ECONOMIC & ECOLOGICAL IMPLICATIONS of HYDRAULIC FRACTURING

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Abstract

The Energy Information Administration (EIA) reports that the United States has abundant shale gas deposits and estimates it to be more than 1,744 trillion cubic feet (tcf) of technically recoverable shale gas, including 211 tcf of proved reserves. Technically recoverable unconventional gas (shale gas, tight sands, and coalbed methane) accounts for 60% of the onshore recoverable resource. At the U.S. production rates for 2007, about 19.3 tcf, the current recoverable resource estimates provide enough natural gas to supply the U.S. for the next 90 years. Separate estimates of the shale gas resource extend this supply to 116 years. The EIA says that shale gas production has increased 17-fold since 2000 to reach nearly 30% of dry gas production in 2011 in the United States. IPCC (2001), Intergovernmental Panel on Climate Change, reported that most of global warming in recent decades could be attributed to human activities causing significant increases in the amount of greenhouse gasses' concentration in the atmosphere. IPCC also projected that the average global surface temperatures will continue to increase between 1.4 centigrade degrees and 5.8 centigrade degrees above 1990 levels, by the year 2100. Scott Kell, President of the Ground Water Protection Council (GWPC), said that "water and energy are two of the most basic needs of society. Our use of each vital resource is reliant on and affects the availability of the other. Water is needed to produce energy and energy is necessary to make water available for use. As our population grows, the demands for both resources will only increase."

Keywords: Hydraulic fracturing, shale gas, global warming, economic & environmental impact

JEL Classification Code: O13, Q30, Q34, Q40, Q43, Q50, Q54

1.0 INTRODUCTION

The development of shale gas in the United States in many ways is considered a unique transformation of the energy industry. Already billions have been spent to further expand development of these shale gas plays which strongly suggest generation of billions in local, state and federal tax revenue and creating thousands of new jobs that will help stimulate economic activity worth hundreds of billions of dollars. However, it is uncertain at this point how the development of this massive energy source is going to benefit consumers in terms of utility prices, but most experts anticipate that the impact on natural gas prices will be positive.

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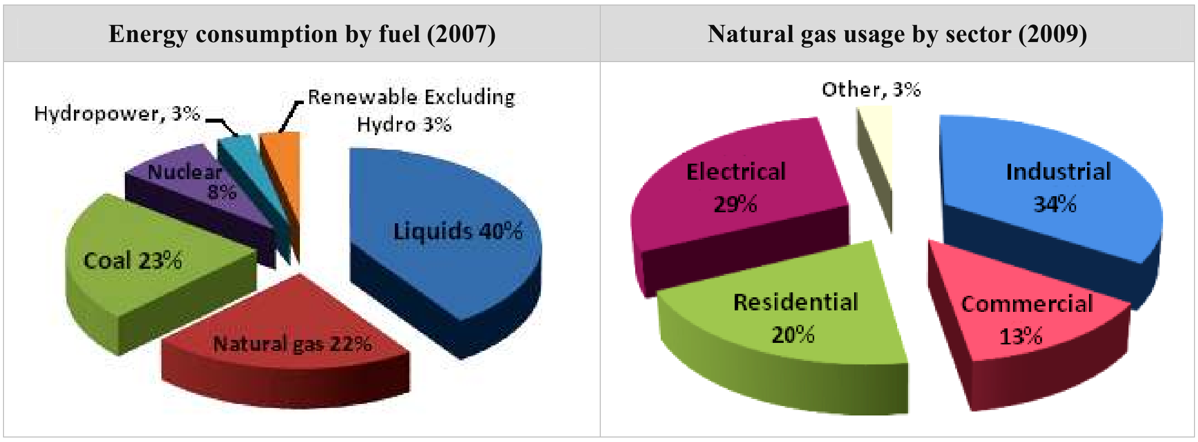
Hydraulic fracturing, or more commonly known as “shale fracking,” a highly questionable and unconventional to some, is a very complex and chemically intensive method of extracting gas trapped inside shale formations (plays) located few thousand meters (8,000-10,000 feet or 2,000-3,000 meters) below the Earth’s surface. Hydraulic fracturing has been around since 1950s; however, the application became economically viable with the discovery of a new technique called “horizontal (slickwater) drilling” in later part of 1990s. Shale-gas fracking was first used at the beginning of 2000 in the United States in northern Texas and Oklahoma, and now it is being used in the Marcellus shale formation. Shale, like sandstone and limestone, is a type of sedimentary rock which is found inside pool of water or few thousand meters beneath the Earth’s surface.[1]

Scott Kell, President of the Ground Water Protection Council (GWPC), said that “water and energy are two of the most basic needs of society. Our use of each vital resource is reliant on and affects the availability of the other. Water is needed to produce energy and energy is necessary to make water available for use. As our population grows, the demands for both resources will only increase. Smart development of energy resources will identify, consider, and minimize potential impacts to water resources.”[2] Most industry experts claim that the need for additional energy will only increase in the future with fast increasing global population capable of affording more (increasing purchasing power). Many countries in developing or emerging markets status will require much more energy to develop and foster their growing and expanding economic activities.

The Energy Information Administration (EIA) reports that the U.S. has abundant shale gas and estimates it to be more than 1,744 trillion cubic feet (tcf) of technically recoverable shale gas, including 211 tcf of proved reserves. Technically recoverable unconventional gas (shale gas, tight sands, and coalbed methane) accounts for 60% of the onshore recoverable resource. At the US production rates for 2007, about 19.3 tcf, the current recoverable resource estimates provide enough natural gas to supply the US for the next 90 years. Separate estimates of the shale gas resource extend this supply to 116 years. Natural gas, coal and oil make up about 85% of the nation’s energy, with natural gas supplying about 23% of the total; however, the EIA projects that it has a potential to reach 47% of the US total dry gas production by 2035.[3] The US domestic shale gas production more than doubles in the next 20 years; 5.0 tcf in 2010 is projected to increase to 13.6 tcf in 2035 (a 272% increase). The substantial rise in shale gas production also helps the U.S. natural gas production go up from 21.6 tcf in 2010 to 27.9 tcf in 2035.[4]

Figure 1: United States Energy Consumption by Fuel[5]



[1] See The U.S. Energy Information Administration (EIA), http://www.eia.gov/
[2] See Ground Water Protection Council (GWPC); Modern Shale Gas Development in the United States: A Primer, p.7
[3] Ibid., p.7
[4] See the EIA, http://www.eia.gov/energy_in_brief/about_shale_gas.cfm
[5] Source: Slightly modified from EIA energy consumption by fuel (2008), natural gas usage by sector (2009)

The total energy consumption by fossil fuels in 2010, about 85% of the US domestic consumption was supplied by; crude oil, 36.74% (as the leader), coal 21.25%, natural gas 25.17%, and nuclear 8.62%. Biomass and hydropower provided 4.39% and 2.56% respectively. Although wind energy was less than 1%, this was still an improvement from 0.76% level in 2009 to 0.94 in 2010 (a 23.68% increase). The contributions of renewable energy as in geothermal and solar energy were quite insignificant; 0.22% and 0.11% respectively. Natural gas, with increasing importance, continues to play a vital role in four main sectors of the U.S. economy: industrial (34%), electrical (29%), residential (20%), and commercial (13%).[6]

Although the United States (314 million in 2012) is the third most populated country in the world after China (1.36 billion) and India (1.22 billion); nonetheless, the US with 18,835 thousand barrels of oil per day (tbpd), consumes nearly 1/3 of the world's entire oil which is more than China, India, Japan, and Saudi Arabia combined. With oil supplying 36.74% of the US total energy sources by fuel, the United States is by far the number one oil consuming country in the EIA's "Top World Oil Consumers, 2011" list.[7] Even though China has about 4.5 times larger population than the US, its 8,924 tbpd oil consumption hardly comes even close to half of the United States' total. Nuclear power in the US (8.62%) is certainly vital in the energy mix but always considered environmentally hazardous and draws large protests of people who consider it unsafe especially after the nuclear accident at Fukushima Daiichi of Japan following the 2011 Tohoku earthquake and tsunami.

According to the reports by the Energy Information Administration, approximately 60% (about 800 billion of barrels-bbls) of the world's proved crude oil reserves (about 1,420 bbls) are found in a handful of countries in the Middle East region: Saudi Arabia, 262.6 bbls (18.45% of the world's proved reserves); Iran, 137.0 bbls (9.65%); Iraq, 115.0 bbls (8.10%); Kuwait, 104.0 bbls (7.32%); United Arab Emirates, 97.8 bbls (6.89%); Libya, 46.4 bbls (3.27%); Qatar, 25.4 bbls (1.79%). Other few countries outside of the Middle East with the largest proved crude oil reserves are: Venezuela, 211.2 bbls (14.87%); Canada, 175.2 bbls (12.34%); Russia, 60.0 bbls (4.23%); Kazakhstan, 30.0 bbls (2.11%); the US, 25.2 bbls (1.78%); and China, 20.4 bbls (1.44%).[8] Similarly, more than half of the world's proved shale gas deposits are found in two countries, which also happen to be the world's biggest number one and two CO_2 emitters respectively; China released 8,320 million metric tons (mmt) of CO_2 into the atmosphere in 2010, nearly 1/3 of the world's 29,778 mmt, and the United States came in second place with 5,610 mmt, close to 1/5 of the world's total. It is astounding that the United States and China combined generate almost 50% of all CO_2 released into the atmosphere worldwide. The US Department of Energy on greenhouse gases reports that the burning of fossil fuels produces around 21.3 billion tons of carbon dioxide (CO_2) per year, but it is estimated that natural processes can only absorb about half of that amount, so there is a net increase of 10.65 billion tons of atmospheric carbon dioxide per year which is directly contributing to the rise of global warming and climate changes.[9]

Fossil fuels are non-renewable energy sources and they literally take hundreds of millions of years to form; nevertheless, surging global population along with fast acceleration of energy consumption in recent decades have led to further depletion of oil, coal and natural gas reserves. Based on 2006 production levels and the EIA's estimates of current proved reserves, oil has production life of 43 years, coal has 148 years and natural gas may last for 61 years; moreover, even in the best optimistic scenario, the production life of oil remains the same (43 years), but the lifespan of coal and natural gas may be extended to 400 and 160 years respectively.[10] Global warming has gained considerable speed especially during the last three decades coinciding with the rise of China as an industrial powerhouse (second biggest economy) fueled by enormous usage of coal adversely affecting global warming. IPCC (2001), Intergovernmental Panel on Climate Change, reported that most of global warming in recent decades could be attributed to human activities causing significant increases in the amount of greenhouse gasses' concentration in

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[6] See Ground Water Protection Council (GWPC); Modern Shale Gas Development in the United States: A Primer, p.19

[7] See EIA: "Top World Oil Consumers, 2011" http://www.eia.gov/

[8] See EIA: http://www.eia.gov/countries/index.cfm?view=reserves

[9] See US Department of Energy on greenhouse gases" http://www.eia.doe.gov/oiaf/1605/ggccebro/chapter1.html

[10] See EIA: World Proved Reserves of Oil and Natural Gas, Most Recent Estimates. eia.doe.gov

the atmosphere. IPCC also projected that the average global surface temperatures will continue to increase between 1.4 and 5.8 centigrade degrees above 1990 levels, by the year 2100.[11]

Out of the three fossil fuels (coal, oil, natural gas), coal continues to be the biggest CO_2 generator along with other greenhouse gasses (SO_2). It is not shockingly surprising that China is the number one CO_2 emitter in the world because as of 2010, the world's total coal consumption was 151.5 quadrillion Btu of which China burned 75.5 quadrillion Btu (50% of the world's entire coal); this was three times more coal than the United States used (20.2 quadrillion Btu). In a way, this is also misleading because even though China is the largest CO_2 emitter by volume, however the United States by far is the top country in CO_2 emissions per capita; for instance, a person in China on average generates 6.17 tons of CO_2 per year compared to 17.99 tons of CO_2 generated by an American each year, which is nearly three times more CO_2 than a person in China.[12]

Table 1: Top Ten Carbon Dioxide Emitters in 2010 (Million Metric Tons of CO_2)[13]

Country	CO_2 Emissions	Region	World	Rank
China	8,320	12,800	29,778	1
United States	5,610	6,412	29,778	2
India	1,696	12,800	29,778	3
Russia	1,634	2,224	29,778	4
Japan	1,164	12,800	29,778	5
Germany	793	4,314	29,778	6
Canada	548	6,412	29,778	7
Iran	560	1,708	29,778	8
South Korea	579	12,800	29,778	9
United Kingdom	532	4,314	29,778	10

Most scientists worldwide now believe that the global warming is primarily caused by increased human activities involving burning of fossil fuels which ultimately has led to amplified concentrations of greenhouse gases (GHGs) in the atmosphere, mainly carbon dioxide (CO_2), sulfur dioxide (SO_2) and methane (CH_4). Furthermore, a century long industrial development and uninterrupted economic prosperity, powered by fossil-fuel based industries, have considerably raised the standards of living in developed and emerging economies where people are constantly encouraged to live in huge homes and drive multiple cars per household. As a result, the situation of increased human activities has dangerously caused the level of GHGs to rise noticeably since 1800s; however, Earth's temperature heating up faster than ever before since 1980s.[14]

The fast increasing world population makes the global warming situation get worse; for example, according to the United States Census Bureau (USCB), it took little over three centuries, 304 years to be exact, for the world population to double its size from 500 million people to 1 billion by 1804 at which time the case of global warming was unheard of. Thereafter, the world population grew so rapidly taking only 127 years to reach the milestone of 2 billion by 1927. Unfortunately, adding another billion after 1927 onward became so easily achievable. Exactly 33

[11] See IPCC: Intergovernmental Panel on Climate Change http://www.ipcc.ch/
[12] See EIA, International Energy Statistics, last Update: June 30, 2010 (All Fuels), July 14, 2010 (Petroleum)
[13] Ibid
[14] See EPA (2007) "Recent Climate Change: Atmosphere Changes" http://www.epa.gov/climatechange/science/recentac

years later by 1960, the world population was already massive 3 billion. The global population rose at even a much quicker pace in 1960s, 1970s and 1980s during which times the population added 1 billion for every 12-13 years.[15] It has taken nearly five centuries (exactly 460 years) for the global population to reach the milestone of the first 3 billion; but, it is unbelievably astonishing that it has taken only 51 years for the world population to grow another 4 billion to reach the amazing 7 billion people mark by 2011. The estimates of largest population growth will continue to take place in Asia representing 59.2% (4.917 billion people) of 8.309 billion people by 2030 (see table 2); in addition, Africa's share of the global population is projected to increase gradually (nearly 1% rise every 5 years) till 2050 where it becomes 21.8% (1.998 billion) of all people in the world, which will mean that more people will be in Africa than the combined population of Europe, Latin America and North America. In the case of North America (mainly the U.S. and Canada), the population grows slightly (about quarter of 1% every 5 years), but its share of the world population remains to be constant at 4.9% from 2030 to 2050. The world's most populated two countries, China[16] (1.353 billion in September 2012) and India[17] (1.210 billion in March 2011) represent 36.2% of the world's population as of 2012.

Table 2: UN 2008 Estimates and Medium Variant Projections (in millions)[18]

Year	World	Asia	Africa	Europe	Latin America	N. America
2030	8,309	4,917 (59.2%)	1,524 (18.3%)	723 (8.7%)	690 (8.3%)	410 (4.9%)
2035	8,571	5,032 (58.7%)	1,647 (19.2%)	716 (8.4%)	706 (8.2%)	421 (4.9%)
2040	8,801	5,125 (58.2%)	1,770 (20.1%)	708 (8.0%)	718 (8.2%)	431 (4.9%)
2045	8,996	5,193 (57.7%)	1,887 (21.0%)	700 (7.8%)	726 (8.1%)	440 (4.9%)
2050	9,150	5,231 (57.2%)	1,998 (21.8%)	691 (7.6%)	729 (8.0%)	448 (4.9%)

According to the data from the Energy Information Administration, use of natural gas to produce electricity generated nearly five times less CO_2 emissions than burning of coal. For example, coal was used in the production of 1,755,904 thousand megawatt hour electricity in 2009; and at the end, the process generated 1,742.2 million metric tons (mmt) CO_2. Same year, 920,929 thousand megawatt hours of electricity generated using natural gas, but only 372.6 mmt of CO_2 was released into the atmosphere. Advocates of shale gas claim that natural gas burns cleaner and its combustion produces far less (about 50% less) carbon dioxide (CO_2) and methane (CH_4) emissions (GHGs) than coal or oil. Conversely, opponents see it differently and consider this unconventional method of extracting gas from shale formations as hostile to the environment due to the fact that massive amount of pressurized water (more than a million gallons or about 4 million liters) is used in each fracking operation along with sand and a long list of other dangerous chemicals. As a result, there have been numerous public uproars about the potential adverse impacts on human health and environment. Water Sustainability throughout the world is already a very challenging task in the 21st century; and because of that, environmentalists in the US are very outraged regarding massive water usage in thousands of drilled wells for two main reasons; first, opponents of fracking are significantly concerned that shale gas production may in fact affect the ecosystem in regards to aquatic habitats causing water contamination; second, they believe that it is totally unfair to use billions of gallons of water for gas production when a great number of people throughout the world are struggling just to find clean drinkable water.

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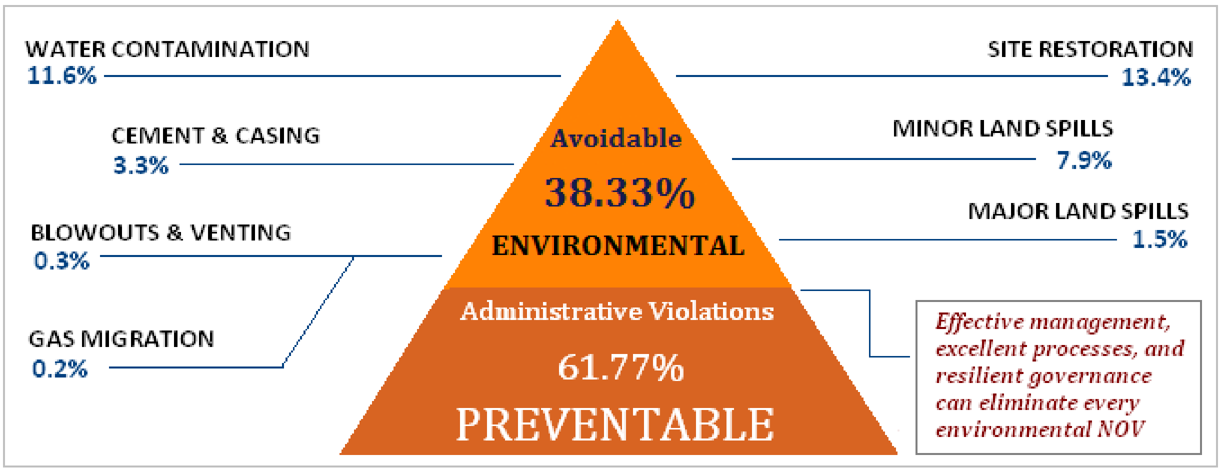
[15] See Wikipedia http://en.wikipedia.org/wiki/World_population_milestones
[16] See Chinese Official Population Clock (in Chinese) http://www.CPDRC.org.cn
[17] See 2011 Census of India, 2011
[18] World Population Prospects: The 2008 Revision Population Database

1.1 Environmental Impact of Hydraulic Fracturing

The use of any new technology, process, a technique, or even an unconventional method such as hydraulic fracturing is going to create public concern mainly for two reasons; advocates and drilling companies will argue that it is safe, and overall water usage is insignificant, and no risk of water contamination; conversely, environmentalists and opponents will insist that shale fracking will adversely affect air and water quality. Other potential issues may exist as well; for instance, noise and dust caused by construction and drilling works; additional traffic from heavy-duty trucks which may also lead to deterioration of roads' pavement; and change in landscape appearance due to cutting of trees and drilling thousands of wells. People in all different communities near the drilling sites in the US are very concerned because the super-fast growth of shale gas production in a decade may in fact deplete scarce water supplies; the EIA says, shale gas production has increased 17-fold since 2000 to reach nearly 30% of dry gas production in 2011 in the United States alone.

The process of extracting natural gas from shale formations is believed to cause a significant reduction in water quality. Landowners and environmentalists are largely concerned about the use of massive hydraulic fracturing fluid in these wells that may ultimately lead to water contamination because only close to half of the water used in each fracking process is recovered later and the remaining highly toxic wastewater ends up staying underground. Moreover, the human factor (spills and leakages due to mismanagement, poor processes, lack of control and governance) in these highly explosive and chemically intensive operations raises other issues to watch for. According to the United States Geological Survey, small seismic activities have been experienced nearby drilling sites where shale formations are found. Recent research papers on the topic indicate that the highly pressurized fracking fluid containing so many different chemicals could be powerful enough to create small earthquakes; in addition, it is also said that the wastewater recovered from wells is disposed of by a way of injection (huge force is applied) into deep wells which is more capable of causing larger underground eruptions.[19]

Figure 2: Distribution of Environmental Violations, 2010[21]



A very detailed study by Considine et al. (2012) did not indicate any violation of water contamination due to migration of waste water beneath the surface as a result of fracking during Marcellus shale gas drilling from January 2008 to August 2011. However, the study listed the following major notice of violations (NOVs): administrative, 61.7%; site restoration, 13.4%; water contamination, 11.6%; minor land spills, 7.9%; cement & casing, 3.3%; major

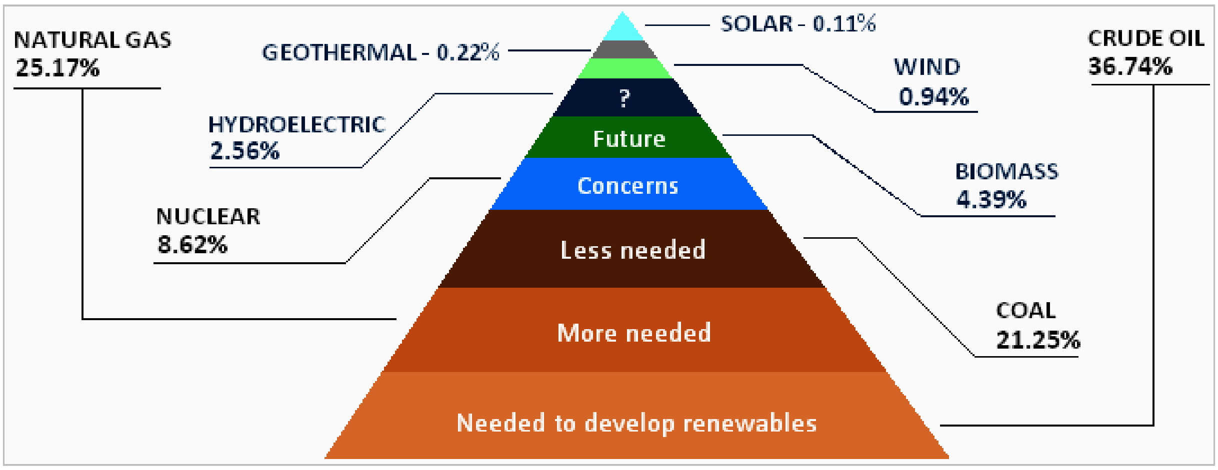
[19] See EIA: Energy in Brief, http://www.eia.gov/energy_in_brief/about_shale_gas.cfm
[21] Source: The EIA, Considine et al., (2012), "Environmental Impacts, During Marcellus Shale Gas Drilling: Causes, Impacts, and Remedies" SRSI - Shale Resources Society Institute

land spills, 1.5%; blowouts & venting, 0.2%; and gas migration, 0.2%.[20] If we take out the preventable NOVs such as administrative (61.7%), the remaining 38.3% of NOVs are very concerning; which means, 1,144 of 2,988 NOVs during three years were in most part either water contamination or land spill related. Environmentalists claim the process could contaminate rivers and aquifers and pollute the air; while the natural gas companies point out that the fracking has been used safely for decades (Thorn, 2012).

1.1.1 Water Use and Disposal of Wastewater

As expected, most experts involved in shale gas drilling operation believe that it is unlikely for the waste water to migrate from 5,000 feet deep (close to 1,700 meters) through solid rock formations below the surface upward to around 500 feet (about 170 meters) where underground water is usually found. Advocates of shale gas along with drilling companies also argue that no such incident has occurred for 60 some years since hydraulic fracturing first used. However, the New York City Department of Environmental Protection (2009) study raises some concerns that wastewater from hydraulic fracturing could actually migrate from the gas-bearing layers, from 5,000 feet below the surface upward to 500-1,000 feet. Water contamination violation has occurred 346.6 times during Marcellus shale gas drilling from January 2008 to August 2011, and this is exactly the reason why environmentalists and opponents of hydraulic fracturing are outraged.

Figure 3: The US Energy Consumption by Source, 2010[23]



In spite of recent studies showing a decline in notice of violations (NOVs) during Marcellus shale gas drilling from January 2008 to August 2011; however, still 2,988 violations occurred in 3,533 wells drilled, of which 1,844 or 62 percent were for administrative or preventative reasons. The remaining 38 percent, or 1,144 NOVs, were for environmental violations (Considine et al., 2012).[22] The same study shows that approximately 902 violations were surface water contamination related which took place in 266 wells drilled; the level of contamination in 258 wells was minor, but 8 wells had significantly major surface water contamination violations. The study also demonstrates that the Marcellus shale gas industry has managed to reduce its NOVs more than 50% from 2008 to 2011; in 2008, 90 violations occurred in 170 wells drilled (52.9% ratio); 2009 saw 173 NOVs in 710 wells (24.4%); in 2010, 322 incidents took place in 1,405 wells drilled (22.9%); and 2011 witnessed smallest percentage ratio of NOVs, 260 violations recorded in 1,248 wells amounting to 20.8% which is a 61% reduction from 2008 level. The ratio of

[20] See SRSI: "Environmental Impacts during Marcellus Shale Gas Drilling: Causes, Impacts, and Remedies," p.12
[23] Ibid., p.11
[22] Source: The EIA, Considine et al., (2012), "Environmental Impacts, During Marcellus Shale Gas Drilling: Causes, Impacts, and Remedies" SRSI - Shale Resources Society Institute, p. 11 Ibid., p.11

NOVs per drilled well may have been reduced substantially, but this does not make shale gas production any safer or it does not hold off environmentalists and opponents of fracking because all it takes is one incident to create an irreversible environmental disaster.

The diagram in figure 3 was constructed with a specific thought in mind, and for it to look like the Maslow's hierarchy of needs pyramid was intentional. If the future of energy sources is explained using Maslow's theory, then the three lower level fossil fuels (oil, natural gas and coal) would be treated as unsatisfied energy needs in physiological stages meaning they are found in the nature with easier access to them than shale gas and they must be satisfied in order to move forward meeting more complex higher order of energy needs (renewable energy) which require further advancement in related technologies and development of innovative processes to make them economically viable (solar, biomass, wind, and geothermal energy sources as in higher order of needs). In this analogy, shale gas development plays a particular importance that the U.S. can achieve independence from foreign natural gas which would in turn enable development of other renewable energies in the future. Natural gas's benefit over coal as to global warming is less clear-cut, but it's there, and gas can also coexist with renewable energy, providing inexpensive backup for wind and solar. "Natural gas could be crucial to integrating renewable energy into the power grid," says Ralph Cavanagh, co-director of the Natural Resources Defense Council's energy program (Walsh, 2011).

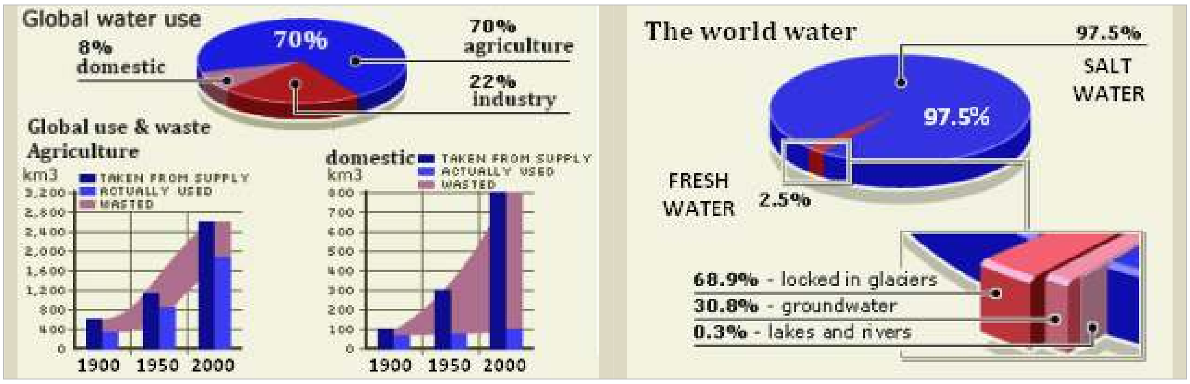
1.1.2 Groundwater Contamination

Environmentalists and opponents of shale fracking strongly believe that rapid growth of this unconventional as well as questionable method of extracting shale gas threatens to contaminate underground and surface water supplies. Manuel (2010) argues that recent evidence suggests fracking may have contributed to groundwater contamination with methane in some instances and the proprietary chemicals used in the procedure could theoretically pose a public health threat. For all kinds of fracking related problems, Pool (2011) made reference to the Oscar-nominated documentary entitled 'Gasland' which tracks the lives and chronic health problems of the US families living in regions where shale gas drilling has taken place. The documentary made legitimate claims of groundwater pollution amid images of flaming faucets not only angered the U.S. citizens but also roused concern at the White House. Although fracking chemicals used in each drilling make up less than 1% of the entire drilling fluid, Walsh (2011) argues that highly toxic chemicals can still amount to 25,000 gallon (about 95,000 litters) which is 0.5% of 5-million gallon. Even if everything goes right, hydraulic fracturing can easily produce over 1 million gallon of toxic, briny wastewater in a well.

A massive amount of water (8-20 million liters) is required each time to frack a well and the process may be repeated few times during the life of the well, which means as much as 30-100 million liters of water could be used. The advancement of technologies enable drilling companies to recycle some of the used water, but the amount is not sufficient, so it is still necessary to draw water from the aquifer or other water resources. According to the EIA reports and the information from local authorities in Pennsylvania, New York and West Virginia, the water usage may reach to 650 million barrels per year or 103.34 billion liters[24] of water per year. To put things in an interesting perspective, the authorities argue that the Marcellus shale gas production in aforementioned states uses roughly about 0.8% which amounts to 108 billion liters of water based on the current consumption of 85 billion barrel of water (or 13.5 trillion liters). Some research reports indicate that as the shale gas development will progress more in the next decade, as much as 50% of water supply in some rural areas may be drawn for fracking operations, making the water scarcer than ever before.[25] A research paper by Thorn (2012) highlights the view of drilling companies along with advocates of shale gas that fracking chemicals and waste water are better off staying few thousand meters below the Earth's surface than above ground, and interestingly they also claim that toxic wastewater will not migrate 5,000 feet (close to 1,700 meters) below to upward near 500 feet (about 170 meters) to cause water contamination.

[24] 1 barrel = 42 US gallons = 158.99 liters
[25] See Environmental Issues Surrounding Shale Gas Production: The U.S. Experience A Primer

Figure 4: Global Water Use & Waste and Available World Water[26]



The studies conducted by the United Nations Environment Programme (UNEP) & World Water Assessment Programme (WWAP) highlights that the world's entire fresh water available for humans (currently over 7 billion) to use is only 2.5%, and the remaining 97.5% happens to be salty water found in seas and oceans throughout the world. Ironically, the situation gets even worse from here, because nearly 70% of the 2.5% fresh water is locked in glaciers (1.75% not drinkable), meaning not available for people to use or drink. Another 30% of the world's 2.5% fresh water is groundwater (0.75%) some of which may have already been contaminated due to shale gas fracking and other industrial activities (i.e. dumping chemicals into lakes, rivers or contaminating groundwater through shale gas fracking fluid).

After all said and done, the water available for more than 7 billion people to use today in agriculture, industry and domestic is only less than 1% of which 92% is used for agricultural and industrial purposes; only 8% of 1% is used in and around homes. When Nicot and Scanlon (2012) assert that water use for shale gas is less than <1% of statewide water withdrawals; this information may create a misperception or it may mislead people to think that 1% is awfully low; therefore, it is not big of a deal. Well, on the contrary, it is a big deal because about 1% of less than 1% available fresh water for the entire human race which has been putting on an extra billion people on average of 12-13 years since 1970s. On top of all this, people in general have been using and wasting more water since 1900s (see figure 2). For instance, in year 2000, people wasted 31% of the water in agriculture (2,650 km^3 taken from water supply but actual usage was 1,850km^3) and 87.5% of the water drawn for home use was wasted (800 km^3 taken from water supply but actual usage was 100 km^3).

1.1.3 Air Pollution Related to Methane Emissions

Unlike the cases of water contamination, which are 100% preventable; however, negative impact on air quality due to shale gas fracking is not something that can be avoided completely because all fossil-based fuels generate greenhouse gases (GHGs); now maybe the two proper questions that need to be asked are; how much and how bad is air pollution from shale gas production and its usage in relation to coal and oil both of which according to experts produce more GHG emissions than natural gas.

Table 3: U.S. emissions of GHGs, based on global warming potential 1990-2009 ($MMTCO_2e$)[27]

Gas	1990	1995	2000	2003	2004	2005	2006	2007	2008	2009

[26] Source: Modified from UN (WWAP) & UNEP (United Nations Environment Programme) http://www.unep.org/

[27] See the EIA Report: Emissions of Greenhouse Gasses in the United States, 2009, p.

CO_2	5,040.9	5,353.4	5,900.3	5,923.3	6,031.3	6,055.2	5,961.6	6,059.5	5,865.5	5,446.8
Methane	768.8	732.7	663.1	660.6	661.6	669.2	678.5	690.9	724.2	730.9
N_2O	221.4	236.2	217.8	211.8	222.0	223.6	223.7	228.6	223.5	219.6
High-GWP	102.1	119.4	154.0	145.4	157.0	161.3	163.6	171.4	169.9	178.2
Total	6,133.2	6,441.7	6,935.3	6,941.1	7,071.9	7,109.4	7,027.4	7,150.4	6,983.1	6,575.5
Difference from 2005 Total							-82.0	41.0	-126.3	-533.8

The U.S. Energy Information Administration (EIA) claims that natural gas (shale gas) burns much cleaner than coal and oil; for instance, one million Btu equivalent of natural gas generates about 117 pounds of carbon dioxide (CO_2), which is 70.94% less CO_2 than coal and 36.75% less CO_2 than oil. One million Btu equivalents of coal and oil combustion produce, 200 and 160 pounds of CO_2 respectively.[28] Clean burning of shale gas easily qualified itself as the number one choice for the utility companies in the United States to use it in generation of electricity. According to the EIA, greenhouse gas emissions from human activities declined the largest from 2008 to 2009 in two decades since the measurement began being tracked in 1990. Total anthropogenic GHGs fell from 6,983 million metric tons carbon dioxide equivalent ($MMTCO_2e$) in 2008 to 6,576 $MMTCO_2e$ in 2009, which was a 5.8% reduction. Experts contribute the decline to three possible reasons; adverse effects of 2008 financial crisis, economy in recession post crisis, and power companies switching to natural gas for electricity production instead of using coal or oil.[29]

The U.S. Energy Information Administration reported that total GHGs from natural gas was 6,575.5 $MMTCO_2e$ in 2009, of which; 81.5% (5,359.6) was energy production related; during the same period methane emissions had totaled a slight increase (0.9%) from 2008 (723.9 MMTCO2e) to 2009 (730.9 $MMTCO_2e$). The EIA said that the rise in methane emissions was related to underground coal mining and waste management operation (increased 7 MMTCO2e). The EIA data also showed a drop in emissions of nitrous oxide from 223.5 MMTCO2e in 2008 to 219.6 $MMTCO_2e$ in 2009 (a 1.7% reduction). The emissions of man-made gases considered high-global warming (High-GWP) rose significantly (4.9%) from 2008 to 2009; 169.88 MMTCO2e and 178.2 MMTCO2e respectively.[30]

1.1.4 Small Seismic Activities around Shale Formations

The United States Geological Survey (USGS) reported that small seismic activities might be contributed to hydraulic fracturing related activities such as fracking of the wells to extract shale gas and disposing of the fracking fluid into the ground through a way of highly pressurized injection. The USGS also announced that seismic activity in midsection of the U.S. increased substantially in recent years; in fact, small earthquakes more than doubled in 2009 (50 recorded incidents) compared to the average number of annual seismic activity around 21 since 1980s. The number of tiny micro earthquakes further increased in later years; 87 occurrences in 2010 and 134 recorded incidents in 2011.[31] Advocates of shale gas fracturing and drilling companies argue that only few small seismic activities could be potentially linked to 140,000 or more disposal wells in operations in the United States.[32]

The Center for Strategic & International Strategies (CSIS) said that Ohio's Department of Natural Resources closed the injection well nearest the epicenter of the December 31, 2011 earthquake and also suspended activity at four

[28] Slightly modified from the EIA, http://www.eia.gov/energyexplained/index.cfm?page=natural_gas_environment
[29] See the EIA, http://www.eia.gov/environment/emissions/ghg_report/
[30] See the EIA, http://www.eia.gov/environment/emissions/ghg_report/
[31] See the USGS, http://www.usgs.gov/
[32] See "Fracking Tied to Unusual Rise in Earthquakes in U.S." http://www.bloomberg.com/

other nearby injections wells to more fully evaluate the situation.[33] Reuters reported that a recent study by the National Research Council points out that injecting or removing underground water in the process of developing energy from shale plays as a form of hydraulic fracturing can be the biggest factor causing micro earthquakes near drilling sites.[34]

1.2 The History of Stimuli Technology (Fracturing)

Some people may think of hydraulic fracturing as a new, unconventional technology; on the contrary, it has been in use since 1950s. Some experts even believe that a type of fracturing might have been used about 250 years ago. However, the first two wells were commercially fracked by Halliburton Oil Well Cementing Company (Howco) in 1949 with an average cost of $950 for each fracking operation at the time. Fracturing treatment in 332 wells in the first year produced 75% more oil exceeding all expectations and leaving industry participants in disbelief. By mid-1950s, as many as 3,000 wells/per month were fracked. In 2008, more than 40,000 fracking operations were conducted worldwide costing between $10,000 and $6 million. It is very common today that a well can be fracked anywhere between eight to forty times (Montgomery and Smith, 2010). Advocates of fracking claim that hydraulic fracturing has increased US recoverable oil by at least 30% and natural gas by a whopping 90%. Montgomery and Smith (2010) used three "F" words to describe the world of hydraulic fracturing; "The Fuss, The Facts, The Future."

Table 4: Fracture Treatments by Well Type[35]

Source	USA %	Canada %	Rest of World %
Shale gas	36.5	10.0	3.0
Tight gas	37.0	38.0	1.7
Oil	22.1	40.0	73.7
Conventional gas	------	10.0	19.7
Other	4.4	2.0	1.9
Total	**100.0**	**100.0**	**100.0**

In early fracturing treatment attempts, gelled-crude was used, then in later part of 1952, refined and crude oils were used in most fracturing operations. At the time, these fluids were inexpensive which improved unit cost, plus they provided less friction enabling injection at lower pressure. Water started being used in 1953 with other surfactants additives. Montgomery and Smith (2010) assert that the concentration of sand remained low until the mid-1960s, when viscous fluids such as crosslinked water-based gel and viscous refined oil were introduced. Almost all fracking fluids contained a combination of acid, water, and brines; however, in early 1970s, metal-based crosslinking agents were used to enhance the viscosity of gelled water-based fracturing fluids for higher-temperature wells (Montgomery and Smith, 2010).

The global hydraulic fracturing revenues have increased fivefold from $2.8 billion in 1999 to nearly $13 billion in 2007 ($12.8 billion to be exact).[36] There are 1,080 fracturing equipment including land spreads and vessels in the world, and 80.28% of those are in North America; 756 in the U.S. and Mexico, and 111 in Canada. Therefore, according to Michael Economides, it is not shockingly surprising that more than three quarters of all fracturing is conducted in North America, Australia and Europe have the smallest number of equipment, 5 and 8 respectively.

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[33] See "Fracking and Seismic Activity" http://csis.org/publication/fracking-and-seismic-activity

[34] See Reuters, http://www.reuters.com/article/2012/06/15/us-usa-earthquakes-fracking-idUSBRE85E14K20120615

[35] Source: Modified from Michael Economides, Energy Tribune (as cited in Montgomery and Smith, 2010)

[36] Source: Michael Economides, Energy Tribune (as cited in Montgomery and Smith, 2010)

Surprisingly, the Middle East region has only 10 fracturing equipment despite having five largest oil producers in the world. Other countries and regions with sizable fracturing equipment are; Latin America (72), Russia (49), China (32), Rest of Asia (21), and Africa (16).[37]

2.0 LITERATURE REVIEW

The world energy consumption has been gradually increasing year over year since 1990 forcing energy prices move upward and making them unstable; consequently, the last two decades unpredictable energy prices have been higher than the world has ever seen since the oil was discovered in 1930s. The world's total energy consumption has increased from 1990 (354 quadrillion Btu) to 2000 (406 quadrillion Btu), resulting in a 14.69% increase. However, the next eight years have witnessed a more significant rise in energy consumption from 2000 to 2008, during which the world consumed 96 quadrillion Btu more energy bringing the total consumption figure to 505 quadrillion Btu in 2008, which meant a 24.38% increase. The rise of world energy consumption is projected to slow down a bit from 2008 to 2015 (projected 573 quadrillion Btu), making it a 13.47% increase. From 2015 to 2035, the world energy consumption is estimated to grow on average 8%, ultimately reaching to 770 quadrillion Btu by 2035.[38]

The temperature rise in the future will be primarily caused by a huge surge in human activities due to fast rising world population, technological development, and economic prosperity; in addition, people are becoming increasingly more dependent on using various modern devices powered by fossil-based nonrenewable energy sources causing further acceleration of burning fossil fuels that will ultimately lead to increased concentrations of carbon dioxide (CO_2) and methane (CH_4) in the atmosphere; therefore, speeding up global warming. Global warming will certainly have considerable negative effects on all living forms through climate changes causing heat waves, storms, severe droughts, ocean acidification, hurricanes, extinction of certain species, and loss of food security due to major climate shifts affecting crop yields.

A century long industrial development, economic prosperity and related increased human activities have caused the carbon dioxide (CO_2) and methane (CH4) levels in the atmosphere to rise substantially since 1800s, but noticeably more so since 1980s.[39] Modern time tools used both in homes and businesses, plus all various transportation vehicles powered by burning of fossil fuels along with acceleration of deforestation in recent decades are primarily responsible for building up the CO_2 and CH_4 concentrations in the atmosphere causing global warming and major climate changes. Researchers found that increased methane emissions affect climate in several ways: Directly through increased CH_4 concentrations and indirectly through the chemical feedback on CH_4 levels and through production of O_3 and stratospheric H_2O. Furthermore, CO_2 will increase since it is the end product of atmospheric CH_4 oxidation.[40] The top ten CO_2 emissions contributor nations are listed in table 1.3, according to which both China and India combined produce nearly one third of the world's total CO_2 release into the atmosphere. Dessai (2001) reported that the US President George W. Bush rejected signing the Kyoto Protocol treaty on the basis that "it exempts 80% of the world, including major population centers such as China and India." Even though the U.S. is the world's second biggest greenhouse gas emitter after China, nonetheless it is still by far the biggest emitter per capita.

The United States' dependency on fossil fuels is so irreversible that breaking away from it is not going to happen anytime soon. According to the Energy Information Administration (EIA), still a colossal 83.12% of domestic energy consumption in 2010 was predominantly supplied by oil (36.7%), natural gas (25.17%), and coal (21.25%). Renewable energy only comprises 8.22% of the energy mix which includes; biomass (4.39%), hydroelectric (2.56%), wind (0.94%), geothermal (0.22%), solar (0.11%). Remaining 8.62% is supplied by nuclear energy which always draws protests of people who consider it unsafe especially after the nuclear accident at Fukushima Daiichi of Japan

[37] See Montgomery, C., T. & Smith, M., B. (2010) "History of AN ENDURING TECHNOLOGY" NSI Technologies

[38] See EIA, "International Energy Outlook, 2011" http://www.eia.gov/forecasts/ieo/index.cfm

[39] See EPA (2007) "Recent Climate Change: Atmosphere Changes" http://www.epa.gov/

[40] See Isaksen, I. S. A., M. Gauss, G. Myhre, K. M. Walter Anthony, and C. Ruppel (2011), "Strong atmospheric chemistry feedback to climate warming from Arctic methane emissions"

following the 2011 Tohoku earthquake and tsunami. In just four years, the share of natural gas has increased from 22.3% in 2006 to 25.17% in 2010, which is a 12.87% rise. The EIA projects that shale gas has a potential to reach 47% of the U.S. total dry gas production by 2035.[41]

The U.S economy is fueled by consumer spending which makes up more than two thirds of all economic activity. Therefore, Americans are directly or indirectly encouraged to keep spending on bigger homes, cars, yachts, and other products that demand for substantially more energy. Thus, it is not shocking surprising that the U.S. always ranks either first or second when it comes to consumption of fossil fuels; for instance, first in oil and natural gas, and second in coal consumption. In 2012, the world's coal production was 6,817.5 million tons, of which, 50% was used by China alone (3,397.5 million tons) which largely contributed to China being the biggest CO_2 emitter by percentage in the world. The U.S. coal production in 2009 and 2010 were; 1,184.91 and 1,196.32 million tons correspondingly. During the same period, the consumption was 1,100.64 and 1,155.56 million tons respectively. Insignificant amount of coal surplus was exported in 2009 and 2010; 41.25 million tons in 2009 and 69.02 million tons in 2010.[42]

The Energy Information Administration says that natural gas is the fastest-growing fossil-based fuel, with consumption projected to increase on average 1.6% annually from 2008 to 2035 by which date the world natural gas consumption will reach 169 trillion cubic feet (tcf). The world natural gas consumption estimates as follow; 111 tcf in 2008 (actual), 123 tcf in 2015, 133 tcf in 2020, 144 tcf in 2025, 157 tcf in 2030, and 169 tcf in 2035. Consumption increased 10.81% from 2008 to 2015 (1.81% per year); 8.13% from 2015 to 2020 (1.63% per year); 8.27% from 2020 to 2025 (1.65% per year); 9.03% from 2025 to 2030; and 7.64% from 2030 to 2035 (1.53% per year). Total world natural gas consumption is projected to increase at an average rate of 1.7% per year from 2008 to 2035.[43]

The average daily demand for oil in the United States is nearly twice the amount it produces, which easily puts the U.S. in top position as the biggest oil consumer country in the world. As of 2011, the U.S. produced 10,142 thousand barrels per day (bpd) amounting to 11.65% of the world's total production output of 87,093 bpd, during the same year, the U.S. consumed 18,835 bpd which comes to 21.63% of the world's daily oil production resulting in a deficit of 8,693 bpd covered through imports.[44] Even though the situation looks significantly better in natural gas, the United States still was not able to cover domestic demand in 2010 as well as in 2011. It is very ironic that the U.S. ranks as number one both in production and consumption of natural gas; it produced 21.33 trillion cubic feet (tcf) in 2010, which was 19.16% of the world's total natural gas production (111.35 tcf), and the consumption was 23.78 tcf in that year; the difference of 2.60 tcf was imported from Canada. Although natural gas production increases (contribution of shale gas) by 7.82% in 2011; however, consumption also increases by 2.32% which slightly helps reduce import from 2.60 tcf in 2010 to 1.95 tcf in 2011.[45]

Table 5: Top World Oil Net Production, Consumption, Importers and Exporters, 2011[46]
Thousand Barrels per Day

Rank	Production		Consumption		Importers		Exporters	
1	Saudi Arabia	11,153	United States	18,835	United States	8,694	Saudi Arabia	8,167
2	Russia	10,229	China	8,924	China	4,625	Russia	7,504

41 See Ground Water Protection Council (GWPC); Modern Shale Gas Development in the United States: A Primer, p.7
42 See EIA, the U.S. coal, http://www.eia.gov/countries/country-data.cfm?fips=US&trk=r
43 See the EIA, "International Energy Outlook, 2011" http://www.eia.gov/forecasts/ieo/nat_gas.cfm
44 See EIA, the U.S. Oil, http://www.eia.gov/countries/country-data.cfm?fips=US&trk=r
45 See EIA the U.S. Natural Gas, http://www.eia.gov/countries/country-data.cfm?fips=US&trk=r
46 See EIA: http://www.eia.gov/countries/index.cfm?topL=exp (all figures are in thousand barrels per day)

3	United States	10,142	Japan	4,464	Japan	4,329	UAE	2,609
4	China	4,299	India	3,426	India	2,483	Kuwait	2,343
5	Iran	4,234	Saudi Arabia	2,986	Germany	2,235	Nigeria	2,242
6	Canada	3,600	Brazil	2,793	Korea, South	2,170	Iran	2,206
7	UAE	3,096	Russia	2,725	France	1,697	Iraq	1,817
8	Mexico	2,959	Germany	2,400	Spain	1,346	Norway	1,752
9	Brazil	2,687	Canada	2,259	Italy	1,292	Angola	1,752
10	Kuwait	2,682	Korea, South	2,230	Netherlands	948	Venezuela	1,490
11	Iraq	2,635	Mexico	2,133	Taiwan	902	Algeria	1,482
12	Nigeria	2,528	Iran	2,028	Singapore	885	Qatar	1,455
13	Venezuela	2,470	France	1,792	Turkey	650	Kazakhstan	1,377
14	Norway	2,007	The UK	1,608	Belgium	634	Canada	1,341
15	Algeria	1,884	Italy	1,454	Thailand	549	Mexico	827

Scott Kell, president of Ground Water Protection Council (GWPC) believes that natural gas, particularly shale gas, is an abundant U.S. energy resource that will be vital to meeting the nation's future energy demand and to enabling transition to greater reliance on renewable energy sources.[47] According to the GWPC, three factors played a fundamental role in the last several years to make shale gas production economically viable: 1) discovery of horizontal drilling in later part of 1990s, 2) further advances in hydraulic fracturing, and, improvements in disposal process, 3) macroeconomic factors along with increase in demand pushed the natural gas prices upward substantially in recent years. The U.S. Department of Energy claims that the use of horizontal drilling has not created any new environmental concerns. The EIA asserts that hydraulic fracturing actually reduced the number of wells that needed to be drilled, therefore significantly reduced surface disturbances and impacts to wildlife, dust, noise, and traffic.[48]

Hydraulic fracturing, in very basic terms, means extracting once considered inaccessible petroleum, natural gas, or hydrocarbon from source rocks through the injection of highly pressurized fracking fluid.[49] Scott Kell, President of the Ground Water Protection Council (GWPC), said that "water and energy are two of the most basic needs of society. Our use of each vital resource is reliant on and affects the availability of the other. Water is needed to produce energy and energy is necessary to make water available for use. As our population grows, the demands for both resources will only increase. Smart development of energy resources will identify, consider, and minimize potential impacts to water resources." The GWPC President also said that "natural gas, particularly shale gas, is an abundant U.S. energy resource that will be vital to meeting future energy demand and to enabling the nation to transition to greater reliance on renewable energy sources."

Finite fossil-based nonrenewable energy sources throughout the world have become nearly depleted by means of unreasonably excessive consumption driven by global population rise, technological advancement and economic prosperity in recent decades; in addition, an increasing number of corporations today are exploring new but highly controversial ways to produce more natural gas in order to limit their energy dependency (i.e. Europe's dependency on Russia). One of these "unconventional" sources (EIA: 46% of the total US production) is called hydraulic fracturing, also known as "fracking" opponents of which strongly argue that this questionable technique could be the

[47] See Environmental Issues Surrounding Shale Gas Production: The U.S. Experience A Primer, p.11
[48] Ibid., Forward by Scott Kell
[49] See IEA: Golden Rules for a Golden Age of Gas. World Energy Outlook Special Report on Unconventional Gas

real cause behind the unusual small seismic activity experienced around shale formation in some countries. Moreover, environmentalists and landowners are largely concerned about the use of massive amount of water in these wells which ultimately may lead to underground or drinking water contamination because only close to half of the water used in fracking process is recovered later and the remaining highly toxic wastewater stays underground. Advocates, usually people who are involved in the fossil based oil industry, favor fracking and argue that natural gas produces fewer less greenhouse gas emissions (GGEs) than coal and oil.

About 80% of all countries in the world especially developing and developed countries, for their energy need from oil, depend on a hand full of countries in the Middle East region where 799.21 billion barrels (bbls) of proved reserves of crude oil are found in five countries, which happens to be more than 60% of all proved reserves worldwide. According to a very detailed report by the EIA on proved oil reserves; out of 217 countries worldwide, 120 countries show no signs of having any proved oil reserves and 80 countries seem to have less than 10 billion barrels of proved reserves of which in some cases may not be all economically feasible to drill.

The EIA said that proved reserves of U.S. oil and natural gas in 2010 rose by the highest amounts ever recorded since the EIA began publishing proved reserves estimates in 1977. The EIA report shows that both proved reserves of oil and natural gas have increased in 2010 (2.93 bbls and 33.8 tcf) from their 2009 discovery levels (1.8 bbls of oil and 28.8 tcf of natural gas), 63% and 17.36% respectively.

Table 6: Changes to U.S. Proved Reserves, 2010[50]

Status of Proved Reserves	Crude oil + lease condensate (bbls)	Wet natural gas (tcf)
Reserves at December 31, 2009	22.3	283.9
Total discoveries	2.1	48.9
Production	-2.0	-23.2
Reserves at December 31, 2010	25.2	317.6
Percentage change in reserves	12.8%	11.9%

EIA has said that U.S. natural gas demand is projected to exceed 30 trillion cubic feet per year within two decades. In order to meet this demand, producers will increasingly rely on production from unconventional gas such as tight sands, coalbed methane, and gas shale. The Intergovernmental Panel on Climate Change (IPCC) said that average temperatures would have been about 30 centigrade degrees lower than what they are today in the absence of greenhouse gases. However, the IPCC also claims that extensive amounts of fossil fuels burned by increasing level of human activities are starting to have serious adverse impacts on atmospheric concentrations of greenhouse gases including carbon dioxide, methane, tropospheric ozone, and nitrous oxide – and make them rise well above pre-industrial levels. Recent "Joint science academies' statement: Global response to climate change" highlights that carbon dioxide (CO_2) levels have increased from 280 ppm in year 1750 to over 375 ppm today – higher than any previous levels that can be reliably measured (i.e. in the last 420,000 years). Consequently, increasing greenhouse gases have been causing temperatures to rise; the Earth's surface warmed by approximately 0.6 centigrade degrees over the twentieth century.[51]

[50] See EIA: http://www.eia.gov/naturalgas/crudeoilreserves/index.cfm (oil in billion barrels-bbls & natural gas in trillion cubic feet-tcf)

[51] See IPCC: Intergovernmental Panel on Climate Change http://www.ipcc.ch/ "Joint science academies' statement: Global response to climate change"

Table 7: U.S. Carbon Dioxide Emissions 1990 - 2008 (million metric tons CO_2)[52]

Energy	Residential	Commercial	Industrial	Transportation	E. power	Nonfuel	Total
Petroleum	99.2	70.1	367.2	1,547.7	101.8	75.5	2,261.5
Coal	3.0	11.8	256.8	0.0	1,531.2	0.5	1,803.3
Natural gas	238.3	142.3	432.5	36.1	175.5	14.7	1,039.5
Electricity	618.2	560.8	632.5	3.2	0.0	0.0	1,814.7
1990 Total	958.6	785.1	1,689.5	1,586.9	1,814.6	97.1	6,931.8
1995 Total	1,035.5	845.1	1,739.5	1,682.2	1,947.9	104.9	7,355.1
2000 Total	1,179.8	1,013.1	1,784.7	1,872.7	2,293.5	109.8	8,253.6
2005 Total	1,254.5	1,059.6	1,671.4	1,988.7	2,396.8	104.7	8,475.7
2007 Total	1,235.1	1,070.3	1,655.2	2,025.7	2,409.1	106.7	8,505.1
2008 Total	1,220.1	1,075.1	1,589.1	1,930.1	2,359.1	100.2	8,273.7

The United Nations Framework on Climate Change (UNFCCC) defines climate change as; "a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods."[53] Although climate changes, as a direct result of global warming, will have many adverse impacts, may also be beneficial to some regions where the climate is already harsh to begin with and life is hardly sustainable (i.e. desert like or extremely cold, no rain, minimal or no water resources and horrendous living conditions); these places may receive benefits of climate changes due to global warming but it is never certain that it may actually be the case. The IPCC estimates that the combined effects of ice melting and sea water expansion from ocean warming are projected to cause the global mean sea-level to rise by between 0.1 and 0.9 meters between 1990 and 2100. Even though the largest portion of greenhouse gas emissions released into the atmosphere causing global warming is mainly done by G8 countries;[54] however, the action plan of reducing atmospheric carbon dioxide (CO_2) and methane (CH_4) must involve all countries worldwide; moreover, if nothing is done immediately, then developing or underdeveloped countries with lack of resources and basic infrastructure will be more affected.

First time since 1990, total U.S. carbon dioxide emissions showed a major decline in 2008 (see table 1.7); in fact, the fall was the largest in 18 years. CO_2 emissions in 2008 fell by 231.4 million metric tons (mmt) compared to 2007 emissions level of 8,505.1 mmt, which was a 2.79% reduction. Almost 99% of all carbon dioxide emissions in U.S. come from combustion of fossil fuels by consumers and the utility companies producing electricity. Approximately less than 2% of CO_2 emissions come from nonfuel activities involving industrial processes of manufacturing cement and limestone. The EIA claims that the decline of CO_2 emissions in 2008 can be largely credited to macroeconomic factors resulting from the 2008 global financial crisis and its adverse impacts on energy prices leading to reduced consumer demands for energy. Although opponents of shale fracking argue that natural gas is a much cleaner choice of fossil fuel that burns with less CO_2 emissions; nevertheless, coal still remains to be the foremost source for electricity generation producing the highest level of CO_2 emissions annually in U.S. (28.51%); transportation comes

[52] Source: Modified from EIA estimates, http://www.eia.gov/oiaf/1605/ggrpt/carbon.html
[53] See The United Nations Framework on Climate Change (UNFCCC)http://unfccc.int/2860.php
[54] See Wikipedia: G8 originally started in 1975 as G6 including; France, Germany, Italy, Japan, the United Kingdom, and the United States. Canada joined the group in 1976 and Russia was admitted by 1997; however, two of the actual eight largest economies by nominal GDP: China (2nd) and Brazil (6th) are not part the G8 country list.

in second with 23.33%; industrial sector is in third place generating 19.21%; residential contributes 14.75% to total CO_2 emissions: and commercial (12.99%) comes in last even though it is the only sector showing no reduction in CO_2 emissions from 1990 to 2008.

Table 8: World Energy Consumption by Region, 2012[55]

Country	Petroleum[1]	Coal[2]	Natural gas[3]	Hydroelectricity[4]	Nuclear[5]	GDP[6]
United States	20.0	20.2	23.9	8.0	813	13,976
Canada	2.0	1.0	3.5	4.3	88	1,266
Japan	4.0	4.6	3.7	1.4	286	4,701
Russia	3.0	4.5	16.3	1.7	172	975
China	10.0	75.5	3.8	8.9	133	4,456
India	3.0	11.7	2.5	3.2	48	1,418
Brazil	3.0	0.6	0.9	6.4	14	1,214
OECDEurope	14.0	11.8	19.6	10.7	947	15,936
OECD Total	47.0	43.3	55.6	26.8	2,302	39,141
Total World	**90.0**	**151.5**	**116.2**	**60.6**	**2,871**	**54,479**
1: Million barrels per day; 2: Quadrillion Btu; 3: Trillion cubic feet; 4: Quadrillion Btu; 5: Billion kilowatthours; 6: Million-2005 dollars						

Two decades of strong economic growth enabled U.S. consumers to afford bigger homes and more electronic devices around the house. Gradual population increase (1.1% annually) along with economic prosperity did not help residential CO_2 emissions which increased about 1.6% annually from 1990 to 1995 and 2.79% per year from 1995 to 2000; thereafter, the increase slowed down and showed a small decline in 2008. Residential CO_2 emissions primarily originated from basic but necessary home-living activities such as heating, cooking (predominantly natural gas or electricity is used), lighting and use of other electric powered devices (i.e. television, computer and small home appliances). The good news is that the insignificant rise of residential CO_2 emissions is offset by energy efficient homes and home appliances (i.e. A+ energy saving refrigerator, dishwasher and oven).

The large part of commercial sector CO_2 emissions mainly comes from the use of electricity for lighting and commercial sector carbon dioxide emissions are less weather sensitive than residential. Industrial CO_2 emissions have dropped slightly over the years due to a structural shift from energy intensive to less energy intensive manufacturing (i.e. chip and electronic component manufacturing). Petroleum (i.e. gasoline, diesel) combustion is a significant source of CO_2 emissions in transportation sector where there is a parallel relationship between vehicle miles traveled and the amount of CO_2 emissions from burning of gasoline and diesel fuels by drivers. The electric power companies emit CO_2 into the atmosphere through burning of fossil fuels with the sole purpose of generating electricity. The EIA said that electricity generation from all fossil fuels fell by 57.4 billion kilowatthours from 2007 to 2008 due to the lower overall carbon intensity of power generation in 2008 was the result of a 50-percent increase (17.6 billion kilowatthours) in generation from wind resources.[56]

[55] Source: Modified from the EIA, International Energy Statistics database (as of March, 2012), http://www.eia.gov/ies. Projections: EIA, Annual Energy Outlook 2011, DOE/EIA-0383(2011)
[56] See EIA estimates, http://www.eia.gov/oiaf/1605/ggrpt/carbon.html

Energy, waste management and agricultural are the three largest sources of methane emissions in U.S.; 295.7, 225.0 and 212.1 million metric tons of CO_2e respectively. Human activities involving fossil based energy sources (i.e. oil, coal and natural gas) still generate the largest methane emissions in 2008; management of livestock (225.0) and waste (212.1) are the other two leading sources of methane emissions. Coal mines and natural gas are two major sources of methane emissions in the energy sector. The EIA has reported that methane emissions from underground mines accounted for about 10% of total U.S. methane emissions and 1% of total U.S. greenhouse gas emissions. Surface mines contributed about 2% of U.S. methane emissions.[57] U.S. methane emissions from natural gas substantially grew after late 1990s when the use horizontal slickwater fracking technique made extraction of shale gas much more economical.

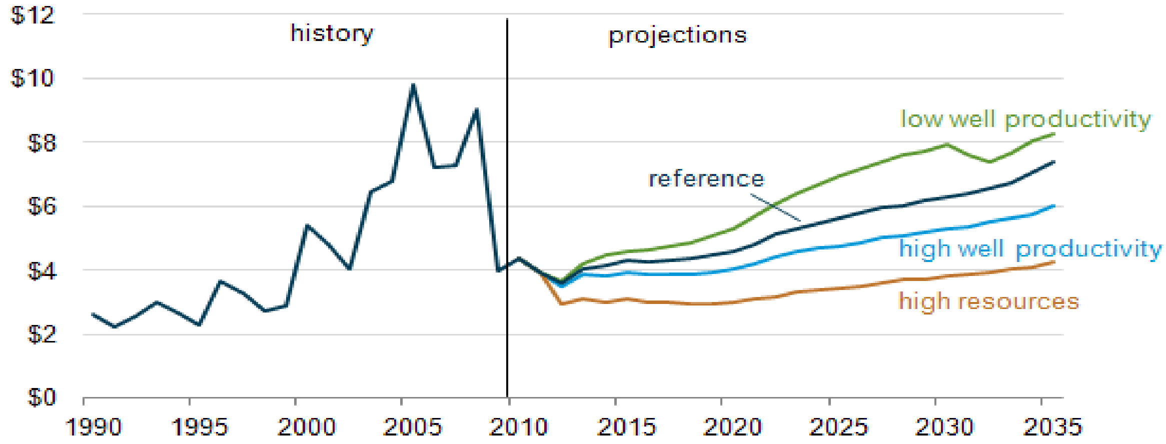
Table 9: U.S. Methane Emissions 1990 - 2008 (million metric tons CO_2 equivalent)[58]

	Energy	Agricultural	Industrial	Waste management	Total CH_4	CH_4 & CO_2 Total
1990 Total	294.4	201.5	4.6	283.0	783.5	7,715.3
1995 Total	284.8	219.1	5.6	246.8	756.2	8,111.4
2000 Total	277.6	211.1	5.7	188.6	683.0	8,936.6
2005 Total	274.2	218.8	5.1	193.7	691.8	9,167.5
2007 Total	282.8	222.6	5.2	212.1	722.7	9,227.8
2008 Total	295.7	225.0	4.7	212.1	737.4	9,011.2

Coal is mainly used worldwide (151.5 quadrillion Btu) to generate electricity and China by far is the largest coal consumer with 75.5 quadrillion Btu which amounts to 50% of the world's total coal consumption. As of 2011, major fuel energy sources for U.S. electricity generation consisted of 46% coal, 34% non-fossil fuels, 20% natural gas and 1% petroleum. Resulting carbon dioxide emissions from electricity generation by fuel in 2011 mainly came from coal (79%), natural gas (19%) and petroleum (1%).[59] Although the United States (5,610 mmt of annual CO_2 emissions) is the world's leader in total CO_2 emissions per capita/year; however, China (8,320 mmt of CO_2) and India (1,696 mmt of CO_2) together account for little more than one third of the world's total annual CO_2 emissions (29,778 mmt of CO_2).

[57] See EIA, http://www.eia.gov/oiaf/1605/ggrpt/methane.html
[58] Source: Modified from EIA estimates, http://www.eia.gov/oiaf/1605/ggrpt/methane.html
[59] See EIA, http://www.eia.gov/energyexplained/index.cfm?page=coal_environment

Figure 5: Henry Hub spot natural gas prices in four shale gas resources scenarios[60]



EIA estimates that there are 2,203 trillion cubic feet (tcf) of natural gas that is technically recoverable in the United States. At the rate of U.S. natural gas consumption in 2011 of about 24 Tcf per year, 2,203 Tcf of natural gas is enough to last about 92 years.[61] EIA says that there is considerable uncertainty regarding the size of the economically recoverable U.S. shale gas resource base and the cost of producing those resources. The Annual Energy Outlook 2012 (AEO2012) provided three shale gas resource scenarios: (1) low well productivity case assuming a 50% reduction in unproved shale gas resources (reduced from reference case of 482 tcf to 241 tcf); (2) high well productivity case where unproved shale gas resources are improved to 723 tcf (50% increase from 482 tcf); (3) high resources case in which unproved shale gas resources are increased to 1,091 tcf (723 tcf with 50% increase plus 50% capacity increase with 8 wells per square mile). EIA also projects natural gas prices dipping in 2031 when the new pipeline starts transporting 1.6 tcf per year of gas from the North Slope to the lower 48 states.[62] Due to slow growth in electricity demand and introduction of new environmental regulations, EIA estimates a 26.52% decline in coal usage for generation of electricity over the next 25 years, meaning less coal for electricity production (dropping from 38% to 48% in 2008).[63]

The new EIA-sponsored study's initial assessments of 48 shale gas basins in 32 countries suggest that shale gas resources, which have recently provided a major boost to U.S. natural gas production, are also available in other world regions. The study does not include Russia and the Middle East region where already significant resources of conventional natural gas exist. The report suggests that there are seven times more technically recoverable shale gas resources in 32 foreign countries (5,760 tcf) than the United States (862 tcf).[64] Natural gas prices are much lower in U.S. than rest of the world because North American natural gas markets are highly competitive due to many buyers and sellers; however, Northwest Europe has limited suppliers, mainly Russia and Qatar and a very limited spot market exists in many Asian countries including Japan. According to EIA, U.S. dry natural gas production rose 20% between 2005 and 2010.[65] Villar and Joutz (2006) assert that according to what economic theory suggests, natural gas and crude oil prices should be related because natural gas and crude oil are substitutes in consumption and also complements, as well as rivals, in production. Based on research work, Villar and Joutz (2006) confirm that the observed pattern of crude oil and natural gas prices tend to support this theory.

[60] Source: Slightly modified from U.S Energy Information Administration, Annual Energy Outlook 2012
[61] See EIA, http://www.eia.gov/tools/faqs/faq.cfm?id=58&t=8
[62] See EIA, http://www.eia.gov/todayinenergy/detail.cfm?id=7710
[63] See EIA, http://www.eia.gov/forecasts/aeo/source_natural_gas_all.cfm
[64] See EIA, http://www.eia.gov/todayinenergy/detail.cfm?id=811
[65] See EIA, http://www.eia.gov/todayinenergy/detail.cfm?id=3310

Table 10: Global Unconventional Natural Gas Resources in Place (trillion cubic meters)[66]

Region	Tight	Coal-bed	Shale	Total
Middle East & North Africa	23	0	72	85
Sub-Sahara Africa	22	1	8	31
Russia	25	112	18	155
Asia Pacific	51	49	174	274
North America	35	85	109	233
Latin America	37	1	60	98
Central & Eastern Europe	2	3	2	7
Western Europe	10	4	14	29
World	**210**	**256**	**456**	**921**

A hand full of countries (Canada, Venezuela and five other countries in the Middle East) possess 1,175 billion barrels (bbls) of proved reserves of crude oil, which happens to be nearly 85% of the world's total proved reserves. Rising oil prices accompanied with constant tensions in the Middle East have forced governments' of developed countries into searching for new ways of exploring natural gas. The relentless pursuit for energy independence has substantially increased the popularity of unconventional natural gas extraction known as hydraulic fracturing or "shale fracking." A country's desire for energy independence is quite understandable; however, solutions to a problem cannot possibly be considered real solutions if environment or human health are adversely affected. Recent research shows evidence of groundwater contamination as a result of shale fracking. In 2005, the U.S. Congress exempted fracking from the "Safe Drinking Water Act" partly on the basis of the EPA report[67] the authors of which wrote that hydraulic fracturing poses "minimal threat" to drinking water and that "additional or further study is not warranted at this time" (Manuel, 2010).

There are two sides to the story of shale fracking and horizontal drilling; the story of upside and downside. The upside of fracking is argued to: (1) create new jobs for people and provide much needed revenue to boost sagging economies (local, state or federal); (2) increase property and land values: (3) impact the country's GDP positively; (4) reduce greenhouse gas emissions due to natural gas' cleaner burn (nearly 50% less CO_2 and CH_4); (5) achieve energy independence from foreign oil and gas (the U.S. is currently the biggest oil importer); (6) help ease global warming; and (7) create an opportunity to buy time to work on improving renewable energy sources. The downside of fracking is believed to: (1) contaminate ground and surface waters; (2) generate further greenhouse gases (natural gas in unburned state can be more intoxicating than the CO_2 generated from oil or coal); (3) affect human health negatively in the short or long-term; and (4) cause environmental disasters and lead to small seismic activity around shale formations. The Department of Energy and Climate Change in the UK published a "Memorandum of Understanding (MoU)" which said that "climate change is not only a massive threat to the global environment; it is also perhaps the greatest economic challenge facing us in the twenty-first century. It demands an urgent and radical response across the developed and developing world."[68]

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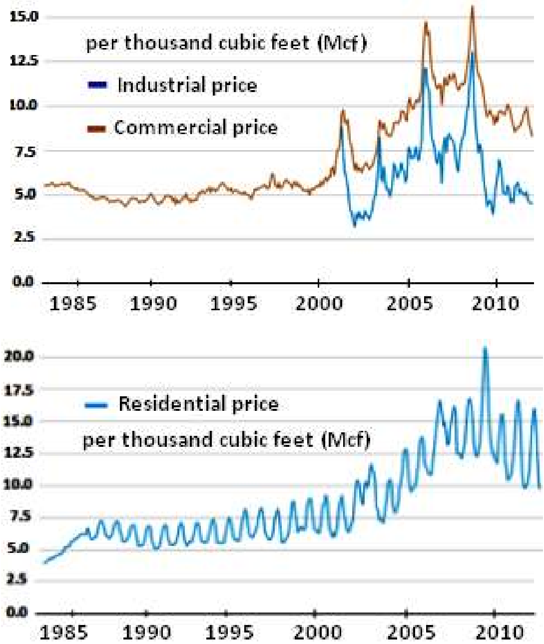
66 Source: Modified from DECC - The Department of Energy and Climate Change – The United Kingdom, http://www.decc.gov.uk/assets/decc/What%20we%20do/lc_uk/loc_reg_dev/1380-mou-lggroup-decc.pdf

67 EPA report "Evaluation of Impacts to Underground Sources of Drinking Water by Hydraulic Fracturing of Coalbed Methane Reservoirs"

68 See DECC: Memorandum of Understanding, Between the LG Group and the Department of Energy and Climate Change (9 March 2011)

Figure 6: Natural Gas Prices in US and Estimated Value of Proved Reserves[69]



Natural gas (Mcf)			2012
	May	**June**	**July**
Wellhead price	1.94	2.54	2.59
Imports price	2.28	2.35	2.77
Imports by pipeline	2.15	2.33	2.64
Imports as liquefied	4.37	3.10	5.15
Exports price	2.75	2.93	3.05
Exports by pipeline	2.50	2.65	3.05
Exports as liquefied	16.10	17.55	8.49
Citygate price	4.31	4.65	4.86
Residential price	12.46	14.23	15.29
Commercial price	7.93	8.23	8.32
Industrial price	2.99	3.27	3.53
Electric Power price	3.02	3.20	3.53
July 2012 prices	\$(1)	\$(2)	\$(3)
Residential Value	3,685	11,055	16,681
Industrial Value	850.7	2,552	3,851
Commercial Value	2,005	6,015	9,077

*Author's estimates may not reflect the actual values

2.1 Economic and Societal Impacts of Hydraulic Fracturing – Shale Fracking

Scott Kell, President of Ground Water Protection Council (GWPC), said that "water and energy are two of the most basic needs of society. Our use of each vital resource is reliant on and affects the availability of the other. Water is needed to produce energy and energy is necessary to make water available for use. As our population grows, the demands for both resources will only increase. Smart development of energy resources will identify, consider, and minimize potential impacts to water resources. Natural gas, particularly shale gas, is an abundant U.S. energy resource that will be vital to meeting future energy demand and to enabling the nation to transition to greater reliance on renewable energy sources."[70]

In its 2009 World Energy Report, the International Energy Agency (IEA) stated that "the share of unconventional gas in total US gas output is expected to reach 60% in 2030."[71] Based on EIA's special report on natural gas in 2011, the consumption of natural gas first time in history of fossil fuels will overtake coal usage by 2030 and become 25% of the total global energy mix by 2035.[72] The Energy Information Administration estimates that the U.S. has more than 1,744 trillion cubic feet (tcf), which is enough natural gas to supply the U.S. for nearly a century based on 2007 annual production rate of 19.3 tcf.

Economic reasons seem like the most compelling argument behind natural gas explorations through unconventional methods such as shale fracking. Potential returns of revenue could be in trillions of dollars; in addition, new and fast growing natural gas industry in U.S. could potentially create employment opportunities for thousands in local markets where the economy has been sagging for years, which in turn could lead to further economic activity (i.e.

[69] See EIA: http://www.eia.org/ (modified and calculations done by the author)
[70] See GWPC: "Modern Shale Gas Development in the United States: A Primer" April 2009, http://www.gwpc.org, p.5
[71] See EIA: http://www.eia.org/press/pressdetail.asp?PRESS_REL_ID=294
[72] International Energy Agency "Are we entering a golden age of gas?" Special Report World Energy Outlook 2011 http://www.worldenergyoutlook.org/docs/weo2011/WEO2011_GoldenAgeofGasReport.pdf

buying homes, cars and other financial investments). Considine co-authored an industry-sponsored study in early 2010 that estimated that Marcellus drilling would create or support 88,000 jobs that year and more than 100,000 in 2011, plus billions of dollars in economic value for the state (Walsh, 2011).

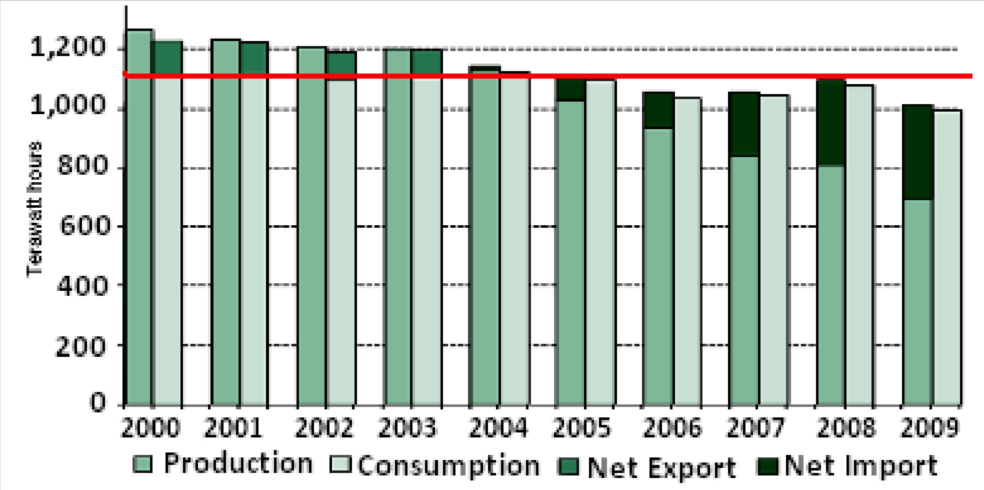
The Annual Energy Outlook 2012 (AEO2012) provided three shale gas resource scenarios: (1) low well productivity case assuming a 50% reduction in unproved shale gas resources (reduced from reference case of 482 Tcf to 241 Tcf); (2) high well productivity case where unproved shale gas resources are improved to 723 Tcf (50% increase from 482 Tcf); (3) high resources case in which unproved shale gas resources are increased to 1,091 Tcf (723 Tcf with 50% increase plus 50% capacity increase with 8 wells per square mile).[73] Based on EIA's three projected scenarios (see table 2.1), the proved reserves of natural gas may potentially generate trillions of dollars based on July 2012 natural gas prices in the U.S.; residential sales could amount to $3.685 trillion (scenario, 1), $11.055 trillion (scenario, 2), $16.681 trillion (scenario, 3). If the U.S. government takes approximately one third of the revenues as taxes, it could potentially mean from $1 to $5 trillion dollars; in addition to that, income tax revenues from corporations and their highly paid executives (double taxation).

When the price of natural gas began to climb along with that of oil early in the decade, newly equipped shale gas drillers went to work. In 2000, shale gas was merely 1% of the U.S. gas supply; but now it is 22% which continues to increase each year with new discoveries (Kerr, 2010). Range Resources based in Fort Worth - Texas, established in 2003 as a natural gas company with a market value of $400 million, is now valued more than $8 billion thanks to its huge discovery of a large shale gas deposit in Pennsylvania called the Marcellus Shale. The company was among the first of its competitors working on extracting gas from shale formations through unconventional method of fracking. Once horizontal drilling was used, the yields got steadily better, until Range Resources hit a jackpot in 2006: a gas-rich formation that might generate 50 years of profits for the company, according to spokesman Matt Pitzarella. That discovery helped confirm that the Marcellus—which cuts across portions of at least eight eastern states from New York to Tennessee—is one of the largest shale gas deposits in the world (Scmidt, 2011). In a Time Magazine article, it was mentioned that when the word got out that the Marcellus was for real meaning there was a huge potential of shale gas reserves; the price for leases skyrocketed— rising to $5,000 an acre by the summer of 2008 (Walsh, 2011).

Deborah Solomon, the Wall Street Journal (WSJ), reported on August 25, 2011 that New York and Pennsylvania sit on the giant Marcellus Shale, an underground formation that has become a fracking hotbed because of the large quantities of natural gas there. Just a week before this news piece, Noble Energy Inc. paid $3.4 billion for a stake in developing 663,350 acres there. Yergin (2011) points out that natural gas' share in the U.S. energy mix increased from 1% in late 2000 to nearly 25% today. According to the EIA's estimates, the entire natural-gas resource including shale gas could be as high as 2,500 trillion cubic feet (tcf), with a further 500 tcf in Canada. This means more than 100-years of natural gas supply for North America, which is used for everything from home heating and cooking to electric generation, and industrial processes. Proponents of shale gas fracking believe that the U.S., once thought to be short of natural gas, could even become a natural-gas exporter in near future (Yergin[74], 2011). The UK started importing natural gas first time in 2004 and its import level gradually increased ever since then. British Geological Survey (BGS) estimated that 150 bcm (or 5.36 tcf) of reserves exist which is about 1.5 years of consumption at the 2009 level. The total natural gas demand in 2009 was approximately 100 bcm (3.57 tcf) and the DECC stated that the UK imported 10 bcm of liquefied natural gas (LNG), so this would mean that the reserves would provide 15 years of supply if all 150 bcm is recoverable.

[73] See EIA, http://www.eia.gov/forecasts/aeo/source_natural_gas_all.cfm
[74] Daniel Yergin, chairman of IHS Cambridge Energy Research Associates. His new book "The Quest" will be published in September. He received the Pulitzer Prize for his book "The Prize: The Epic Quest for Oil, Money and Power."

Figure 7: UK's Natural Gas Production, Net Exports/Imports and Consumption[75]



The British Geological Survey (BGS) estimated that the UK's shale gas reserve potential could be as large as 150 bcm (billion cubic meters) or 5.36 tcf (trillion cubic feet) which could be worth $81.96 billion dollars using the US residential gas price $15.29 in July 2012. This is equivalent to approximately 1.5 years of the UK's current gas consumption, or 15 years of the UK's current LNG (liquefied natural gas) imports.[76] The EIA study highlights two countries in Europe with the largest possible natural gas reserves; Poland (3,740 bcm[77] or 134 tcf) and France (3,600 bcm or 129 tcf). According to the same study, the US (17,240 bcm or 616 tcf) and China (25,500 bcm or 911 tcf) have the largest estimated technically recoverable shale gas reserves. For the calculation purposes, if July 2012 residential natural gas price is used, then the estimated value for aforementioned countries would amount to $2.049 trillion for Poland, $1.972 trillion for France, $9.419 trillion for the United States, and $13.929 trillion for China, which is more than all three countries combined.

The idea of 'made in the USA' shale gas was enough to excite all kinds of different people in the society. From a politicians' view point and a legitimate concern for national security, first time ever, this is seen as a replacement for foreign oil and gas; proponents of fracking along with environmentalists see it as stepping on the break of global warming because natural gas burns cleaner and yields only 45% of CO_2 emissions of coal (Kerr, 2010). Societal benefits of shale fracking may be realized indirectly through further development of natural gas industry where vast employment opportunities are created to foster a healthy growth of local economies; consequently, working people would have more chances to provide their families a higher standard of living (i.e. buying better homes, cars, home appliances, and investing in financial markets) where children receive quality education that promises a bright future.

Newly formed companies in this industry can prosper financially in the years to come and as a way of appreciation return some of the wealth created back into their local economies by means of building parks, libraries and schools (corporate social responsibility). Strong natural gas industry can encourage various new business ventures to start and ultimately have a positive impact on the country's GDP. Widespread usage (see table 2.1) of natural gas not only can reduce the horrible effects of coal, which happens to be the largest greenhouse gas emitter of all fossil fuels, but it can also slow down the speed of global warming because natural gas burns at least 50% cleaner.

[75] Source: Modified from DECC, Digest of UK Energy Statistics 2010, Chart 4.1 p 97
[76] See Parliament, http://www.publications.parliament.uk/pa/cm201012/cmselect/cmenergy/795/79506.htm#note37
[77] 1 tcm = 1 trillion cubic meters = 1000 bcm 1tcf = 1 trillion cubic feet = 28 bcm

Conventional (readily available) natural gas or unconventional shale gas are never going to be enough to solve the United States' total energy needs today or in the future completely. Micro and macro-economic factors such as increasing population, growing economies in last two decades or so, globalization of financial markets and technological developments have enabled people afford more and therefore burn more fossil fuels due to a huge surge in human activities in this decade alone. Although advancements in technology and further progress in science have increased energy efficiency, growing demand for power in the U.S. could still require the equivalent of 540 new coal plants or 200 new nuclear power plants. Coal is inexpensive and abundant, but there is regulatory and environmental opposition to its use because of carbon and other emissions adversely affecting global warming. Nuclear power is carbon-free and has evolved new passive safety features, but it is expensive and, especially after the catastrophe in Fukushima Daiichi of Japan following the 2011 Tohoku earthquake and tsunami, faces regulatory and political uncertainty (Yergin, 2011).

2.2 Environmental Impacts of Hydraulic Fracturing – Shale Fracking

Environmentalists and opponents of shale fracking strongly believe that rapid growth of this unconventional as well as questionable method of extracting shale gas threatens to contaminate underground and surface water supplies. Manuel (2010) argues that recent evidence suggests fracking may have contributed to groundwater contamination with methane in some instances and that proprietary chemicals used in the procedure could theoretically pose a public health threat.

For all kinds of fracking related problems, Pool (2011) made reference to the Oscar-nominated documentary entitled 'Gasland'[78] which tracks the lives and chronic health problems of the U.S. families living in regions where shale gas drilling has taken place. The documentary made legitimate claims of groundwater pollution amid images of flaming faucets not only angered US citizens but also roused concern at the White House. Although fracking chemicals used in each drilling make up less than 1% of the entire drilling fluid, Walsh (2011) argues that highly toxic chemicals can still amount to 25,000 gallon (about 95,000 litters) which is 0.5% of 5-million gallon. Even if everything goes right, hydraulic fracturing can easily produce over 1 million gallon (3.8 million L) of toxic, briny wastewater over the lifetime of an individual well (Walsh, 2011).

The US environmental Protection agency (EPA) is investigating the safety and risk implications of hydraulic fracturing while the New York State Senate has imposed a moratorium halting all practices within its State. 'Gasland,' produced by Josh Fox, provides the following very useful information: (1) an average well is 8,000 feet deep and the depth of drinking water aquifers is about 1,000 feet; (2) generally 1-8 million gallons of water may be used to frack a well which may be fracked up to 18 times; (3) 80-300 tons of chemicals may be used in each fracking process and companies are not required to disclose these highly toxic chemicals (although some states are starting to require drilling companies to disclose all the chemicals used in fracking); (4) after fracking, the gas reaches the surface mixed in the water and other chemicals used; however, only 30-50% of the water is typically recovered from a well and remaining highly toxic wastewater ends up staying underground. Yergin (2011) has said it perfectly; "in an era of heightened environmental awareness, any incident, even involving single water well, can become a national event."

Not one, but so many incidents have occurred since hydraulic fracturing of shale gas gained popularity. In Colorado, some 206 chemical fluid spills from oil and gas wells, connected to 48 cases of suspected water contamination, happened in 2008 alone. In New Mexico, toxic fluid had seeped into water supplies at more than 800 oil and gas drilling sites as of July 2008. In Avella, Pennsylvania, a wastewater impoundment caught fire and exploded on a 480-acre property, producing a 200-foot-high conflagration that burned for six hours and produced a cloud of thick, black smoke visible 10 miles away (Bateman, 2010).

[78] See Gasland, a film by Josh Fox http://www.gaslandthemovie.com/whats-fracking

The Delaware, once one of the cleanest free-flowing rivers in the United States, is now the most endangered river in the country, according to the conservation group American Rivers. Moreover, up to 8,000 gallons of Halliburton-manufactured fracking fluid leaked from faulty supply pipes, with some seeping into wetlands and a stream, killing fish, in September 2009 (Bateman, 2010). Some fines have been issued to companies causing hazardous accidents, but according to Bateman (2010) Atlas Energy's $85,000 fine for environmental violations related to fracking is simply a drop in the bucket for a corporation that brought in $1.5 billion in revenue last year.

The fracking process injects extremely pressurized liquids into a well in order to penetrate exceptionally solid rock formations located thousands of meters below the surface. According to Love (2005), fracturing equipment operates over a range of pressures and injection rates, and can reach up to 100 megapascals (15,000 psi) and 265 liters per second (9.4 cu ft. /s) or 100 barrels per minute. Moreover, Northrup (2010) compares the effect of fracking liquid pressure to a massive pipe bomb underground. In fact, he also argues that some of these powerful underground explosions may have been capable of producing earthquakes in natural faults, such as the tremor measuring 2.8 on the Richter scale on June 2, 2009 at Cleburne, Texas – the epicenter of shale gas production where previously, no earthquakes had ever been recorded. A University of Texas study led by Charles G. Groat listed water contamination and consumption, blowouts, explosions, spill management, atmospheric emissions, and health effects as associated problems with shale fracking.

Even though many opponents of shale fracking along with environmentalists believe that this highly unconventional method of extracting gas from shale deposits has the clear potential of causing serious environmental disturbances including small earthquakes around shale formations where well drillings take place; however, not everything should perceived as negative about the fracking process as a whole because it can certainly provide a number of environmental benefits as long as all necessary steps (i.e. regulation, laws, chemical disclosures, effective and efficient company specific processes) have been taken by everyone involved in it; local governments, company executives, regulators, law enforcement agents and citizens. Companies will always tend to abuse the system that is absent of all the necessary elements mentioned above. If the United States has the unique opportunity first time in decades to become energy independent of foreign oil, the U.S. will definitely use its abundant supply of shale gas no matter what.

Natural gas produces emissions that are much lower than those from oil and coal: 30%−40% lower for CO2, 80% for NO, and ∼100% for SO2, particulates, and mercury (Nicot and Scanlon, 2012). Natural gas should help displace coal; from mountaintop-removal mining to its impact on climate change, after all cheap coal is toxic to the human race. Thousands die in coal mines annually around the world; in the U.S. alone, air pollution from coal combustion leads to thousands of premature deaths a year. Natural gas power plants, by contrast, emit far fewer air pollutants. Natural gas's benefit over coal when it comes to climate change is less clear-cut, but it's there, and gas can also coexist with renewable energy, providing inexpensive backup for wind and solar. "Natural gas could be crucial to integrating renewables into the power grid," says Ralph Cavanagh, a co-director of the Natural Resources Defense Council's energy program (Walsh, 2011).

Natural gas is primarily used in residential homes for heating and powering other small home appliances. It is also used by power utility companies for generation of electricity (the largest area of consumption), and natural gas is used to power vehicles. Here is an example that can give the readers a good idea what 1 trillion cubic feet of gas (tcf) is capable of producing; 1 tcf can heat 15 million homes per year and generate 100 billion kilowatt hours of electricity. 1 tcf can also power up 12 million cars per year on the road releasing less GHGs into the atmosphere. This means that the U.S. 1,744 tcf can equal to heating 150 million homes for 175 years and generating 100 trillion kilowatt hours of electricity for the next 175 years; in addition, 1,744 tcf can power 100 million cars for almost two centuries.

Petroleum (i.e. gasoline, diesel) combustion is a significant source of CO_2 emissions in transportation sector where there is a parallel relationship between vehicle miles traveled and the amount of CO_2 emissions from burning of gasoline and diesel fuels by drivers. The electric power companies emit CO_2 into the atmosphere through burning of fossil fuels with the sole purpose of generating electricity. The most obvious growth area for natural gas in transportation is for urban fleets (taxis, buses and other service vehicles) that have access to a central refueling facility. Some argue for adding long-distance trucks to that list (Yergin, 2011). Residential CO_2 emissions primarily originated from basic but necessary home-living activities such as heating, cooking (predominantly natural gas or electricity is used), lighting and use of other electric powered devices (i.e. television, computer and small home appliances). If natural gas is used more than current levels in transportation, generation of electricity and heating homes, then this would be an important step towards reducing carbon dioxide and methane greenhouse gasses which adversely affecting global warming.

Table 11: Costliest U.S. Atlantic Hurricanes (adjusted for wealth normalization – 2005 USD)[79]

Rank	Hurricane	Season (year)	Cost (2005 USD)
1	Miami	1926	$157.0 billion
2	Galveston	1900	$99.4 billion
3	Katrina	2005	$81.0 billion
4	Galveston	1915	$68.0 billion
5	Andrew	1992	$55.8 billion
6	New England	1938	$39.2 billion
7	Cuba-Florida	1944	$38.7 billion
8	Okeechobee	1928	$33.6 billion
9	Donna	1960	$26.8 billion
10	Camille	1969	$21.2 billion
		Total	**$620.7 billion**

Although hurricanes may not be directly linked to potential outcomes of global warming; however, a good number of scientists believe that there must be a logical relationship between global warming and hurricanes' frequency and strength. According to a new simulation study by a group of scientists at NOAA's Geophysical Fluid Dynamics Laboratory (GFDL), the findings of various studies and simulations indicate that "the strongest hurricanes in the present climate may be upstaged by even more intense hurricanes over the next century as the earth's climate is warmed by increasing levels of greenhouse gases in the atmosphere."[80]

From a span of 1903 till 2008, there have been 50 costliest Atlantic hurricanes with estimated total property damage amounting to little over $1 trillion dollars ($1.009 trillion). The recent three costliest US hurricanes had a colossal $175.7 billion in property damages; Katrina - $108 billion (2005 USD), Andrew – $40.7 billion (2008 USD) and Ike - $27 billion (2008 USD).[81] Of course, the extent of property damage, loss of lives and other financial losses that

[79] Modified from main article: List of costliest Atlantic hurricanes http://en.wikipedia.org/wiki/List_of_costliest_Atlantic_hurricanes

[80] Geophysical Fluid Dynamics Laboratory "Global Warming and Hurricanes" National Oceanic and Atmospheric Administration http://www.oar.noaa.gov/spotlite/archive/spot_gfdl.html Retrieved October 17, 2012

[81] See Wikipedia, List of costliest Atlantic hurricanes, http://en.wikipedia.org/wiki/List_of_costliest_Atlantic_hurricanes

people have incurred during and after these hurricanes could be as much as 10 times of the estimated property damages listed here because it usually takes several years for the surviving people to recuperate and get back on their feet literally and financially.

3.0 CONCLUSION

Shale gas fracking, an economic solution or an environmental disaster waiting to strike, will largely depend on how this critical energy resource will be managed by drilling companies (i.e. disclosing all chemicals used in each fracking along with implementation of safe business processes), monitored by regulatory agencies (i.e. setting standards, issuing fines to companies with unsafe practice records and revoking their licenses in the case of repeated offenses) and governed by government authorities (i.e. applicable laws, legislations and a well working trustable judiciary process to punish those company executives who engage in unethical business conduct). Because the end product of shale gas fracking is highly flammable, explosive and toxic; therefore, the U.S. federal laws such as the Safe Drinking Water Act, the Clean Air Act, and the National Environmental Policy Act (NEPA) must do their jobs to ensure that no harm is or will be done to the environment or the human health.

The question is not so much 'shale gas' or 'no shale gas,' the answer is an obvious one; just because some issues exist surrounding the unconventional method of onshore shale gas fracking, the United States as the world's biggest consumer of fossil fuels will not by any means back away from utilizing a rare opportunity to become energy independent of foreign oil (this is also important for political reasons) and use these abundant natural gas resources found on its soil to transform itself from a major energy importer to maybe an energy exporter status. Although the estimate numbers keep being revised now and then, the Energy Information Administration (EIA) reports that the U.S. has more than 1,744 trillion cubic feet (tcf) of technically recoverable natural gas, which could be worth trillions of dollars in today's natural gas prices.[82]

It has not even been a century old since oil (petroleum) was first discovered in Bahrain in early 1930s, and the situation there initially was not so much different than today's shale gas state. There were also a number of uncertainties surrounding oil at the time, a great deal of public concern coming from not really knowing how this discovery was going to affect their lives (positively or negatively) and an outcry by the environmentalists; however, all that did not stop forward progress of the oil industry which led to development of super nations such as the United States of America. The raised issues related to shale gas fracking (i.e. air pollution, leakages, explosions on drill sites and groundwater contamination) are all valid concerns of by the general public and they can be resolved through the use of currently available technologies.

Environmentalists first argued that shale gas fracking operations were not safe; on the contrary of a common belief, Yergin (2011) claims the industry, for its part, points to a long safety record, with some form of fracking having been used in more than 1 million wells in the U.S. since the end of the 1940s. Next, huge amount of water used in each fracking process became a major concern; however, Yergin (2011) argues that the industry has moved to increase the amount of wastewater recycled in drilling operations, currently at over 70% by some estimates; in addition, around 3,500 shale-gas wells drilled in 2010 had only used approximately 0.02% of the entire water consumed in the U.S.. Furthermore, the best gas players can keep improving their rates of recycling wastewater — Chesapeake Energy says it has a 100% recycling rate — while making use of new technologies like those offered by the Utah-based firm Purestream, which can evaporate and clean wastewater at the wellhead (Walsh, 2011).

Although the U.S. population has being increasing slower (little less than on average 1% annually) compared to some other nations in the world (i.e. China, India, and Brazil); however, demand for these extremely critical fossil based energy resources in the U.S. is only going to continue to increase due to quick rises in global population since 1970s adding 1 billion people to its total every 13-14 years, which by the way is projected to exceed 9 billion people

[82] See GWPC: "Modern Shale Gas Development in the United States: A Primer" April 2009, http://www.gwpc.org, p.19

by 2045. The EIA reported that the U.S. production rates for 2007, about 19.3 tcf, the current recoverable resource estimates provide enough natural gas to supply the U.S. for the next 90 years and half of the total natural gas consumed today is produced from wells drilled within the last 3.5 years (since 2009).[83] Shale gas may be what the United States has needed as long as it does not produce adverse effects.

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5.0 BIOGRAPHY

John Taskinsoy has been teaching business communication, marketing, finance and various other business courses for several years. Since 2011 he has been teaching at Universiti Malaysia Sarawak (Unimas), where he has worked as senior lecturer. John has served in a variety of leadership roles in technology companies. Other experiences in corporate management include manufacturing manager, system integration manager, project manager, international business manager, overseas operations director, project director, senior editor, director of global manufacturing & procurement, and operations director. Over 20 years of professional experience in sales, manufacturing, operations, marketing, human resource, budgeting, forecasting, outsourcing, ISO implementations, new product introduction, international marketing, and management positions enable John to bring “real world” examples and cases into his classroom teaching environment. After graduating from San Francisco State University (SFSU) in 1997 with a BSc degree in business administration, he was offered a management position at Nortel Networks where he worked from 1997 to 2001, and then he joined Flextronics International, LSI Logic, and Trexta in later years. While he was employed, he also went on completing his first master’s (MBA) degree in 1999 at University of Phoenix, and then he decided to finish a second master’s (MSc - Telecommunication) at Golden Gate University in 2002.

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[83] See GWPC: “Modern Shale Gas Development in the United States: A Primer” April 2009, http://www.gwpc.org, p.20

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