts conclude that out of the many criteria, a few key areas are **consistency, compliance, and flexibility.**

Companies practice supplier differentiation, and can be as subjective as the selection criteria. Generally, companies tend to differentiate their suppliers into different tiers. The allocation of a supplier to a particular tier depends on the type of product or service the supplier provides to the company and the criticality of that product or service. For this discussion, we have developed the following chart to describe a 'typical' supplier differentiation structure, from an overall supply chain perspective. Companies may fit into multiple tiers, depending on the product or service offered, however the following diagram attempts to characterize the hierarchy.

Figure 10: Marcellus Shale Supply Chain Tiers



Tier 3 Supplier: Any company supplying a Tier 2 supplier with a product or service. Tier 3 suppliers are most likely indirect suppliers

Tier 2 Supplier: Any company supplying a Tier 1 supplier with a product or service, or indirectly a Producer

Tier 1 Supplier: Any company supplying the producer directly with a product or service.

Producer: Drilling and Exploration Companies.

5.4 Supplier Support Programs

Supplier diversity has become an integral management practice in the corporate world and most of the Fortune 500 companies have extensive supplier diversity programs. Forward-thinking companies are leading the way in a multicultural marketplace by infusing supplier diversity into their main business processes in unique and creative ways. Some have developed strong relationships with minority business owners and are reaping the benefits (Whitfield, 2008). Also, there are economic benefits for the companies implementing supplier diversity programs as these programs provide a competitive edge by expanding its supplier bases and strengthening strategic partnerships with diverse suppliers (Adobor, 2007). Manufacturers that have implemented supplier diversity programs say the payoff has come in the form of stronger relationships with their supply base, new business opportunities, and a more agile supply chain (Katz, 2011). Companies like Chevron, Shell, and EQT insist that suppliers participating in their Supplier diversity/small businesses programs be certified by certain organizations and agencies. Some examples of these types of organizations include:

- **National Minority Supplier Development Council (NMSDC) --** Providing a direct link between corporate America and minority-owned businesses is the primary objective of the NMSDC, one of the country's leading business membership organizations. The NMSDC Network includes a National Office in New York and 37 regional councils across the country. There are 3,500 corporate members throughout the network, including most of America's largest publicly-owned, privately-owned and foreign-owned companies, as well as universities, hospitals and other buying institutions. The regional councils certify and match more than 16,000 minority owned businesses with member corporations which want to purchase goods and services. Website: www.nmsdc.org

- **Women's Business Enterprise National Council (WBENC) --** WBENC, founded in 1997, is the largest third-party certifier of businesses owned, controlled, and operated by women in the U.S. WBENC is dedicated to advancing the success of corporate members, certified women's business enterprises (WBEs), and government entities in partnership with its Regional Partner Organizations (RPOs). Website: www.wbenc.org

- **U.S. Small Business Administration (SBA) --** Since its founding in 1953, the SBA has delivered millions of loans, loan guarantees, contracts, counseling sessions and other forms of assistance to small businesses. The SBA was created as an independent agency of the federal government to aid, counsel, assist and protect the interests of small business concerns, to preserve free competitive enterprise and to maintain and strengthen the overall economy of our nation. The SBA helps Americans start, build and grow businesses. Through an extensive network of field offices and partnerships with public and private organizations, the SBA delivers its services to people throughout the United States, Puerto Rico, the U. S. Virgin Islands and Guam. Website: www.sba.gov

There are certain expectations which the companies have from their suppliers along with other requisites of certifications. An Industry consultant said, "It is imperative for suppliers to innovate beyond a specific request of the client. Also the supplier must maintain value beyond customers. Suppliers must continue to invest in building new markets and applications to raise capabilities which are applicable to other customers." In the end, experts suggested that if qualified and willing, industry is happy to use local business. Companies are willing to encourage suppliers to initiate contact, if they capable and competent. Although large companies encourage supplier diversity, purchasers also have to consider the cost aspect, and small businesses must remain competitive, despite economies of scale disadvantages.

5.5 ISNetworld – A Case Study

As the industry's ecosystem expands, and more and more businesses are trying to enter the market, it becomes more difficult for drilling companies to distinguish good suppliers from bad ones. Thus, there is an increasing need for independent third-party assessments that can match suppliers with drilling companies and eliminate the information asymmetry emerging in the market. This has created an opportunity for agents who can help companies sort through the plethora of suppliers willing to work with them. The same agents can also act as a low-cost way for new entrants to get the attention of these large companies. A few companies help audit the safety certifications of manufacturers, and then maintain them in a database for the larger companies to review. For the purposes of this research, one such company, ISNetworld, will be highlighted[1].

ISNetworld maintains a database of contractors and suppliers offering their services to potential buyers. ISNetworld audits and verifies the information offered by contractors and suppliers, as well as all the safety certifications and affiliations they may list. ISNetworld has developed a significantly large database, currently used by 245 owner-buyers, being large production companies. Several other downstream, midstream, and upstream companies are part of ISNetworld's owner-client list. Additionally, as of 2012, more than 40,000 contractors and suppliers have entered the ISNetworld database. Although ISNetworld's main focus appears to be the energy sector, the company also caters to several other industries, including manufacturing, health services, pharmaceuticals, food, and agriculture.

The main service offered by ISNetworld is access to its database. From the perspective of the owner-buyer, ISNetworld supplies an easy to navigate list of credible contractors/suppliers, reducing the time and effort needed to find, vet, and compare different suppliers in the beginning of the buying process. On the other

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[1] All ISNetworld material sourced from company website and interviews.

side, contractors/suppliers sign up in order to be included in the ISNetworld database and have access to contracts offered by the owner-buyers.

ISNetworld charges both owner-buyers and suppliers annual fees for access to their database. The pricing model for suppliers is based on the size of the company, as determined by number of employees. The owner-buyer companies pay a flat subscription fee. As of April 2012, subscription pricing for contractor/suppliers ranged between $600 to $12,800 per year (not including a set-up fee for the first year). Owner-buyers pay an annual subscription of $30,000 and an additional $5,000 in installation costs the first year with ISNetworld.

ISNetworld is not without competitors. One is PEC, which offers training programs for HSE management as well as standardized forms for suppliers to report safety information. A key selling point for their services is that they are universally accepted by all industry participants. This eliminates the cost of participating in multiple safety programs in order to qualify for contracts offered by different buyers. PICS, another company offering services similar to ISNetworld, was founded in 2003. PICS collects complete contractor safety related qualification information and offers large exploration companies access to a database with their contractors. PICS charges subscription fees to both the production companies and the contractors featured in the company's database. Browz, CanQual and ComplyWorks are more examples of similar companies offering access to databases of contractors with standardized safety qualification information. The fact that all these companies are focusing on HSE-related qualifications demonstrates the significance of these criteria in the supplier qualification process.

The value of a database tool like ISNetworld relies heavily on its users. From the buyers' perspective, the service becomes valuable as more suppliers join the database and demonstrate comparable credentials. From the suppliers' perspective, their incentive to join ISNetworld increases as it is adopted by more buyers. These demand side economies of scale coincide with the industry's need for standardization in certifications and regulatory requirements. As more businesses are attracted to the industry, the need for such two-sided networks will increase.

5.6 Technology Transfer

Marcellus Shale industries will utilize a variety of resources within its supply chain, ranging from high-tech computer monitoring systems to very non-technological mechanical items. Several of the main support groups in the supply chain for the Marcellus Shale include surveyors, heavy equipment operators, logging and land clearing, concrete, quarries, gas processing, equipment manufacturers, pipeline producers, and construction. Some of these suppliers are known within the industry, while others may have yet to be identified. The concept of technology transfer is not new around natural gas drilling, but understanding what technologies from other industries can be applied to Marcellus Shale is critical. The drilling process brings the best organizations from several industries together. Transferring technology between them is only logical. The primary suppliers to the project are directly related to the drilling and fracking process. Pipe, water, concrete, sand, and machinery are just a few of these suppliers. Provided the water purification unit, or units, can meet the capacity needs of the operation, there is no need to transport waste water off site. Additionally, concrete is used prevalently during the drilling and fracking operation. Producing concrete requires access to the correct raw materials and the ability to mix the slurry to the proper consistency. Having it trucked to the site requires a concrete supplier within a certain proximity. The location of the drilling site could dictate which option is utilized but this creates an opportunity for concrete suppliers, similar to that of the water treatment systems.

Radio Frequency Identification (RFID) is becoming an integral part of the supply chain as more companies are mandating its implementation through its suppliers. Even though RFID is primarily used in the manufacturing, distribution, and retail industry, significant cost, labor, and efficiency savings can be realized through its implementation. Applications for RFID technology in the gas drilling industry can be achieved through preventative maintenance schedules, theft protection, and procurement and purchasing activities:

- **Preventative Maintenance --** Large manufacturing equipment typically have preventive maintenance schedules to replace worn parts, upkeep on oil changes, and calibration standards. RFID technology would give a gas drilling company significant cost advantages by regularly performing the required preventive maintenance and reducing the downtime associated with malfunctioning equipment.

- **Theft Protection --** Knowing where a company's assets are at all times is critical to managing costs and maintaining the project timeline. RFID technology can eliminate production site thefts by labeling tools and significant capital equipment. This will ultimately reduce the risk of drilling at unfamiliar production sites and gaining employee trust.

- **Procurement and Purchasing Activities --** Procurement and purchasing activities can realize significant cost and efficiency advantages by implementing a RFID system. Upstream suppliers do not see the same type of cost, labor, and efficiency savings as their downstream partners; however, gas drilling companies can leverage their buying power and demand that suppliers implement a RFID system. Additionally, the Bullwhip Effect has a negative impact on the supply chain as there can be significant variation in inventory levels and a manufacturer's ability to utilize capacity. Gas drilling companies would obtain better demand forecasting for critical supplies and equipment needed for day-to-day operations.

This Marcellus Shale region is not new to drilling, or even horizontal drilling, but now the level of complexity is greater, which can make for more issues. These issues cannot be treated the same way each time, since often they will be well-specific solutions. Due to the one-off nature of these issues, many groups are studying problems at the wells. DOE has provided funding for grants to study different areas of the development of oil & natural gas. The Research Partnership to Secure Energy for America (RPSEA) has been contracted to administer the grants for the DOE. The RPSEA has acknowledged the difference in complexity in the Marcellus Shale and has responded by focusing the program on identifying the potential safety and environmental risks and the technologies to counter them. They are developing a Knowledge Management Database of issues and solutions to better educate those companies involved, through program-level technology transfer workshops that are focused on certain areas of concern where new solutions are commercially available. The National Energy Technology Lab (NETL) is tasked with overseeing the RPSEA's efforts in administering the grants. The NETL also conducts outreach workshops on new and best practices using technology in the oil & natural gas industry through its partner the Petroleum Technology Transfer Council (PTTC). The PTTC also works with several universities and industry groups to produce a technology newsletter on a quarterly basis. This industry-focused newsletter provides important technical news and information including new processes or products.

6 Conclusion

This study has attempted to add awareness to the current composition of the general Marcellus Shale supply chain. Through analysis of demand-side uses of natural gas, to the supply chain ranging from exploration to marketing, to understanding the characteristics and best practices of successful supply chain entrants, we have attempted to shed light on the vast amount of data available. Through this analysis, we have identified some important action items that a prospective supply company may take as entrance is considered to the Marcellus Shale supply chain. These are, in no particular order:

- **Partnering with Tier 1 or Tier 2 Suppliers --** Small manufacturers can partner with larger suppliers as their sub-contractors, in order to gain experience.

- **Use agreements to enhance production capability --** Given the advantage of economies of scale, small manufacturers can enhance their production capability and incorporate more products to cater to the Marcellus Shale Gas Industry, by initiating "as-needed" agreements.

- **Executing a Master Service Agreement with a major production company --** Getting selected as one of the approved vendors or manufacturers for a drilling company will allow for a more rapid acclimation as demand rebounds.

- **Concentrate on meeting health, environment and safety requirements --** Natural gas producers can only expect more regulatory scrutiny in the future. It therefore becomes important that their suppliers and contractors are able to adhere to all HES regulations, and exceed expectations.

- **Learn to adapt to changes in drilling activity --** The energy market is cyclical, and dependent on many macroeconomic factors.

- **Network, Network, Network --** As is the key for most business, who you know is important. Attend industry educational events, open houses, and tours, with the intent to widen the breadth of your professional network.

By understanding the broad economic forces at play, understanding the complexities and progression of the supply chain itself, and then understanding the proper background and characteristics for participants, regional businesses and manufacturers may be better positioned to participate in the Marcellus Shale development.

Acronyms & Abbreviations

API	American Petroleum Institute
Bcf	Billion Cubic Feet
DEP	Department of Environmental Protection (PA)
EHS	Environmental, Health, & Safety
EPA	Environmental Protection Agency (U.S.)
FY	Fiscal year
HBP	Held By Production
HES	Health, Environmental, & Safety
IRR	Internal rate of return
LNG	Liquid Natural Gas
Mcf	Thousand Cubic Feet
MMcf	Million Cubic Feet
MSDS	Material Safety Data Sheet
NGL	Natural Gas Liquid
NYMEX	New York Mercantile Exchange
OCTG	Oil Country Tubular Goods
PA	Pennsylvania
PADEP	Pennsylvania Department of Environmental Protection
PSI	Pounds per Square Inch
PUC	Public Utility Commission
RFID	Radio Frequency Identification
Tcf	Trillion Cubic Feet
US	United States
USEIA	United States Energy Information Administration
USGS	United States Geological Survey

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Appendix A – About the Research Team

Shaun Seydor, Associate Director, Institute for Entrepreneurial Excellence, engages in focused business consulting for start-up entrepreneurs as well as existing companies. One program that Mr. Seydor leads, PantherlabWorks, focuses on various forms of energy, sustainability, and emerging technologies. These initiatives encompass a broad array of emerging entrepreneurial opportunity, including renewable forms of energy, natural gas, green certifications, waste reduction strategies, inventions, and intellectual property.

Eric Clements, Management Consultant, Institute for Entrepreneurial Excellence, works with companies, through consulting engagements with the PantherlabWorks program, in the energy and technology sectors. Spyros Pantelemonitis and Vinay Deshpandeas worked as student intern consultants, with the PantherlabWorks Program, at the Institute for Entrepreneurial Excellence. In their work as contributors to this study, they represent the Katz Graduate School of Business.

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