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THE EFFECTS OF COAL AND NATURAL GAS IN PENNSYLVANIA

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ABSTRACT

The purpose of this paper is to point out three important aspects of the coal and natural gas industries that will influence their future in the Pennsylvania energy industry. Though these energy sources are used globally, local effects of production are significant. The communities that surround the energy reserves have a role in deciding how much they will publicly support the development of the resource and also will experience the economic and environmental impacts of it. The oil and gas in the US is both owned privately and by the government in the form of public lands. If people own the mineral rights, they have the freedom to determine which minerals they want to extract, where they want to go to extract it, and how much of it they want to produce. The US is one of the few countries where the minerals are not owned by the government. Energy companies have the right to extract energy, and this has opened up economic opportunities for those who live near the reserves and also those who consume it. Energy companies are among the most profitable businesses in the world. They can benefit people and communities on a local and regional scale by adding value to the Gross Domestic Product (GDP) of a state's economy, making more people employed, and having a positive impact in other ways. Although energy companies have significant roles in the extraction of natural resources, the federal and state governments in the US determine the legal framework in terms of taxes and laws, and they can provide financial support. The government can subsidize energy companies, resources, research and development, and other important aspects of the energy industry.

Economic incentives are important in a society where people can own the mineral rights to resources under private and public lands, and they are a major reason for why certain minerals are developed more than others. The price of coal is going up while the price of natural gas is going down. Understanding the current and historical trends of the costs of

extracting, refining, and distributing resources like coal and natural gas are critical. The fact that the price of coal and natural gas are both low is one reason why they are so widely used for goods and services like electricity, cooking, making steel, and others. There are many underlying reasons for why resources can be low-priced and, in general, why the supply, demand, and other economic forces on these resources change. People need energy, but it is important to develop these resources while taking into account the effects on the environment and peoples' health. Not factoring externalities into the price of the resource during the production of a resource can lead to consequences for others, and these issues are not always internalized by the companies that are causing them. There is a struggle among special interest groups and others to get coal and natural gas producers to internalize their costs.

There are many sources of energy that could be produced and consumed in Pennsylvania and the surrounding region. Coal has long been one of the most important sources of energy for Pennsylvania residents. Compared with coal, the use of natural gas has been expanding due to its competitive low price and the mitigated environmental and human effects from producing it. There is less air pollution, fewer fatalities at the workplace, a lower incidence of health problems for the workers and their local communities, and smaller negative effects on the environment where the resource is extracted. With respect to coal and natural gas production, this paper will examine the negative effects on peoples' health and the environment, the underlying economic forces that make it profitable, and other influences, such as the government and the people of Pennsylvania. It will conclude with a comparison of these major issues and factors. This will lead to a better understanding of the direction of the Pennsylvania energy industry, and whether coal or natural gas will become the more significant energy source for Pennsylvania residents.

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INTRODUCTION

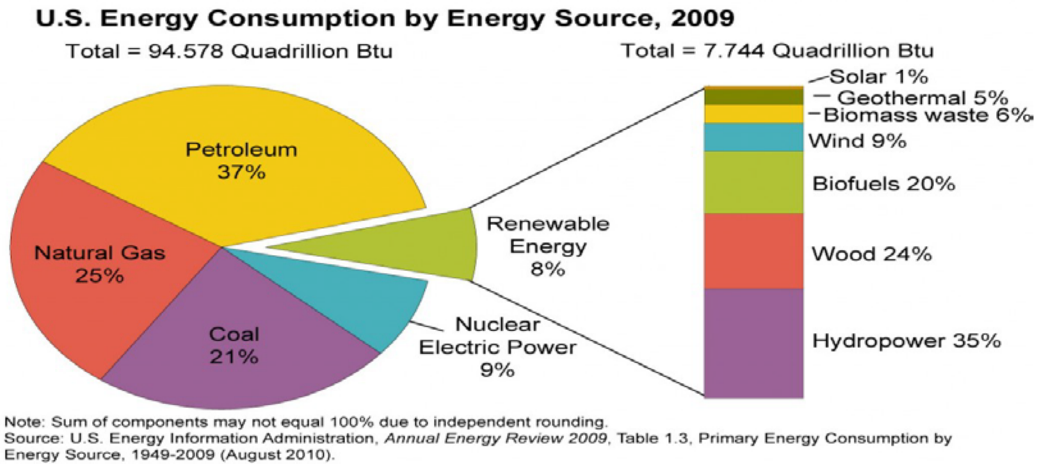
US Energy Market Overall

The United States is one of the top two of the largest consumers of energy in the world (International Energy Agency, 2010). One reason why the United States consumes so much energy is that the US has the largest economy in the world. One way to look at the US economy in relation to the economies of other nations is to compare its Gross Domestic Product, or GDP. US GDP is over double the GDP of any other nation, not including the total GDP of all of the member nations of the European Union (World Bank, 2011).

The US economy can be divided up into different sectors. Energy is being consumed in different places and in different ways. In the US, 41% of energy is consumed by residential and commercial buildings, 30% by the industrial sector, and 29% by the transportation sector as of 2009. In the residential sector, where people live, and the commercial sector, where people work, the majority of energy is used for heating and cooling, lighting, and appliances (US Energy Information Administration).

There are many natural sources of energy that power America today. Petroleum, coal, and natural gas are the most common fossil fuels that are burned for energy (Figure 1). Fossil fuels are nonrenewable energies, while solar, wind, and hydropower are renewable energies. Production from nonrenewable energy sources exceeds that of renewable energies in America.

Figure 1: US Energy Consumption Breakdown

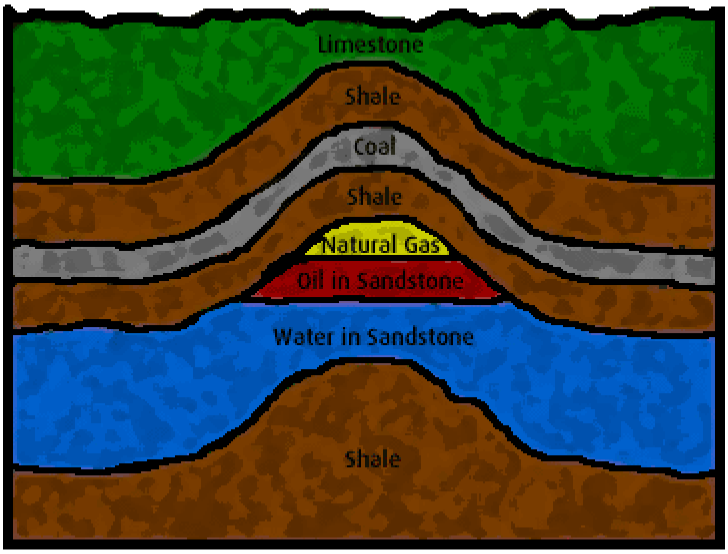


http://repoweramerica.org/wp-content/uploads/2011/04/us_energy_consumption_by_energy_source-large-1024x599.jpg

Coal and Natural Gas Introduction

Fossil fuels have long been the main source of energy for America. There is chemical energy in fossil fuels like coal and natural gas. Out of all of the fossil fuels, coal has been used by Americans for the longest time. Coal is rooted deeply in the history of the continent and of the United States. It was used by Native Americans long before the American Revolution, and it was one of the most important fossil fuels that powered the Industrial Revolution in the US (Kentucky Coal Education). Fossil fuels can be found at different distances and in different geologic formations below the surface of the earth. Coal is typically closer to the surface than natural gas. Due to the increasing demand for energy, developing nations are using more fossil fuels (US Energy Information Administration, 2011).

Figure 2: Where Natural Gas and Coal Are Found



http://www.scienceonline.co.uk/images/cross_section.gif

Figure 2 above shows the fossil fuels in one type of geologic formation underground. The dome-like structure indicates that this is an anticline. An anticline is an upward fold in the layers of the rock that allows for oil and gas to rise through the more permeable rock and collect just below the rock that is more solid, dense, and less permeable (Blue Ridge Group Inc.). Natural gas is a gas that is less dense than air, which is why it will naturally try to move upwards towards the earth's surface (Engineering ToolBox). Natural gas is an odorless, colorless, and combustible mixture of chemicals: over 70% methane, less than 20% butane, propane, and ethane, and less than 10% nitrogen, carbon dioxide, and others (Naturalgas.org, 2011). In Pennsylvania, there is gas in the Marcellus Shale, which is a shale rock that is between 0 and 9,000 feet underground and between 20 and several hundred feet thick (Pennsylvania Department of Conservation and Natural Resources, 2009).

Natural gas in shale is not always found near oil, and gas that is developed unconventionally is typically much deeper underground than coal. Coal is a black solid that can be found within a hundred feet of the surface. Coal mines typically do not go deeper than three to four thousand feet underground (US Geological Survey, 2009). It remains an important resource to developed nations like the US and is being increasingly used in developing nations. The four main types of coal in the US are anthracite, bituminous, sub-bituminous, and lignite.

Coal Versus Natural Gas Extraction

Extracting energy sources from the ground often requires using large machinery. Coal can be extracted by using the Bagger 288 (Figure 3). It is a giant bucket wheel excavator that was built in Germany in the late 1970s and holds world records as a terrestrial vehicle. The sand colored squares at the bottom of the machine on the ground are its wheels, and the yellow and white objects on the right-hand side of the screen are other vehicles. This machine is 2.5 football fields in length and weighs 45,500 tons (Dark Roasted Blend). New technologies have made coal transportation easier as well. One of the biggest trucks in the world, the Liebherr T 282B can transport more coal at a time (Figure 4). This truck can carry up to 365 tons, is powered by a 10.5 ton engine, and can be useful at larger coal mines. Indeed, some of the largest vehicles, machinery, and equipment in the world are built for coal mining.

The two main ways to extract coal are through surface mining and underground mining. Surface mining is used to extract coal within 200 feet of the surface, and it involves removing the surface layer of soil so that the coal underneath can be exposed. Underground mining digs up coal that can be up to 4,000 feet underground. Machines that are put underground dig out the coal, and conveyor systems transport the coal to the surface. Some underground mines require elevator shafts to transport workers to and from the mine (Tribal Energy and Environmental Information).

Figure 3: The Bagger 288

http://www.lubopiten.com/uploads/posts/2011-03/1300409457_takraf-rb293.jpg

Figure 4: The Liebherr T 282B

http://www.womp-int.com/images/story/2008vol6/14f.jpg

Hydraulic fracturing or fracking is a technology has been used for several decades to help produce oil and gas. Recent advances in fracking technologies have made it possible to extract natural gas from tight or less permeable shale rock and other places that were not reachable in the past. By using chemicals and higher volumes of water, hydraulic fracturing makes it possible for natural gas companies to extract more gas at a time. The ability to determine where the natural gas is underground has also improved. By using advanced seismic imaging technologies, gas companies can find natural gas that would have otherwise gone unnoticed. Horizontal or directional drilling is a new technology that allows companies to access gas that would have been unobtainable if only vertical drilling were used. Gas producers can now reach a gas reservoir that is not directly under the drill site. Coiled tubing is another technology that reduces the cost of drilling and reduces the amount of time needed to construct a gas well. New technologies are facilitating the extraction of natural gas (Naturalgas.org, 2011).

The wells are drilled and the wellbore is covered with cement casing to prevent leakage. The mixture of water, sand, and chemicals is then pumped thousands of feet underground to fracture the shale rock and release natural gas. It can be difficult to predict the placement and extent of the fractures, but technology allows for a reasonable estimate of how much natural gas can be extracted. If drilling leads to the extraction of gas, then it is a productive well (Naturalgas.org, 2011).

In the Marcellus Shale, unconventional drilling techniques are used to extract natural gas. Conventional wells are shallower wells that extract oil, natural gas, and other sources of energy that are closer to the surface using older technologies. Unconventional wells, which have been drilled more frequently recently, utilize more advanced hydraulic fracturing techniques to increase the amount of natural gas that can be extracted. While the gas was previously too far underground to be worthwhile to extract, natural gas companies can now create fractures in the Marcellus Shale to release natural gas from far below the surface and profit from producing it. Despite higher profit margins associated with fracking, there are potential environmental damages that result from it (Skeptoid, 2011).

Paper Objective

Coal and natural gas were both essential contributors to the American energy industry in the past, and they still are today. This paper will identify the current trends and the different factors that influence the production of each resource. The result will be a reasonable assessment of each industry based on a compilation of research.

The continued use of soft bituminous coal, and hard and clean-burning anthracite coal in Pennsylvania, and the increase in the drilling and hydraulic fracturing of the Marcellus Shale for natural gas has been important in meeting the region’s demand for energy. In addition to the economic gains of producing coal and natural gas, there have been concerns about their effects on the environment and peoples’ health. Most people need energy, and many people want to mitigate the adverse effects of extracting it.

US AND PENNSYLVANIA ENERGY INDUSTRY

US Energy Market: Why Coal

Most coal is used to supply electricity to the United States. Modern electronic devices today, including cell phones and light bulbs, need electricity to run. Electricity is produced in coal-fired power plants. The process begins when solid, black coal is burned to generate hot air above a fire. The hot air causes water to turn into steam. That steam is hot, moist air, and it can move quickly. The kinetic energy in the moving steam will rotate a turbine, which turns a generator and produces electricity.

Combining all fossil fuels, the United States has more recoverable resources than any other nation in the world (Right Wing News, 2011). With 28% of the earth's proven coal reserves as of 2008, the US also has more coal underground than any other country (US Energy Information Administration, 2008). Despite that coal has been mined for over a century in America, coal is abundant in the US, and it is economical to produce it. In the US, bituminous and sub-bituminous coal account for over 90% of the coal that is produced. Bituminous coal is the predominant type of coal that is mined in Pennsylvania. Anthracite coal comprises only .2% of coal production and is only mined in northeastern Pennsylvania (US Energy Information Administration, 2011). Despite that coal has an integral role in the American economy, there are health and safety concerns associated with mining it. Creating legislation that can reduce the health and environmental risks from coal production has been an ongoing process.

Environmental and Human Health Impacts of Coal

There are health and safety hazards of coal mining, which includes risks for the miners, their families, and other people who are affected by the pollution. The externalities that coal production inflicts on people have begun to be regulated. According to the US Department of Labor Mine Safety and Health Administration, US coal mining has been regulated since 1891. The 1891 law said that children under 12 years of age were not allowed to work, and that there were minimum ventilation requirements for the mines that could reduce risks. Other key legislation to make mining safer was passed in the 1950s and the 1960s, but the legislation that applies to coal mining today is the Federal Mine Safety and Health Act, or Mine Act, of 1977. This act consolidated all of the federal agencies and legislation that applied to coal mining safety. It also strengthened the rights of miners and shielded them from retaliation if they wanted to speak up against dangerous working conditions. In 2006, the passage of the MINER Act added new regulations for the safety responses to mining accidents (US Department of Labor).

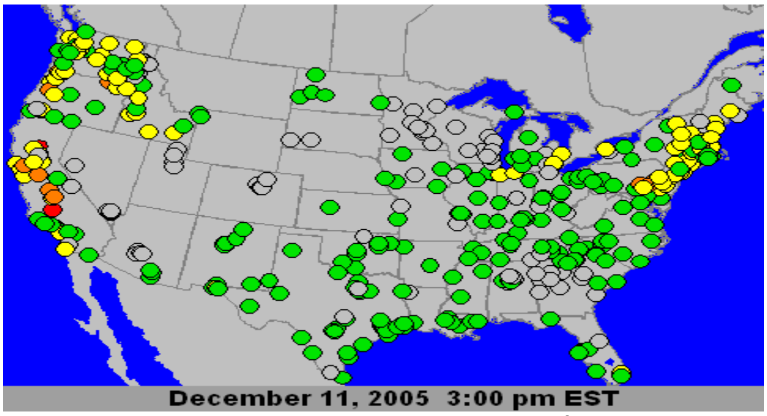
There are many pollutants that are released during coal production that could threaten peoples' health. In 1986, the federal government established the Emergency Planning and Community Right-To-Know Act, which designated facilities such as electric utilities that burn oil or coal to report which of the 650 listed chemicals were released into the air from their plant. The tall stacks at coal plants are supposed to disperse the chemicals as they enter the atmosphere. Air releases, as opposed to water or land releases, account for 77% of coal plants' release of chemicals into the environment (Porter, 2006). In 2011, the EPA enacted its national emissions standards for hazardous air pollutants from coal and oil electric utility steam generating units. Many utilities will need to be install pollution controls to reduce the amount of toxic substances emitted, including mercury, arsenic, and nickel (Environmental Protection Agency, 2012).

There are many chemicals that are released into the atmosphere after coal is burned: nitrous oxides, sulfur dioxide, carbon dioxide, methane, hydrochloric acid, mercury, arsenic, particulate matter, and others. Eighty-four of the 187 hazardous air pollutants that the EPA deems carcinogenic, probable carcinogenic, or toxic (causes human health problems) come from coal plant emissions. In terms of particulate matter, the following chemicals are either probable or proven carcinogens: beryllium, cadmium, chromium, nickel, radium, selenium, tetrachlorodioxin, naphthalene, and uranium. There are also volatile organic compounds (VOCs), which are particles released by coal plants that are toxic: benzene, toluene, ethyl benzene, xylene, and formaldehyde. Coal emissions are the point source cause of 46% of mercury emissions and 60% of arsenic emissions (Environmental Health & Engineering, Inc., 2011).

Another way to look at how the chemicals from coal affect the general population is to examine the distance and time that particles can remain in the atmospheric. Particles' residence time, which is the length of time that a particle will stay in the air, is a good way to measure how far the particulate matter can travel. One report demonstrated that many of the toxic and carcinogenic substances from coal plants that were studied had a residence time of several days or more (Environmental Health & Engineering, Inc., 2011). This means that the local and regional populations were at risk of being exposed to the chemicals.

The greatest impact of pollutant emissions varies. For some particulates, the most negative impacts occur within one mile of the actual coal plant. The particles with higher residence times that stay in the air longer can traverse a wider geographic area, such as from one state to another. See Figure 5. In Pennsylvania, where much more coal is burned than in New Jersey, there are mostly green dots. This indicates acceptable levels of particulate matter. There are yellow dots in New Jersey, which indicate more hazardous levels of particulate matter. New Jersey has far fewer coal plants than Pennsylvania, which ranks among the top five in the US in terms of number of coal-fired power plants (US Energy Information Administration). This could indicate that some of the particulate matter migrated through the atmosphere from Pennsylvania or other states to New Jersey. In one case, New Jersey governor Chris Christie and his administration filed a lawsuit against Pennsylvania-based Allegheny Energy Inc. for letting one of its coal-fired power plants, Homer City Station in western Pennsylvania, continue to emit 100,000 tons of sulfur dioxide annually and violate the Clean Air Act. The governor claimed that eastward winds were bringing the sulfur dioxide pollution from the plant to New Jersey. The residence time of particulate matter is important because it can cause regional effects.

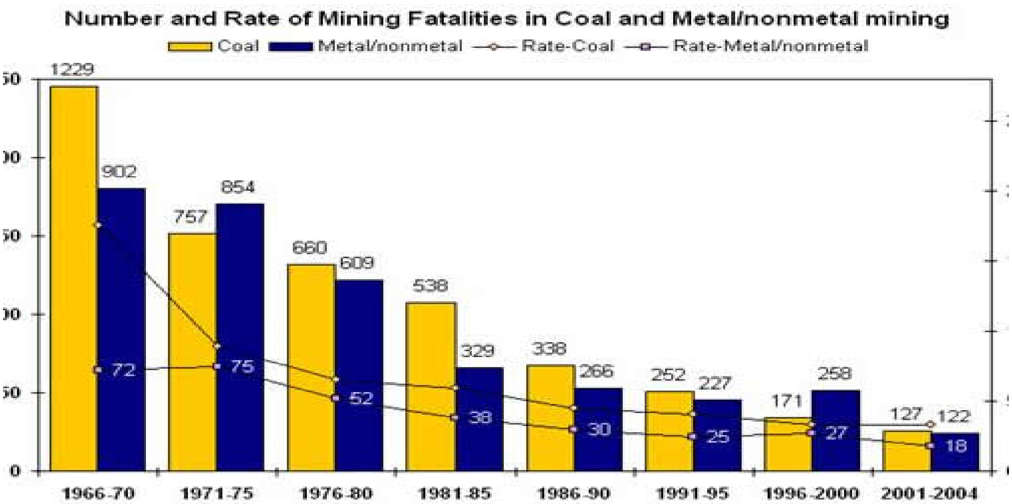
Figure 5: A Random Sampling of Particulate Matter Concentration



http://alg.umbc.edu/usaq/images/pm25_super_12-11-05.gif

People are more at risk of health problems when in contact with dangerous chemicals, but mining coal is particularly dangerous. According to a 2010 report by the Bureau of Labor Statistics, the fatality rate for coal miners in 2007 was 24.8 deaths per 100,000 full time coal mine workers (Figure 6). There has been a decrease in the number of coal mining fatalities from decades past. Safety legislation such as the Federal Mine Safety and Health Act, and the introduction of safer mining equipment and machines has helped reduce the rate of fatalities in coal mining (Mine Safety and Health Administration). Despite the declining rate, the coal industry's fatality rate is still nearly six times higher than the average rate for American private sector industries (US Bureau of Labor Statistics, 2010). There remain many risks associated with coal mining.

Figure 6: Coal Mining Fatalities



http://www.cdc.gov/niosh/programs/mining/images/image004.jpg

Compared to other professions, there is a higher risk that coal miners will be killed while working with coal. First of all, the roof of a coal mine can collapse. This can be caused by an earthquake, the lack of support for the ceilings, or cracks along the ceiling of the mine. The natural earth can crack more easily if the land is dry (Parry, 2010).

Second, explosions can occur unpredictably, whether it be due to methane or coal dust. Methane concentrations need to be kept below one percent for the mine to be considered safe. If methane concentrations are between 5 and 15 percent inside the mine, then the methane is potentially explosive. Methane is very flammable, and it can be difficult to properly detect methane levels due to the fact that it is colorless and odorless (MethaneGasDetectors.com, 2007). Coal dust can also cause explosions. Explosions need fuel, oxygen, and heat to occur. In coal mines, there is always fuel energy in coal, oxygen, and heat in those often small, cramped spaces with many workers. In some mines, less heat is required for explosions to occur than others (Stephan). Coal mining is extremely dangerous due to the fact that explosions can occur at any time.

One study on the health effects on coal miners demonstrated that there could be consequences on the body's respiratory system, including bad development of the lung functions in young children and the aggravation of asthma. The cardiovascular and other vital bodily functions that are vital to good health can be negatively impacted due to the inhalation of particulate matter, NO_2, and other pollutants released by coal (Lockwood et al., 2009).

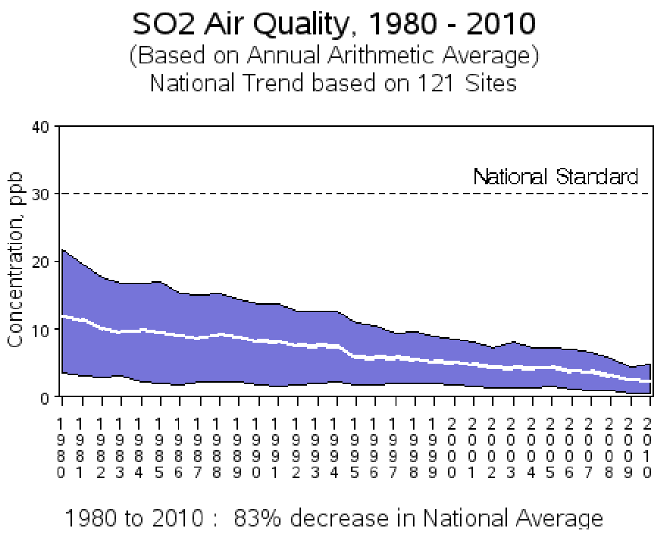
In addition to the coal miners themselves, the communities in which they live are more at risk of being negatively impacted by coal. Miners and their families in these communities, according to a 2008 study by the Institute of Health Policy and Research at West Virginia University, have a 70% increased risk for developing kidney disease and a 64% increased risk for developing chronic obstructive pulmonary disease. The reasons cited in this study include air and water pollution. Coal dust can become airborne after being hauled by a truck and then inhaled, and chemicals can get into the local water supply via rain runoff. Coal dust contributes to black lung disease. People can be exposed to many toxic substances contained in coal by working with coal and interacting with coal miners. These statistics were adjusted for the fact that people who live in these rural communities in West Virginia have less access to healthcare, live in poorer economic conditions, and have statistically higher rates of smoking (Energy Justice Network).

Mining communities are among the areas with the highest mortality rates in the United States (Hendryx, 2009). Also, they are more vulnerable to flooding. In nearby mountaintop removal mining sites, there are no trees and natural earth to absorb water as effectively. Sludge impoundments are open air pits of sludge made up of toxic and carcinogenic chemicals that can leak or fail completely as well. The failure of the impoundment in Martin County, Kentucky in 2000 led to a spill of 300 million gallons of toxic sludge into the Big Sandy River. The EPA declared it shortly thereafter as the worst environmental disaster east of the Mississippi River (Appalachian Voices, 2012).

Nitrogen oxide, sulfur dioxide, and carbon dioxide are the three main pollutants from coal that negatively impact the environment. There are many carcinogenic and toxic chemicals that can adversely impact the environment, but these are three of the most potentially harmful compounds that are usually associated with the environmental impacts from coal plants.

Though it is found from multiple sources and can be used for some positive purposes, sulfur dioxide is a major pollutant from coal plants that can contribute to the issue of smog, can damage trees and agricultural crops, and is a big contributor to acid rain. Acid rain, or rainwater with a pH lower than 5.6, is caused by the release of sulfur into the air by the burning of fossil fuels. The sulfur combines with oxygen to form sulfur dioxide and can travel hundreds of miles in the atmosphere before it comes down as rain and makes the environment more acidic. The Northeast US sees the greatest concentrations of acidity when samples are collected from rain (US Geological Survey, 2012). Sulfur dioxide concentrations have been significantly reduced via environmental regulations (Figure 7).

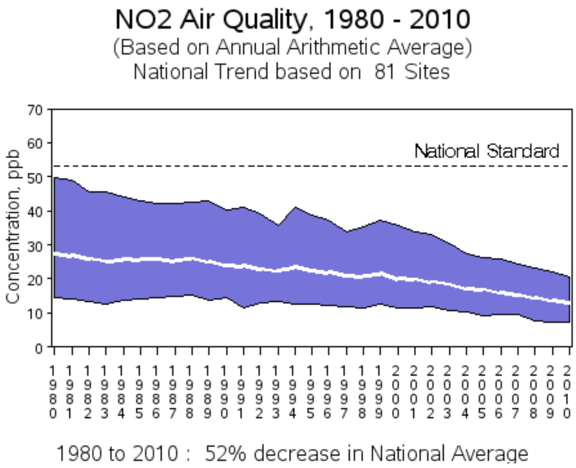
Figure 7: Sulfur Dioxide Concentrations



http://www.epa.gov/air/airtrends/sulfur.html

When talking about nitrous oxides, officials are usually referring to nitrogen dioxide (NO_2). NO_2 reacts with sunlight in the summer to form smog or polluted air. Nitrous oxides also contribute to the formation of acid rain, which can poison the forests, rivers, streams, lakes and fish, and the soils that it comes in contact with. Leaves can become more vulnerable to disease, and rocks and soil minerals are broken down (Phamornsuwana). Nitrous oxides have being reduced in concentration (Figure 8).

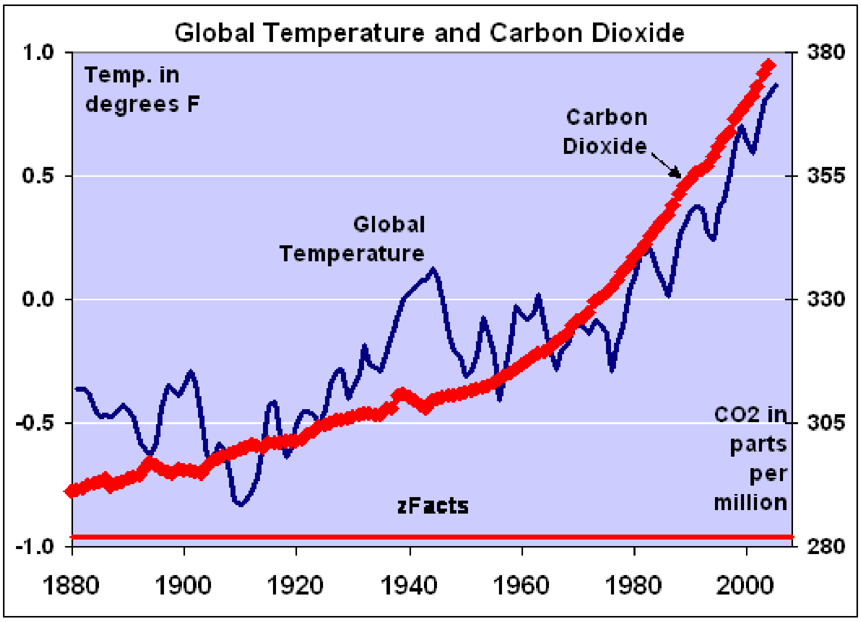
Figure 8: Nitrogen Dioxide Concentrations



http://www.epa.gov/airtrends/nitrogen.html

Carbon dioxide is a greenhouse gas. Studies show that there is a direct correlation between carbon dioxide concentrations and global temperatures (Figure 9). Global warming is the rise in global temperatures due to the increase in heat-trapping greenhouse gases in the atmosphere that absorb the heat that would otherwise be released into space. Many scientists believe that global warming will lead to higher sea levels, the endangered of many animal species, and more severe weather events. With evidence that it is caused by humans, global warming could also adversely affect the American economy by impacting the energy, agriculture, and healthcare industries (US Global Change Research Program, 2009).

Figure 9: Carbon Dioxide and Global Warming Correlation



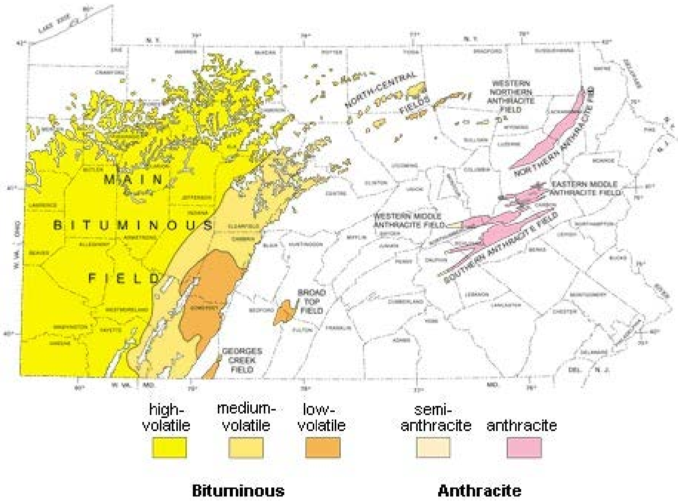
http://zfacts.com/metaPage/lib/zFacts-CO2-Temp.gif

Economic Impacts of Coal

In 2010, the contributions of coal to the Pennsylvania market included significant job creation and economic output. Indirectly and directly, coal is estimated to have generated 41,500 full-time and part-time jobs, as well as contributed $7.5 billion in output to the Pennsylvania economy. Coal workers enjoy higher wages that were 20 percent above the average manufacturing wage (Pennsylvania Economy League of Southwestern PA, LLC, 2010). Another report about the contributions of coal to Pennsylvania's economy confirmed that coal adds $7.5 billion per year. In terms of jobs that are directly related to coal production, 9,000 Pennsylvania residents are employed by the coal industry (Stelle, 2010).

One of Pennsylvania's most abundant resources, coal is cheap in part because there is so much of it. Since supply is high, the relative value per unit of coal is less, which implies a lower price. There is a large section of western Pennsylvania where there is bituminous coal below the surface (Figure 10). West Virginia and Kentucky are the only two states that have more total mines than Pennsylvania, which has 240 mines. Alpha Natural Resources, LLC and CONSOL Energy Inc., the fourth and fifth biggest coal-producing companies in the US, operate mines in Pennsylvania. Clearly, coal can still be found in large areas of Pennsylvania today, and coal companies continue to economically extract it (US Energy Information Administration, 2011).

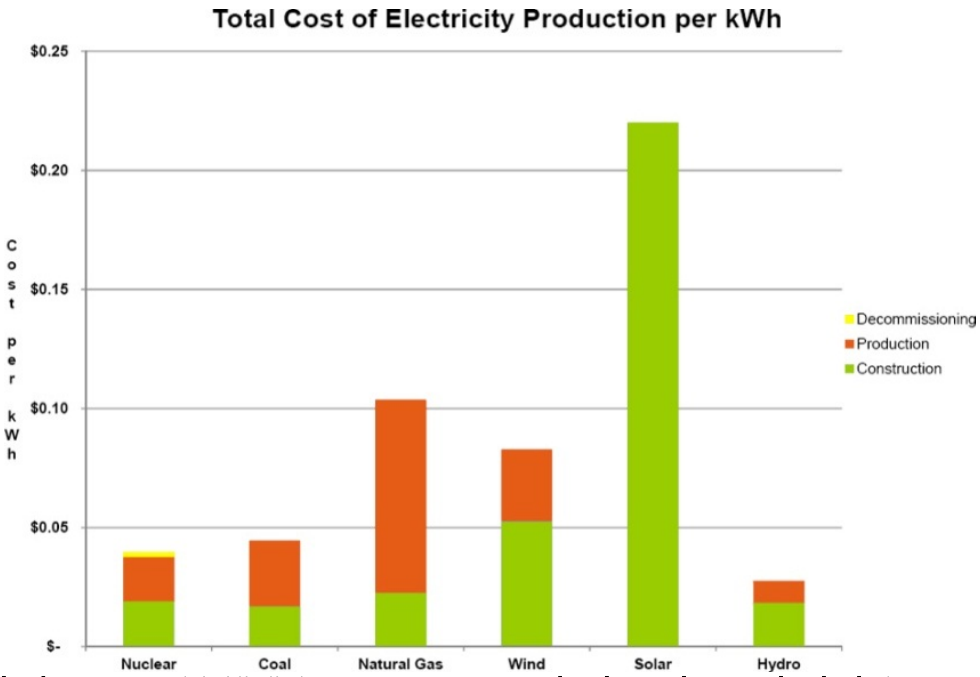
Figure 10: Coal in Pennsylvania



http://www.dcnr.state.pa.us/topogeo/coal/index.aspx

Pennsylvania coal is important to the US coal industry because it is the fourth biggest producer of coal in the country, and over a third of in-state coal production is still exported to nearby markets. Baltimore and Philadelphia, two major metropolitan areas, receive energy from Pennsylvania's coal (Schwartzel, 2011). In addition, Pennsylvania is home to two major research hubs. One of them is the National Energy Technology Laboratory, which focuses largely on clean, efficient, and environmentally friendly power from coal. The other is CONSOL Energy Research & Development, which researches methods of producing power more cleanly and efficiently as well. They incorporate a combined $500 million into their research and development of coal each year. Pennsylvania is also a center for the manufacturing of mining machinery and equipment. Coal is an integral part of not only the economy of Pennsylvania, but also for exporting energy to surrounding markets and for doing research to improve American coal production methods (Pennsylvania Economy League of Southwestern PA, LLC, 2010). One of the main factors that makes Pennsylvania coal economically viable is its price.

Figure 11: The Cost of Coal



http://nuclearfissionary.com/2010/04/02/comparing-energy-costs-of-nuclear-coal-gas-wind-and-solar/

Figure 11 shows the prices of some of the energy sources in the US energy market as of 2008. The bar that is second from the left represents the cost for coal. According to this graph, the price of coal was at about four cents per kWh, compared with four cents per kWh for nuclear, and three cents per kWh for hydroelectric. The price for each energy involved determining the individual costs of construction, production, and then decommissioning the means of production afterwards. According to this graph, the construction costs for coal were equally cheap if not cheaper than the construction and installation costs of other energy sources. Though the price of coal is low and it appears to be one of the cheapest resources that produce electricity, one study indicated that the external costs of coal amount to over $345 billion. The effects included air and water pollution, the adverse impacts on peoples' health, and others (Epstein et al., 2011). There are externalities that are not always reflected in the price of coal.

While coal is cheap compared to other energy sources, Appalachian coal is more expensive than coal from other regions of the US. There is less coal in the Appalachian region that can be mined easily because it is a practice that has been going on in Pennsylvania for over a century, and the remaining coal is deeper and harder to mine. Pennsylvania coal production in 2003 was lower than production in 1973. The number of coal mines in the Appalachian region dropped from 4,423 in 1973 to 1,143 in 2003. On the supply side, more sophisticated technology is needed to extract coal that is further underground, and productivity is lower due to the fact that the coal is harder to extract. This suggests an upward trend in coal prices (US Energy Information Administration, 2011).

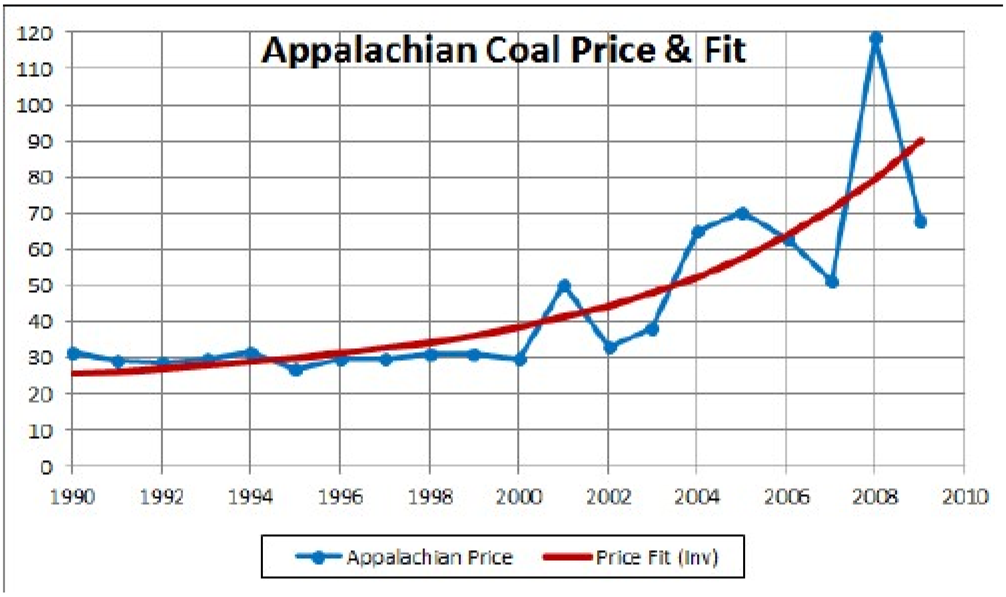
In addition to the lower supply of accessible coal in the Appalachian region, the demand for coal is increasing internationally. Coal consumption in China went up 50% from 2005 to 2010, and more US Appalachian coal is being exported to China (Kasey, 2012). A significant amount of international exports of US coal come from the Appalachian region (US Energy Information Administration, 2012). One reason for this is that bituminous coal produces more heat energy than coal from other regions of the US, where the coal is softer and does not generate as much heat when burned. Bituminous coal and anthracite are harder types of coal with more heat content, which is between 20 and 25 million BTU per short ton for both of these types. The heat content of sub-bituminous coal is around 17 million BTU per short ton (Office of the Texas Comptroller). Coals of higher heat content can be more valuable because they produce more energy when burned.

Reserves of bituminous coal in western Pennsylvania and anthracite reserves in northeastern Pennsylvania are declining, which means that there is a lower supply of coal in the face of rising demand from developing nations like China and India. The demand for coal in China caused the US to export about 2,700 tons of coal to China in 2009. In just the first half of 2010, 2.9 million tons of coal was exported from the US to China (Frick-Wright, 2011). The EIA predicts that China will increase its usage so that its consumption equals more than half of global coal consumption by 2025 (Spears, 2010). According to a 2011 report by the National Mining Association, US exports of coal went up 39% from 2009 to 2010, which represented the highest level of exports since 1997. This increase was helped by an increased demand in Asia for coking coal to make iron and metal. Appalachian coal is becoming an important export to those outside of the US (National Mining Association, 2011). Declining productivity, competition from other regions of the US where coal is mined, and being less able to meet supply expectations may make Appalachian coal more expensive.

There are also government regulations that increase the price of producing coal. One goal of the EPA is to regulate greenhouse gas emissions based on their claims that greenhouse gases endanger the health and welfare of people. On March 27, 2012, the EPA implemented legislation that would require that new power plants emit a maximum of 1,000 pounds of CO_2 per megawatt hour of electricity produced. Coal plants generate around 1,800 pounds of CO_2 per megawatt hour, which means that current plants would not be able to meet regulations (Lemonick, 2012). Additionally, the EPA initiated new standards under the Clean Air Act in December of 2011 to limit emissions of mercury, which is a neurotoxin that is emitted during coal combustion and can be particularly damaging to the health of newborn children (Broder, 2011). Both of these pieces of legislation from the EPA mean that coal-fired power plants are becoming more expensive because coal companies need to pay more for the external costs of coal production on the environment.

Other government programs that will push coal prices up include the Abandoned Mine Lands Fund. In the US, 60% of all abandoned coal mines can be found in Kentucky, Pennsylvania, and West Virginia, and most abandoned coal mines are located closer to more populated areas (Abandoned Mine Lands, 2012). Over one million Pennsylvanians live within a mile of an abandoned coal mine. The government fund requires coal companies to pay a tax in Pennsylvania, which will finance the cleanup of these sites. Though the federal fund expired in 2004, money is still being allocated for this cause. Abandoned mine lands create issues with water pollution and safety. The high walls and low pits are dangerous for children and others that play in and around these sites (PennFuture, 2012). This is another example of environmental regulations requiring energy producers to pay for doing business, and it demonstrates the upward pressure on coal prices due to government regulations.

Figure 12: Price of Coal in USD per short ton



http://www.roperld.com/science/minerals/CoalPriceFit.jpg

The average price of Appalachian coal in the United States in the 1990s was relatively stable, but began a gradual increase in the 2000s (Figure 12). In 2008, the price of coal went up for multiple reasons. Floods in Australia and a power crisis in South Africa led to a shortage of coal. These two countries both produced coal and were now unable to supply as much, which created a shortage that inflated prices (Seeking Alpha, 2008). Another influence in the increase in the price of coal was the expanding economies of the developing countries such as India and China. The shortage of coal in these nations contributed to the higher prices also.

The Great Recession of the late 2000s, which lasted until early summer 2009, was the main reason for the fall of the price of coal in 2008. Most industries in the US and abroad lost business because few companies had the financial means to buy as much coal as usual. This lowered the demand for coal, which led to a reduction in the price of coal.

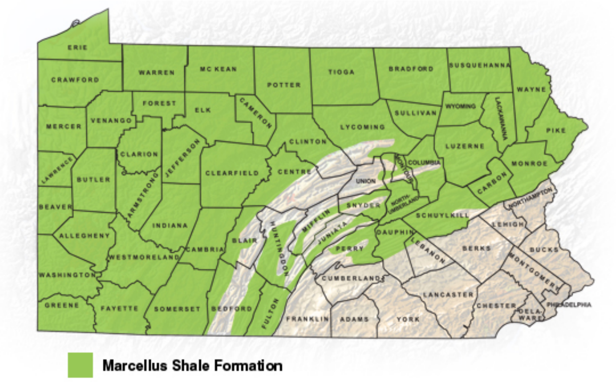
The price of coal became more volatile in the 2000s, spiked right prior to the Great Recession, and declined sharply during the economic crisis. The price of coal was more volatile and less inclined to stay at a constant low price in the 2000s. In an uncertain economy, this trend could continue.

US Energy Market: Why Natural Gas Now

The first use of natural gas in the country was successfully demonstrated in northwest Pennsylvania when Colonel Drake discovered oil and natural gas less than 100 feet below the surface. A gas pipeline was built to connect Drake's well to the village of Titusville, Pennsylvania. In Fredonia, NY, which is nearby in the southwestern part of the state, William Hart dug the first well that was intended solely for natural gas. Fredonia Gas Light Company became America's first natural gas company. Natural gas production is made up of many small, independent producers of gas that have about 12 employees on average (Gjelten, 2009). In the 1800s, there was the idea of using a Bunsen burner to use natural gas for heating and cooking. This represented another way that natural gas could be used. Since then, drilling technologies have evolved so that modern shale gas drilling can reach gas reservoirs thousands of feet below the surface. Natural gas has grown to be used not only for energy, but also for everyday American products, including plastics, fertilizer, and anti-freeze.

In Pennsylvania, the Marcellus Shale is the biggest reservoir of unconventional natural gas (Figure 13). The shale exists several thousand feet underground, from southern New York State through West Virginia. It is being explored by gas companies all across the state, but the highest concentrations of drilling activities are in the northern and southwestern parts of Pennsylvania. The Marcellus Shale is one of the largest natural gas reservoirs in the United States. It is a unique geologic formation because of the existence of many natural fractures and also the presence of pyrite, or fool's good, both of which could make it easier to extract more gas. The average amount of natural gas that is recoverable from a tight shale rock is 10%. However, since there are more natural pathways for gas to move in the Marcellus Shale, the recoverable gas in this basin may be much higher than 10% (Museum of the Earth).

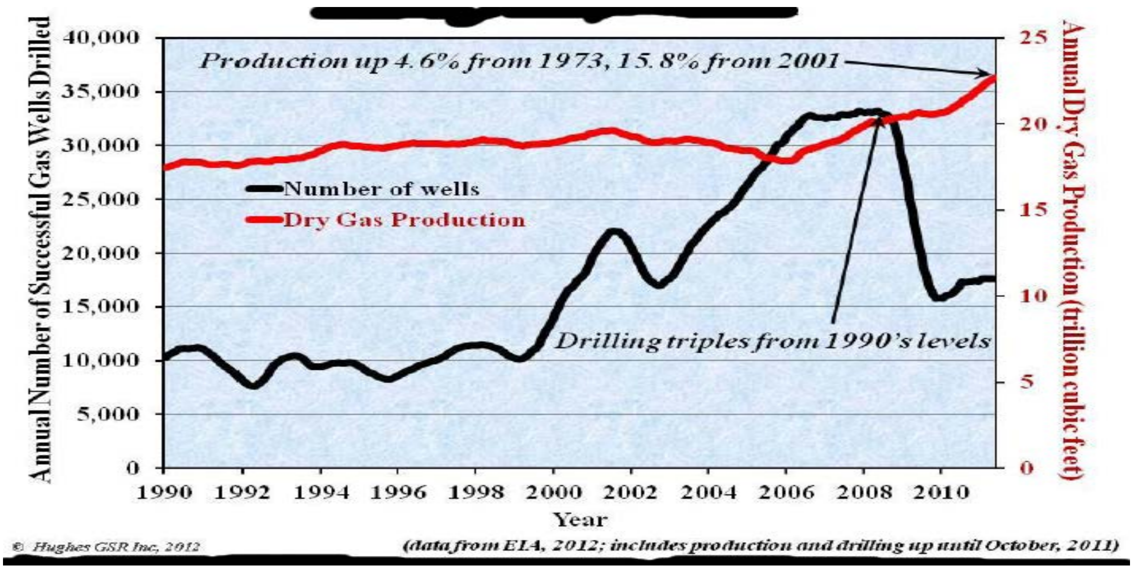
Figure 13: The Marcellus Shale in Pennsylvania



http://www.cleanair.org/sites/default/files/u6/marcellus%20shale.jpeg

The development of unconventional natural gas reserves is allowing for the expansion of natural gas production in the US (Figure 14). Prior to the year 2000, natural gas production was stagnant. In the 2000s, there was a rapid increase in the development of unconventional and deeper gas wells that complemented the continued gas production from conventional, shallower wells. From 2001 to 2011, gas production increased 15.8%. In the late 2000s, the drilling of new wells was over triple the drilling levels of the 1990s. During and after the Great Recession of the late 2000s, the number of natural gas wells being drilled annually was still over 50% above drilling levels of the 1990s.

Figure 14: US Natural Gas Production



http://www.postcarbon.org/articles/Drilling-rates-1990-2011.PNG

There are multiple reasons for the increased development of US natural gas. One is that there are newer technologies that make it economical to develop gas reserves deeper underground, including in shale rock. The shale rock represents one of the geologic formations where natural gas exists naturally. Other unconventional sources include coal-bed methane and tight sandstones. Previously, natural gas in the shale gas regions of the Marcellus, Haynesville, Barnett, and other shale formations thousands of feet below the surface was unobtainable. New extraction potential in the Gulf region and in the Rocky Mountain regions of the US has led the Potential Gas Committee (PGC) to increase its estimates of recoverable gas in the US. The PGC, which is a committee that was originally formed by natural gas industry professionals, placed its total US gas estimates at 1,898 trillion cubic feet as of the end of 2010. The committee has been around for 46 years, and its recent gas estimate is the highest amount that it has ever made (Potential Gas Committee, 2011). According to the US Department of Energy, the amount of natural gas in the Marcellus Shale in and around Pennsylvania is 141 trillion cubic feet. From 2010 to 2011, the daily rate of gas production from the Marcellus Shale doubled (Schwartzel, 2012).

The improvement of technology for gas production involves the advancements in the use of hydraulic fracturing. Hydraulic fracturing was first introduced by Halliburton in the late 1940s to enhance oil and gas well drilling. Since then, over 90% of wells in North America have used hydraulic fracturing to stimulate gas production, including both conventional and unconventional wells. In unconventional wells, hydraulic fracturing requires that a higher volume of water mixed with sand and toxic chemicals be pumped into the ground. Between 70 and 300 times more fluid needs to be injected into the ground when using "slick-water hydraulic fracturing," which is the more modern version of hydraulic fracturing.   The higher volume of water and the need for chemicals are two of the main distinctions between the hydraulic fracturing technique of today and the older form of fracking (TCgasmap.org, 2011). Unconventional gas production using the newer version of hydraulic fracturing is two to three times productive than conventional vertical gas wells (Jackson et al., 2011).

With regard to Marcellus Shale gas wells, three to five million gallons of water must be pumped down underground in each well in order to fracture the shale rock. Since the shale rock that makes up the Marcellus is not uniform, some fractures will be longer than others even if an equal amount of water is pumped. Shale rock in the Marcellus is naturally fractured, and methane and natural gas can migrate upward due to the cracks in the rock. Natural gas can be extracted both unconventionally and conventionally, and it can move around in rock formations due to these cracks. Marcellus is black shale with higher organic content and has more carbon energy than gray shale (Paleontological Research Institution, 2011).

One major component of modern drilling success is directional drilling. Directional drilling is drilling into the ground in both the vertical and horizontal directions. Once the location of the natural gas underground has been estimated, it is important that the drill bit is maneuverable and can move in multiple directions so that the reservoir of gas can be reached. There are many objects that could potentially get in the way of drilling, including cables, pipes, and naturally occurring elements. Also, only being able to drill vertically can limit the amount of gas that is extracted. Directional drilling can help a driller avoid all of the things that might get in the way, surface excavation is not required, and it is safer by not making workers work underground (The Robert Henry Corporation, 2012).

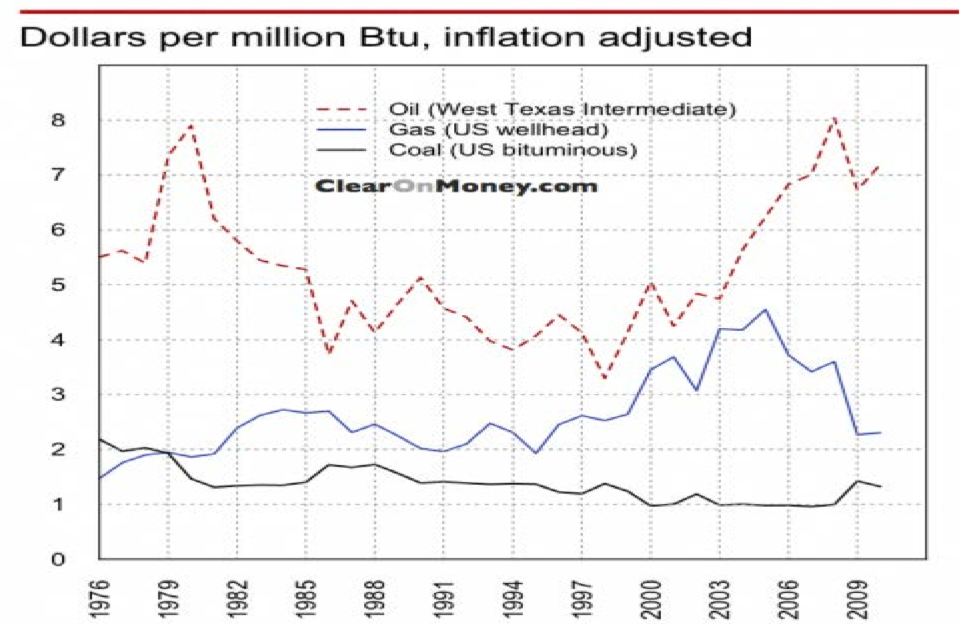
Research in more natural gas extraction technologies was expedited in the 1970s, when scientists were concerned that natural gas supplies may be declining. They began examining the potential for gas in unconventional places, which are in less permeable rock formations and spaces. Funding from the DOE spurred more research and development of more advanced drilling techniques (US Department of Energy National Energy Technology Laboratory, 2011). Another aspect of the improved technology is the underground imaging of the resource. 3D and 4D drilling allows natural gas producers to see natural gas underground more accurately. Dynamite or vibrator trucks can be placed over a potential natural gas reservoir and can create seismic waves. The time it takes for the waves to come back to where they were first emitted will generate a picture of what the subsurface looks like. Three-dimensional imaging allows experts to rotate an image horizontally or vertically to get a better idea of what the underground looks like and where the gas might be. The use of 4D imaging incorporates the element of time. This helps industry analysts better estimate the amount of recoverable gas that will be in the basin over a period of time, as opposed to just at one particular moment (San Joaquin Valley Geology, 2011).

Other improvements in the natural gas industry technology include using sand in drilling, which can help widen the cracks in the earth and allow for more natural gas and oil to come out from the rock. Once the water that is pumped in high volumes fractures the shale rock, the sand will flow into these cracks and prop them open. This helps ensure that the fractures remain open while gas is being collected. Adding chemicals to the mix of sand and water will help with extracting gas, and they can all be used for different purposes. There are chemicals that will facilitate the flow of fluid and gas, prevent the formation of obstructive substances in the well, help keep the fractures open, and prevent the formation of organisms that might contaminate the gas. While chemicals make up less than 2% of the injected fluid, the total amount of chemicals is higher when millions of gallons of water are being injected per well (Earthworks, 2012). Also, slim hole drilling allows gas producers to improve the efficiency of gas extraction and reduce the environmental footprint by using drill bits that are less than six inches in diameter. This form of drilling also leads to lower drilling costs because smaller machinery is generally cheaper. The improvements in technology in the natural gas industry make natural gas production more efficient and profitable for gas companies (Naturalgas.org, 2011).

Another reason for the expansion of the natural gas industry is the increased demand for energy, particularly cleaner energy. There is a growing need for energy in developed countries where natural gas infrastructure is already in place and also in developing nations where natural gas can be integrated. A growing world population means that the total amount of energy produced will need to increase, that energy efficiency must go up, or that sustainable energy choices need to be made. It is important to meet energy expectations in the long run. There will be demand pressures associated with more people wanting energy, and there are typically supply pressures with natural resources as well (World Energy Council, 2007).

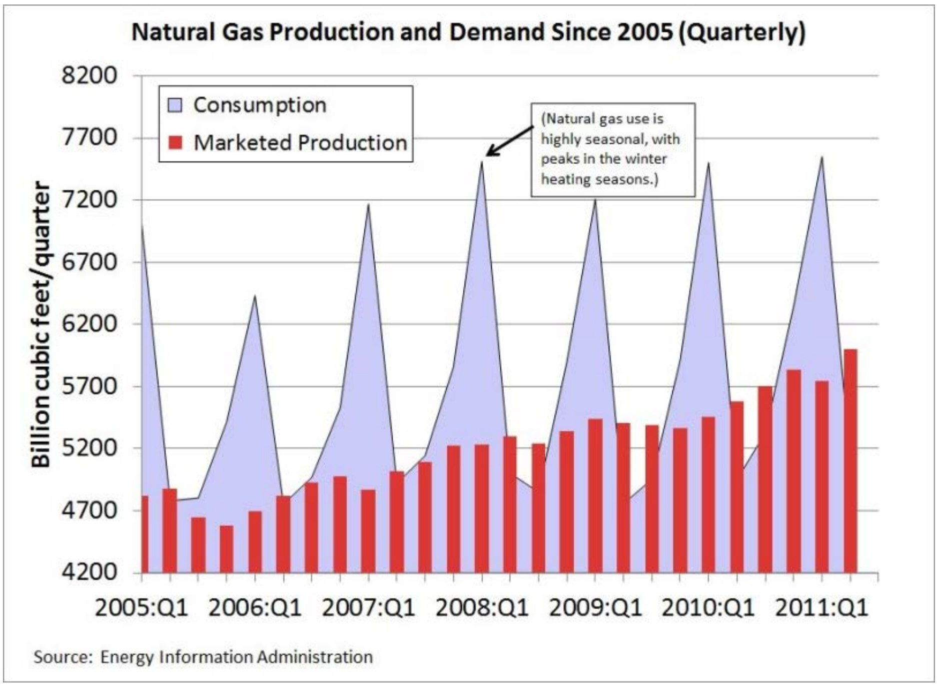
One of the reasons that we are seeing this increase in the demand for natural gas is due to its low cost. Natural gas is currently cheap. The price of natural gas is low enough to make it competitive with other energies. It is dropping much more rapidly than oil, particularly since the mid 2000's (Figure 15). Here are several reasons why natural gas prices are so low. The first reason is that supply exceeds demand. There is much more natural gas being supplied than demanded. The current increase in supply of natural gas can be mostly attributed to the increase in the drilling of unconventional gas wells (WallStreetDaily.com). Since the first quarter in fiscal year 2006, consumption or demand of natural gas has been increasing, and production or supply has been going up, too (Figure 16).

Figure 15: Price of Oil, Natural Gas, and Coal



http://www.clearonmoney.com/dw/lib/exe/fetch.php?w=480&media=public:fossil_price_annual2010.png

Figure 16: Supply and Demand of US Natural Gas



http://www.ipaa.org/news/press_releases/2011/2011-09-19_151.php

Another reason is that the political risk associated with natural gas is smaller than the political risks with coal and oil. When the supply of coal from Australia and South Africa went down, the price of coal for industries in the US went up. US consumption of natural gas does not rely on imports from potentially unstable countries, including nations in the Middle East, as much as the US does with oil. There is more domestic energy security with natural gas. There is less political risk associated with natural gas because more of it can be obtained domestically now, which will reduce foreign reliance on energy supplies. However, this does not mean that there are no risks associated with drilling for natural gas.

There are many risks associated with the US natural gas market. First of all, weather can disrupt gas production. If there is severe weather near where natural gas is produced, then the supply of gas can be affected. Hurricanes can disrupt production locations, and colder temperatures can cause natural gas inventories to be depleted because people will need more natural gas for more heat. Lower supply will cause the price of natural gas to go up. If the supply of natural gas is diminished, then there are many potential consequences to the stability of the market, which results in more risk.

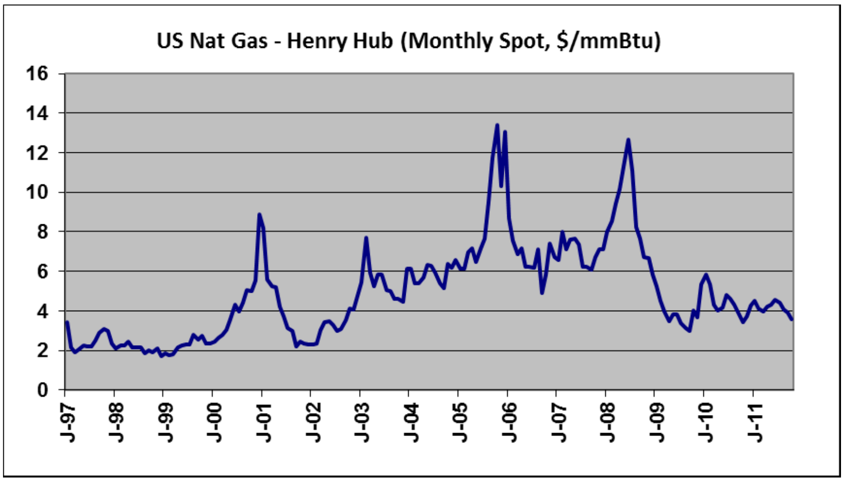
Another way that the natural gas market faces risks is through the government. The contrasting government positions of Pennsylvania and New York is an example of government influence on gas production. The government of Pennsylvania supports natural gas production, while New York's government prefers studying gas fracking first before they will allow drilling in their state (Helman, 2011). Overall, the US government invests in fossil fuels such as natural gas. In one 2012 study, it was found that 72 billion USD in funding was given to the nonrenewable energy industry, while just 29 billion USD was given to the renewable energy industry from 2002 through 2008 (Environmental Law Institute, 2012).

Why Natural Gas Is Cheaper Now

Figure 12 shows the spot price of natural gas at the Henry Hub, which is used as the benchmark for the pricing of futures contracts of natural gas on NYMEX and is arguably the most important hub for natural gas in the US. According to the EIA, 49% of all US produced natural gas either goes through Henry Hub or passes very near it during the downstream process via pipelines. Also, the natural gas futures contracts' pricing and delivery point are at the Henry Hub (US Energy Information Administration).

The price of natural gas can increase sharply at any time. Although it fluctuated more severely around the time of the Great Recession, the price of natural gas can fluctuate at other times as well. Adjusting for inflation, the price of natural gas today is decreasing. This graph demonstrates the potential for large fluctuations in prices that can occur without warning, which suggests that natural gas prices are volatile. Natural gas prices were more stable in the late 1990s but were more volatile in the early and late 2000s.

Figure 17: Henry Hub Natural Gas Spot Price



http://avalonenergy.us/blog/wp-content/uploads/2011/12/Henry-Hub-Nov-97-to-Nov-2011.png

Natural gas prices are volatile partly because of market complexity and risk. The baseline price at which natural gas is sold from the wellhead is increased several times: once it gets into the pipeline, after it has been transported, and after it has been distributed to the customer. There are over two million miles of distribution pipe in the US (Naturalgas.org, 2011). There are risks throughout the process of natural gas production, transportation, and distribution. There could be extraction issues at the wellhead or leaks in the pipelines. There are many factors that could affect the supply, and supply affects prices which halts the natural gas coming out of the well where the spill took place.

According to a report by the EIA, the Effective Capacity Utilization Rate (ECUR) is one way to predict the movement of natural gas prices. The ECUR is the ratio of actual productive output over the total potential productive output at 100 percent efficiency. The ECUR benchmark is 90% efficiency. If natural gas wells are producing less than 90% of the gas that they are capable of producing, then the prices will decrease, and vice versa. The rationale is that if wells are producing 90% or more, then it would be difficult to increase supply very much in the event that supply was diminished or demand were increased in a short time frame, which would increase prices. If the wells were producing less than 90% of their potential and supply was diminished, then the gas producers would have more potential to increase production at the already existing wells to ease the shortage. Increasing the supply would cause prices to fall again. A higher ECUR indicates a tighter natural gas market (Pirog, 2004).

An important change in the structure of the natural gas market was the deregulation of the natural gas market in 1989. It was at first regulated because it was in the public interest for the effective distribution of natural gas. The pipelines were once regulated by one company because it was cheaper and thought to be more efficient to have one company control the entire pipeline network. This created a monopoly of control for natural gas companies, and the government had to regulate the rates at which natural gas would be distributed. When demand for natural gas went up and it began being transported longer distances and to more people, it was more difficult to have sufficient oversight of the pipelines. The deregulation of the pipelines and the natural gas companies was an effective solution because it led to lower prices for gas customers and the competition that was introduced made gas production and transportation more efficient. There was now an incentive to develop technologies, which could put companies at a competitive advantage. Consumers could choose their natural gas supplier (Naturalgas.org, 2011).

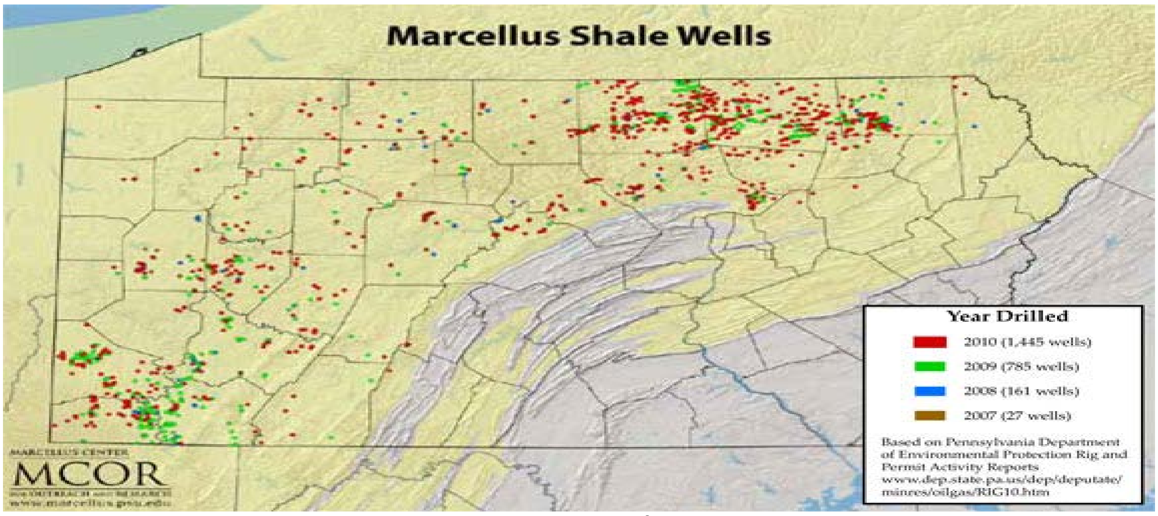
Despite deregulation of the natural gas industry, the pipelines and the local distribution companies (LDCs) are still regulated to ensure the adequate transportation and distribution of gas. The Federal Energy Regulatory Commission is in charge of regulating the natural gas pipelines. However, natural gas prices today are competitive and are determined by the market. The two main influences on natural gas prices are the physical and the financial markets. The physical market is the trading of natural gas from one entity to another. The futures market is the trading of natural gas contracts, which typically occurs without the exchange of physical natural gas. The strength of the US Dollar is another reason why natural gas prices change. Since US natural gas is traded with the US Dollar, a weaker dollar will drive natural gas prices up.

Economic Benefits of Natural Gas

Natural gas wells are being drilled at an increasing pace across Pennsylvania (Figure 13). One 2011 report suggested that the actual value added to the Pennsylvania economy in 2009 was $1.9 billion, and that between 23,000 and 24,000 jobs were created. Leasing and royalty payments to landowners who live on their land, or who live away from their land but still live in Pennsylvania, were a significant contributor to this net gain (Marcellus Shale Education and Training Center, 2011).

A 2011 report demonstrated that the total increase in the number of jobs due to the expanding local gas industry for Pennsylvania residents is over 100,000 jobs. The study explained that the government will support infrastructure upgrades, including to the railroad system, and that royalty payments per landowner will average $300,000 per year (Hefley, 2011).

Figure 18: New Natural Gas Wells Drilled in Pennsylvania since 2007



http://www.digital-topo-maps.com/county-map/pennsylvania-county-map.gif

A report by the Penn State College of Earth and Mineral Sciences and Department of Energy and Energy Engineering demonstrated that gas producers spent $4.5 billion in Pennsylvania to further develop natural gas in 2009. The result was $3.9 million of value that was added to the Pennsylvania economy, as well as 44,000 additional jobs (Considine, 2010).

There are particularly dense areas of wells in Tioga and Bradford counties in the northern part of the state, and in Greene and Fayette counties in the southwestern parts of Pennsylvania (Marcellus Shale Education and Training Center, 2011). These areas have a lower population density (Mapsof.net, 2012). They are also in the bottom 50% of per capita incomes in Pennsylvania, compared to the rest of the 67 counties in the state. The Marcellus Shale natural gas boom in Pennsylvania could have a greater relative impact on less populated communities and on towns with smaller economies (Wikipedia, 2012).

The expanding natural gas industry will create more jobs and contribute value to the GDP of Pennsylvania. A 2011 report about the American economic potential of natural gas stated that an increase in the availability of ethane, which is due to more shale gas being produced, will lead to the growth of the US petrochemical industry. Petrochemical companies use ethane in their products such as detergent and antifreeze. The direct relationship between the growth of the shale gas industry and the petrochemical industry is such that a 25% increase in ethane supply would lead to a $32.8 billion increase in the petrochemical industry and a $132.8 billion positive net impact to the US economy. This includes the direct and indirect economic impacts on the petrochemical industry (American Chemistry, 2011).

The economic benefits are a reason why many Pennsylvania residents support the natural gas industry. According to a poll by the University of Michigan's Gerald R. Ford School of Public Policy, which was published in the Pittsburgh Post-Gazette, 41% of Pennsylvania residents said that the gas industry posed more benefits than problems, compared with 33% believing that it caused more problems than benefits. Also, they feel that the environmental concerns relating to natural gas development are not as serious as they are being portrayed. Forty-eight percent of Pennsylvania residents believe to an extent that environmental groups are overstating the negative impact, and 44% of those who live in Pennsylvania said that the news media is overemphasizing the negativity (Schwartzel, 2011). Also, in a poll by Harris Interactive, 68% compared to 25% of Americans believe that America will see an increase in oil and natural gas consumption by 2030. In the question that followed, 70% of Americans surveyed indicated their support for increased access to domestic sources of natural gas, compared with 20% who opposed it. The sample size was 1,005 people (Harris Interactive, 2011).

While the polls indicate that Pennsylvania residents support natural gas production, Pennsylvania Governor Tom Corbett and the government of Pennsylvania also have indicated their desire for the industry to grow. A top energy adviser to Corbett, Patrick Henderson, wants to expand the incentives to build gas refueling stations. Also, more public transit runs on natural gas (Wilson, 2011). Corbett and his administration want to develop natural gas production in a safe and environmentally-conscious manner. He signed bills that increase state oversight and the enforcement of safety standards on natural gas pipelines in Pennsylvania. Safer pipelines will mean fewer leakages, which will add to the economic benefits of developing natural gas (Micek, 2012).

In February 2012, Governor Corbett signed into law the fee or severance tax on extracting natural gas, which will be imposed by the Pennsylvania counties that choose to do so. The county governments will have the option of enacting the severance tax or declining to enforce it. The fee, which will be based on the price of natural gas, could amount to revenues of tens of thousands of dollars per year per well. Annual revenues will decline each year over the lifespan of the well (Spilman Thomas & Battle, PLLC, 2012).

Additional regulations include obtaining a permit from the Environmental Quality Board if a company wants to reopen an abandoned well, increasing distances from water wells from 200 to 500 feet to reduce the potential contamination of water wells, and establishing a toll-free number that one can dial if there is possible water well contamination. Governor Corbett is adding economic and environmental incentives to the development of Pennsylvania's natural gas production. By adding environmental incentives, gas companies will have less risk of having to pay to clean up after an environmental problem, such as a leak or a contaminated water well. There are potential long-term economic benefits when the environmental is protected (Spilman Thomas & Battle, PLLC, 2012).

Another economic benefit of the Marcellus Shale is that many other industries in Pennsylvania will be positively impacted. In addition to the petrochemical industry, natural gas is being increasingly used to make steel. The demand for steel is increasing, particularly in developing nations (Pennlive.com, 2011).

There are many stories of success due to the growing natural gas industry. A story by NPR in August 2011 reported on the renewed success of Linde Corporation due to the Marcellus Shale. Linde Corporation is a pipeline company in Pittston, Pennsylvania that was able to increase business from 125 to 300 workers due to the increased need for pipelines to transport gas from gas drilling (Phillips, 2011). Also, there is the story of a family-owned business, Dura-Bond Industries Inc, which is involved in pipes and steel. In the business, 99% comes from pipes for natural gas transportation. On average, family-owned businesses do not last longer than a generation. Dura-Bond has been around for 50 years (Napsha, 2011).

In the short term, there are numerous potential economic benefits. With energy companies moving into Pennsylvania to extract natural gas, there are more workers who must live in Pennsylvania communities. They will have to pay taxes, which will support the local government, and they will buy the goods and services from the local community, which could help the economy in the short term.

Environmental and Health Impacts of Natural Gas

There are environmental costs associated with hydraulic fracturing. Many studies indicate that there are substantial methane emissions from the extraction of natural gas, which significantly worsens its carbon footprint. A study led by Dr. Robert Howarth of Cornell University suggested that increased natural gas production would aggravate global warming as much as coal because of methane leaks. Fracking shale rock underground would release methane, which would migrate above the surface and into the atmosphere. This was a major departure from the consensus that natural gas was a cleaner energy source, in terms of its fewer carbon dioxide, nitrogen dioxide, and sulphur dioxide emissions.

Another report from Cornell University led by Lawrence Cathles III rejected Dr. Howarth's claim that methane emissions were a concern for several reasons. Dr. Howarth had no evidence that methane emissions from unconventional shale wells were much higher than methane emissions from conventional wells. Also, Dr. Howarth and others only acknowledged that there are technologies in place that can capture methane emissions. According to this new report, Dr. Howarth did not take them enough into consideration. Dr. Howarth made the assumption that most natural gas companies will vent their methane. Venting methane would be a safety risk at a well site and would not be economical (Cathles III, 2012).

Other major air pollutants that are emitted during natural production include nitrogen dioxide and sulfur dioxide. On average, natural gas-fired power plants in the US will release 1,135 lbs/MWh of carbon dioxide, 1.7 lbs/MWh of nitrogen oxides, and 0.1 lbs/MWh of sulfur dioxide. Compared to coal, this is half as much CO2 released, about a third as much nitrous oxides, and about one percent as much sulfur dioxide (Environmental Protection Agency, 2007). Smog can also be a problem because levels of ground-level ozone increase during gas production (Nelson, 2011).

One study from the University of Colorado demonstrated that there were air pollutants that threatened the health of people who lived within one half mile of the well sites (McKenzie et al., 2012). Those who lived within one half mile were more exposed to these airborne pollutants than those who lived greater than one half mile away. Cancer risks were low. The risks increased from six in one million people who lived more than .5 miles away, to ten in one million for people who lived less than .5 miles away (McKenzie et al., 2012).

There are many chemicals that are released into the environment during natural gas drilling, particularly while fracking the deep shale rock like the Marcellus. They include ammonia, acrylic acid, diesel 2, sodium nitrate, and others. These chemicals can potentially cause adverse health effects, including damage to the skin, eyes, organs, and also cancer (Earthworks, 2012). The chemicals could be detrimental to both the environment and to people.

Although the scope of the issue of health problems has yet to be determined, it has been proven that pumping carcinogenic chemicals into the ground has already impacted local peoples' water wells and livestock (Lustgarten, 2011). Some of the toxic hydrocarbons that can become airborne include ethyl benzene, benzene, and toluene (News-Medical.Net, 2012).

The leaking of natural gas into local water supplies has been a concern for those who live near gas wells. During an experiment in March 2012 by the Environmental Protection Agency in Dimock, Pennsylvania, it was found that Cabot Oil and Gas was not polluting the local water. Well water testing at eleven homes showed that there were safe levels of drinking water. Local people claimed that there was a discrepancy among those that measured the toxicity level of the water. They said that scientists disapproved of the drinking water, while the EPA approved of it (The Associated Press, 2012). In another case, the EPA found that there were high levels of contaminants in drinking water near gas wells in Pavillion, Wyoming, and residents were warmed by federal health officials to not drink or cook with the water. People have reported suffering from neurological impairment and nerve pain after exposure to these elements. Chemicals like nitrates and those from fertilizers were not found in the water testing results, which ruled out the possibility of agricultural activities contaminating the water. This led some people to believe that fracking was the cause of the reported health problems (Lustgarten, 2011).

Drilling for gas can lead to soil erosion, increase sediment and the overall degradation in the quality and quantity of drinking water, and can damage local habitat. The drilling machinery, the large vehicles, and other heavy equipment that is needed to drill for natural gas all contribute to air and water pollution. Also, since most natural gas development is being carried out in rural areas, the opportunity to use the land for agricultural purposes may be permanently worsened. The introduction of well pads has in some cases endangered species and caused the loss of food and water sources for plants and animals. It can allow for the introduction of invasive, exotic species. Forest fragmentation results from more natural gas wells. Since trees are cleared out to make way for the vehicles and equipment, the forest is separated into multiple sections. The destruction of habitat could make it harder for animals and plant species to survive (Pennsylvania Department of Conservation and Natural Resources, 2009).

Expanding the natural gas industry would imply that there would be more exposure to natural gas in the home, which increases health risks. Research has shown that having gas-fired appliances in the home may have adverse effects on a family's health. For instance, having a gas fired stove can increase the chance of emergency room treatment for all family members and can lead to a higher incidence of asthma among residents (Malouf, 2001). In addition to gas fired stoves posing health risks, other gas fired appliances can aggravate peoples' health as well, including heaters, furnaces, and fireplaces. Gas is lighter than air and could rise to the living and sleeping areas in the higher parts of the house. Exposure to high levels of natural gas can reduce the amount of oxygen in the room. People breathe in the chemicals associated with burning even pure natural gas while they cook in the kitchen. This can causenatural gas induced chemical pneumonia (Wimberly, 2000). Natural gas producers will typically supply natural gas with mercaptan because natural gas by itself is odorless. With mercaptan, people can more easily identify gas leaks in their homes.

CONCLUSION

Coal versus Natural Gas Overall

Figure 19 summarizes the key points made in this thesis pertaining to coal and natural gas. It points out the economic and environmental effects associated with each type of fossil fuel.

When looking at the economic benefits of each energy source, one must take into account the influences of supply, productivity, government, and others. Supply of Appalachian coal and productivity of coal mining in Pennsylvania are declining. Also, government regulations aimed at curbing the emissions of carbon dioxide and mercury, and for cleaning up abandoned mine sites, are making it less economical to extract Appalachian coal. With regard to natural gas and the Marcellus Shale boom, both deregulation and the introduction of more advanced hydraulic fracturing technologies that has led to a growth in supply have helped lower its market price. This has led to increased demand for natural gas, added value to the economy of Pennsylvania, aided growth in the petrochemical and steel industries, and has helped small Pennsylvania businesses profit. Compared to coal, the market for natural gas is more favorable in terms of economic benefits. The environmental effects of each resource are also important.

Figure 19: Coal and Natural Gas Comparison

	Coal	Natural Gas
Economic Impacts	Higher wages than the average wage for workers in the manufacturing industry. Pennsylvania is an established coal producing state, with infrastructure in place. More economic and political risk in the global market. Developing nations increasingly need more coal, and Pennsylvania coal is valuable with its high heat content. Supply and productivity associated with mining Appalachian coal is declining. Prices are more stable, but could rise because of government regulations due to environmental effects.	Petrochemical and steel industries see increased growth. More jobs and added value to economy of Pennsylvania. Less economic and political risk in the global market, and less dependence on foreign energy. Prices are more volatile, which generates more economic uncertainty. Declining prices lead to more consumption and expanding market.
Environmental and Health Impacts	Dangerous chemicals emitted. Mining work is very dangerous and can be fatal. More CO_2 emissions could worsen global warming. Emissions of SO_2 and others pollute a larger geographic area due to some of the chemicals' higher residence times. Coal miners, their families, and their communities may be at an increased risk for health and safety issues.	Chemical leakages, water well contamination and air pollution are localized, but could lead to human health problems. Less of a carbon footprint because of small well pads and advanced drilling technologies. Relative to coal, fewer CO_2 emissions means less of a contribution to global warming.

Coal from the Pennsylvania region is valuable because of its high heat content and low price. However, the environmental externalities generated by burning coal are causing an uptrend in the price of coal, and the number of total coal mines in the region has dropped significantly. While the coal companies may internalize their external costs including air pollution and risks to peoples' health more in the future, they are not always doing so currently. Working in the coal business puts miners at a greater risk of being killed at work and increases the chance that members of their families have health problems. Living near coal mines is dangerous for coal miners' families because they face an increased risk of flooding and exposure to mercury as well. The effects of the release of chemicals into the environment during natural gas drilling can cause water pollution and forest fragmentation. However, the effects of the release of drilling chemicals used during fracking are usually local. The pollutants cannot travel through the atmosphere to a neighboring state like SO2 can after burning coal. In one report, cancer risks associated with living near natural gas wells were low. There are dozens of carcinogenic and toxic chemicals associated with coal-burning power plants, whereas only a small percentage of the fluids injected into the ground for fracking contain toxic chemicals.

The current trend is that the natural gas industry is expanding more than the coal industry in the Pennsylvania region. Coal and natural gas are both resources that generate economic output. However, the Marcellus Shale is one of the biggest reserves of natural gas in North America, and the natural gas industry has the potential to be a profitable business for many American gas companies. Although the demand for coal is increasing in developing nations, studies have shown that coal production in the Appalachian region is declining and that it is causing environmental and health problems that make it less economical to extract it. Thus, the economic and environmental forces associated with more expensive coal and cheaper natural gas is likely to result in further natural gas development and less coal mining.

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OBJECTIVE

Dynamic, determined student seeking a full-time position with a responsible and sustainable energy company where I can apply my work experience and strong analytical skill set.

EDUCATION

The Pennsylvania State University, University Park, PA
Schreyer Honors College
B.S. Energy, Business, and Finance; B.S. French; May 2012
CORE SKILLS: Goal-oriented, ability to organize and prioritize tasks; proactive, self-motivated, initiates action; energetic, enthusiasm for learning; team player.

WORK EXPERIENCE

Public Service Electric and Gas, Newark, NJ Intern, Summer 2011

- Managed Traksmart, an online database of executed reports, proposals, and payments of the NJ homes and businesses participating in PSE&G's $261 million energy efficiency program.
- Disseminated information regarding errors or inconsistencies from investment grade audit reports, payment tables, and other internal or external sources to employees of all company levels.
- Initiated and executed multiple projects using creative thinking, including making a visual representation of all current efficiency projects using Batchgeo.

NJ Board of Public Utilities, Newark, NJ Intern, Summer 2010

- Researched and examined the current energy efficiency and offshore wind industries in NJ.

o Evaluated the Home Star Energy Retrofit Act of 2010, and contributed a binder of business and engineering-related information specific to each European wind farm.

Penn State Smeal Junior Core, University Park, PA Proctor, 2010- Present

- Enforced and protected academic integrity while overseeing students taking tests.

United Parcel Service (UPS), Westfield, NJ Driver Helper, 2009-2011

- Handled the high-intensity delivery environment, was punctual and prepared for weather, and responded professionally to reorganizing and restocking the truck with new parcels.

Penn State Food Services, University Park, PA Food Preparer, and Server, 2008- Present

LEADERSHIP ACTIVITIES

- Recruitment and Publicity Chair, The Energy, Business, & Finance Society, University Park, PA
  - Promote club awareness and increase student involvement using strategic marketing techniques.
  - Former Web Team Coordinator.
- Eagle Scout, Boy Scouts of America- Troop 72, Westfield, NJ
  - Assistant Senior Patrol Leader.
  - Bronze Palm Award.

ADDITIONAL INVOLVEMENT

The Pennsylvania State University, University Park, PA

- National Society for Collegiate Scholars.
- Volunteered at The Village, an elderly home, where I made holiday crafts with the residents.