THE ECONOMIC AND EMPLOYMENT EFFECTS OF HYDRAULIC FRACTURING ON STATE AND LOCAL COMMUNITIES

By

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ON STATE AND LOCAL COMMUNITIES

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ABSTRACT

This thesis addresses the issue of the economic and employment benefits of unconventional oil and gas developments which use the controversial hydraulic fracturing technique. In this work, attention is focused on the state and local (county) levels.

A major 2012 study by IHS containing the projected economic and employment benefits of unconventional oil and gas developments is reviewed. It is found that the projected economic and employment benefits are highly concentrated in the producing states (i.e., those allowing unconventional oil and gas developments) as compared to the non-producing states (i.e., those not allowing unconventional oil and gas developments, or having no oil and gas resources).

Similarly, an historical county-by-county analysis of job growth and per-capita income for the Commonwealth of Pennsylvania (part of which lies above the Marcellus Shale) has been carried out using data from the Bureau of Economic Analysis and Bureau of Labor Statistics. The data shows solid correlations between increases in employment and per capita income with the degree of unconventional oil and gas activity occurring in a particular county.

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INTRODUCTION

In November 2012, the International Energy Agency predicted that the United States would overtake Russia to become the world's top producer of natural gas by 2015 and would overtake Saudi Arabia to become the world's largest producer of oil by 2020.

These predictions are the result of a revolution in natural gas and oil production in the United States in the last 10 years, during which companies have learned to extract oil and gas reserves trapped in shale and other impervious rock formations [1]. To achieve this they use a technique called "hydraulic fracturing" or "fracking" in which fluid is pumped into the shale at high pressure to crack the rock and release the oil and gas trapped inside. The "shale revolution" has created many high-paying jobs, enhanced US energy independence, and helped to reduce greenhouse gas emissions by replacing coal with natural gas.

The magnitude of this phenomenon can be appreciated as follows: in 2000, shale supplied negligible oil and only 2% of natural gas in the US [5], and in 2007 the US was preparing to become a net importer of natural gas [4]. However, since 2008, domestic natural gas production has risen by 25%. Today 50% of US domestic natural gas production comes from shale and tight sands, and this number is expected to rise to 80% by 2035 [3]. The second largest natural gas field in the world is in Pennsylvania and large deposits are in Arkansas, New York, Ohio, Louisiana, Oklahoma, West Virginia and North Dakota. In addition to natural gas, there have been huge amounts of oil produced from shale beds. In 2003, 100,000 barrels per day (BPD) of oil were produced from shale, that number increased to 2,000,000 BPD in 2012; and it is anticipated that this will rise to 4,500,000 BPD, representing 2/3 of US oil production. As an example, the Bakken Shale in North

Dakota is 25,000 square miles and is estimated to contain 11 billion barrels of oil recoverable with current technology, and ultimately there may be 30 billion barrels. In 2008, North Dakota was produced less than 1% of the US oil, but by 2012 it had passed California and Alaska to become (after Texas) the second largest oil producing state in the US [1]. The overall distribution of these gas and oil shale basins is shown in Figure 1.

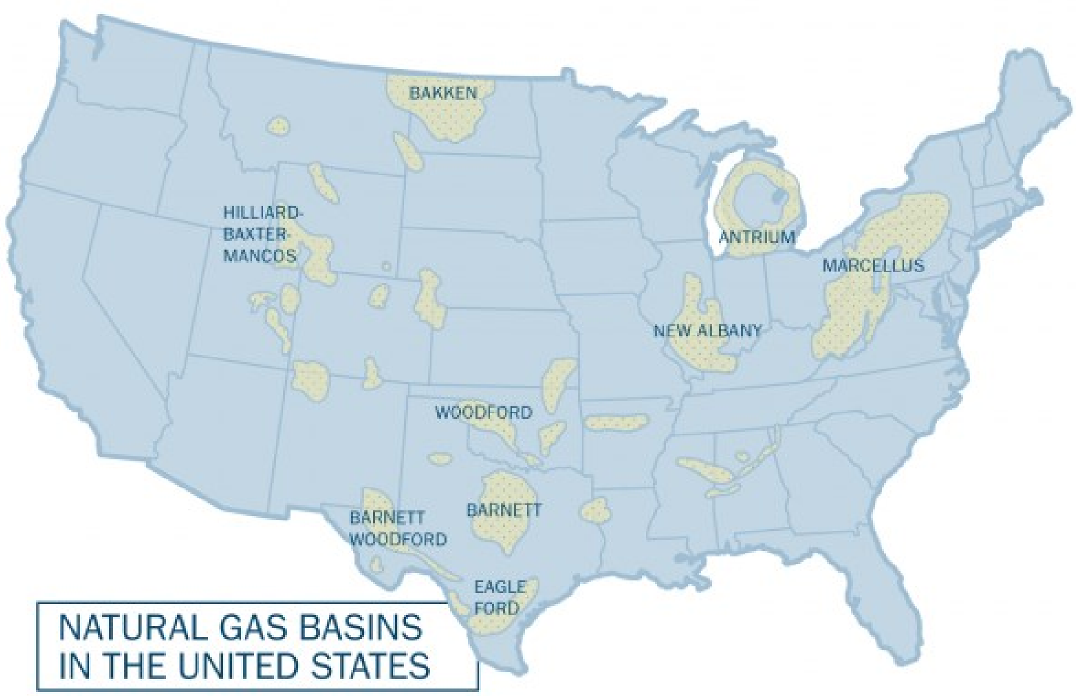

Figure 1: Natural Gas and Oil-Bearing Shale Basins in the USA [2].

However, hydraulic fracturing is controversial. While all oil and gas drilling activities carry some risk, the most serious perceived risk uniquely associated with fracking is the potential contamination of the groundwater by the toxic chemicals contained in the fracturing fluid. There is little evidence of direct groundwater contamination by hydraulic fracturing since the shale layer is typically several thousand feet below the water table with a rock or clay layer between them, however there is widespread public concern. This has been sufficient in some instances for some "local" communities: states, counties etc. to either place a moratorium or an outright ban on drilling activities that use the fracking process. In doing so, these communities are likely to miss out on the vast majority of the economic benefits that the shale revolution brings to their region.

This thesis seeks to investigate the projected and historical economic and employment impact on "local" communities of allowing, or banning, unconventional oil and gas drilling that uses the fracking process. The "local" communities considered are at the state and county level. At the state level there is a large amount of economic and employment data available in the literature. By comparing projections of the relative economic growth of states that allow unconventional oil and gas developments using hydraulic fracturing and those which do not, the expected economic benefits of fracking at the state level can be demonstrated. At the county level, historical data regarding employment and economic performance is available. By tracking the relative historical economic performance of counties within a state that have different levels of unconventional oil and gas developments, the economic benefits of fracking at the county level can be assessed. This quantitative data on the projected and historical benefits of allowing unconventional oil and gas development can then be weighed against the possible environmental risks associated with the fracking process.

The contents of this thesis are as follows: (1) A brief, semi-technical outline of the hydraulic fracturing process; A summary of the economic, national security, and environmental benefits of this practice; (3) A discussion of the risks associated with hydraulic fracturing and directional drilling; (4) The status of hydraulic fracturing in the US, including an assessment of the impact of a total ban across the US; (5) A discussion of the economic impact of fracking on two sets of “local” communities – at the state and county levels; and, finally, (6) A summary of the work and some conclusions.

THE HYDRAULIC FRACTURING PROCESS

Traditionally, oil and gas has been extracted from permeable rock formations, in which oil and gas flows reatively freely. However, it has been known that the oil and gas deposits in permeable rocks are only a small amount of the total of these resources that exist. Much more can be found in shale deposits; however these resources could not be extracted because the shale is not permeable enough.

Figure 2: Typical Rig Drilling for Gas [2].

During the past ten years, energy companies have developed new technologies to extract oil and gas from shale. The key innovation was to combine two technologies that were developed separately: the first is “hydraulic fracturing” or “fracking” and the second is “horizontal drilling”. Neither of these technologies is new – hydraulic fracturing was first used in the 1940s, and horizontal drilling techniques were developed in the 1980s. However, the combination of the two technologies to extract oil and gas from underground shale rock only began in 2003.

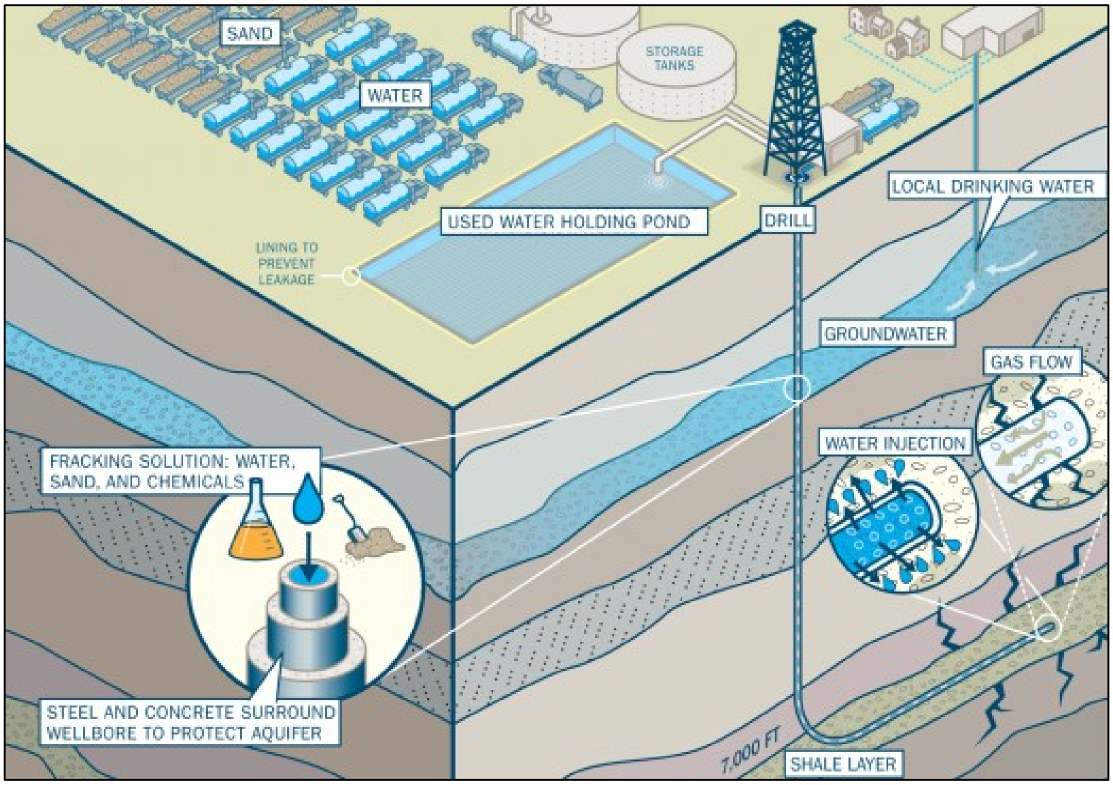

Figure 3: Drilling for Natural Gas by Hydraulic Fracturing [2]

The initial step involves drilling vertically down to the shale layer, which is typically thousands of feet beneath the surface. The second step is to drill horizontally, again several thousand feet from the vertical shaft, and then steel casing is installed in the well and it is then cemented. The next stage is to perforate the horizontal casing using explosives, after which water with sand and chemicals is forced at high pressure into the well. The high pressure water meets the shale through the perforations and generates a series of small fractures in the rock. The sand in the water keeps the cracks open, while the chemicals enhance the release of the gas from the shale. It has been found that up to 25 fracture stages may be required to get a single site ready for production, and more than 400,000 gallons of water may be needed. To reach the stage where a well is operational, 10 million gallons may be required. Releasing the pressure in the well results in a portion of the injected water flows back up to the surface then the well starts to produce gas (see Figure 3). The water that returns to the surface contains the fracking chemicals and the others it has absorbed from the shale, a portion of it is recycled and re-injected into the well to help with the next phase but most of it is stored temporarily in lined ponds at the well site (Figure 4) for transfer to a standard water treatment facility.

Figure 4: Wastewater Holding Pond for a Fracking Well in Rural Pennsylvania [2].

THE BENEFITS OF HYDRAULIC FRACTURING

Economic Growth

Shale oil and gas are capital-intensive industries, and generated $87 billion of capital investments in the US in 2012. Annual investment of $172.5 billion is expected y by the end of the decade and $5.1 trillion (in total) by 2035 [3]. It is estimated that every drilling job creates three to four other jobs, the so-called “employment multiplier”. Also, the effect of this economic growth is felt to some degree outside the oil and gas producing states since the supply chain extends to other states as well [4]. It is estimated that shale oil and gas generated 1.7 million US jobs in 2012, and that this number will increase to 3 million in 2020, representing 2% of total employment in the US [3].

The greatest impact of the shale gas revolution has been its effect on consumers: it has caused the price of natural gas to drop to 1/3 of its price in 2008 [5]. However, gas prices in Europe and Asia are 3 to 5 times higher than in the US, which gives an indication of what US prices would be if they were set by the international markets and natural gas had to be imported instead of produced domestically. It is estimated that every household in the US saves $926 per year in heating costs, and this number is expected to grow to $2000 by 2035 [5].

Lower energy costs have helped US businesses cut costs, generate higher profits and increase their workforces. Lower natural gas prices are expected to reduce electricity prices by 10%, and to be responsible for a 2.9% increase in industrial production by 2017, and a 4.9% increase by 2035 [5]. It is expected that lower petrochemical and energy costs will result in one million more manufacturing jobs in the US by 2025, and will add 0.5% annual growth to the GDP [6].

Overall transportation accounts for about 30% of US energy consumption, so there is a significant long-term advantage to replacing petroleum for cars trucks and buses by natural gas. On an energy-equivalent basis, natural gas costs less than 1/5 of the cost of oil. This switch is especially straightforward for fleet vehicles or municipal vehicles that have their own refueling facilities. Also, electric cars and hybrids can be powered by electricity generated by natural gas.

The US balance of payments will show these economic benefits. The 2012 current accounts deficit of the United States is around $700 billion, which includes $320 billion of oil imports. Without the shale oil and gas production that has occurred since 2008 this deficit would have been 25% larger, for a total of $865 billion. If production increases as expected then the future deficit will be further reduced by $185 billion[3]. This number will increase if the US also starts exporting natural gas.

By combining all of the above effects, shale oil and gas provided over $235 billion to the US GDP in 2012, and is expected to contribute almost $420 billion by 2020, and $475 billion by 2035, approximately 2% of US GDP [3]. Similarly, shale oil and gas contributed over $60 billion in federal, state and local tax revenues in 2012, and is projected to rise to over $110 billion in 2020, for a total of almost $2.5 trillion by 2035 [3].

Energy Independence and National Security

Much of the world's oil and natural gas comes from nations that are either unfriendly to the USA or are unstable. The top eight oil exporting nations are Saudi Arabia, Russia, Iran, the United Arab Emirates, Norway, Iraq, Kuwait and Nigeria [1]. Similarly, over 70% of the world's gas reserves (conventional only, not including shale gas) are found in Iran, Qatar and Russia. Many regimes and use the revenues from oil and gas to further their foreign policy and political agendas which are often in opposition to US foreign policy. In extreme cases these regimes may fund terrorists to attack the US and our allies.

In 2005 the US imported 60% of its oil. That number reduced to 42% in 2012 with further reductions in oil imports expected in the next two decades. It is projected that the

US will be self-sufficient in natural gas by 2020 and 97% energy self-sufficient by 2035 [1]. Developing domestic energy resources may allow the US to reduce its defense budget since the need to protect the flow of imported energy will no longer be necessary.

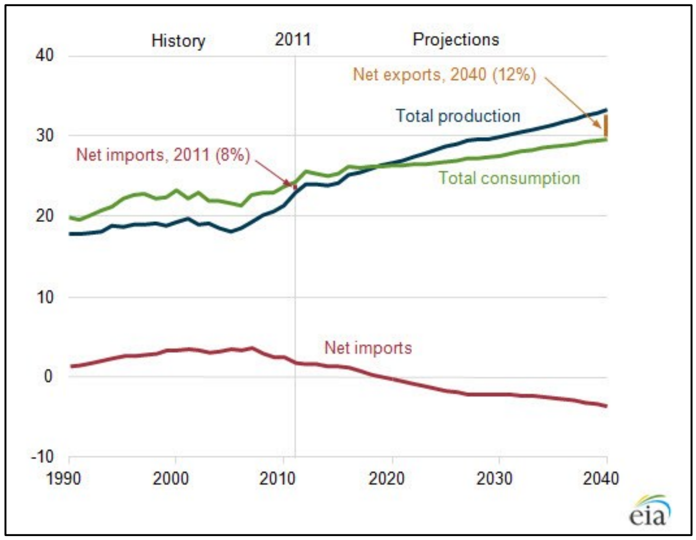

Figure 5: Total US Natural Gas Production, Consumption and Net Imports (Tcf) from 1990 - 2040 [1].

Environmental Benefits

Although most of the discussion about fracking has focused on the potential environmental risks, there are also some significant environmental benefits. Natural gas burns cleaner than other carbon-based fuels, and produces less carbon monoxide, carbon dioxide, sulfur dioxide than coal [9]. Almost half the electricity generated in the US came from burning coal until recently, but this reduced to 42% in 2011 and 36% in 2012 [1]. Shifting from coal to gas is the main reason why US greenhouse gas emissions have reduced 450 million tons in the last 5 years (see Figure 6), at a time when Europe has seen an increase (due to replacing oil with coal).

According to a 2011 MIT Study [7], using natural gas to generate electricity can reduce US greenhouse gases from this sector by 20% or by 8% overall. Therefore, fracking allows the use of natural gas to reduce near-term carbon emissions while renewable technologies are being developed as long-term solutions.

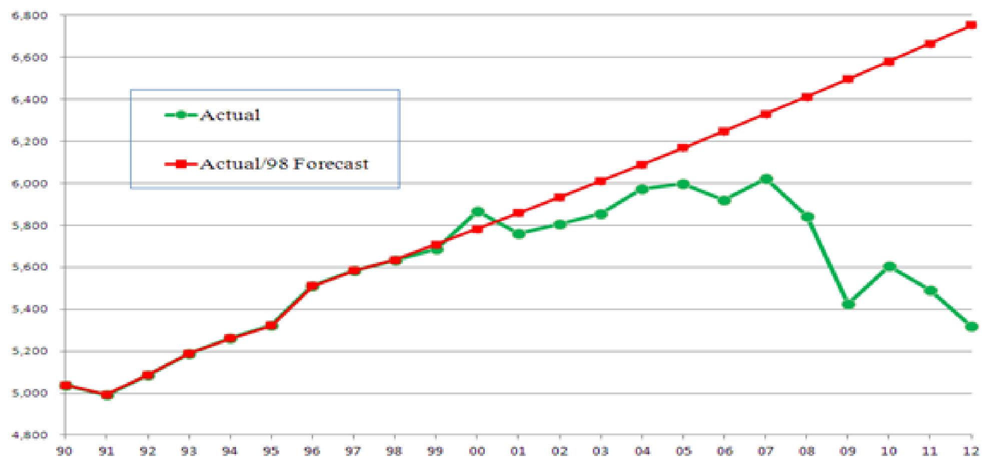

Figure 6: US Carbon Dioxide Emissions from Energy Consumption Between 1990 and 2012 - Including 1998 Forecast (million tonnes) [1].

THE RISKS ASSOCIATED WITH HYDRAULIC FRACTURING

There are several risks associated with hydraulic fracturing, however many of these risks are also associated with conventional oil and gas drilling (i.e., without fracturing and horizontal drilling). Indeed, these risks also occur in coal mining, industrial manufacturing and even in shopping malls or sports arenas. The various risks are discussed in detail in the following sections.

Economic Competition with Renewables

An increase in the supply of oil and natural gas fracking reduces price-based incentives to conserve energy. In particular, it makes renewable energy less attractive, since the required subsidy relative to fossil fuels is larger in a relative sense when oil and gas prices are lower. Finally, the availability of cheap natural gas (which burns in a relatively clean manner) undermines the political will to develop the technologies associated with renewables so that they will never become competitive.

Air Pollution

Air pollution from drilling in shale beds can occur in four ways:

- A well or a pipeline can leak methane and cause greenhouse gas emissions. However, energy companies have a large incentive to minimize these kinds of emissions (so they can sell the gas).
- Fracking fluid contains volatile organic compounds ("VOCs") such as benzene which may be released into the atmosphere when the fluid evaporates. These chemicals can cause cancer as well as other ailments. Therefore, some states (e.g., Texas) require monitoring of VOC emissions near drilling sites while others (e.g., Colorado) require or holding tanks or vapor recovery systems to minimize VOC emissions.
- Drilling deep into the earth, sometimes releases so-called "naturally occurring radioactive materials" or "NORMs". However the state and federal government have various regulations in place to address this issue.
- Drilling equipment and trucks produce additional emissions. This is not unique to drilling activities as factories and shopping malls also produce emissions.

Congestion and Pressure on Local Infrastructure

When oil or natural gas is discovered there is usually an influx of workers into a community. The population surge puts pressure on housing, schools, and other services. Traffic is increased and the transportation infrastructure may be inadequate. However, these challenges occur with any new economic activity that brings economic development to rural areas. Also, drilling in shale beds has an advantage over conventional drilling. In horizontal drilling there are fewer drill pads because one single pad may be used for multiple wells. Also there is some flexibility over where a pad may be located because horizontal drilling allows access to a deposit some distance away. Conventional drilling requires the pad to be located above the deposit, which may be in an especially sensitive area.

Heavy Water Usage

Hydraulic fracturing requires large amounts of water: a single well uses upto 4 million gallons. The effect of this additional water requirement depends on where the fracking activities occur. For example, in the area overlying the Marcellus Shale (Pennsylvania and New York) there is significant precipitation and so the additional water is readily available. However, in the area overlying the Barnett-Woodford Shale in Texas, the water issue is more serious. The cost of transporting water to over long distances makes it attractive to use sources closest to the well sites, which may strain service infrastructure. To overcome these problems, energy companies are now recycling and reusing up to 80% of fracturing fluid.

Induced Earthquakes

There has been a confirmed case of hydraulic fracturing causing a small earthquake in Blackpool, UK. Another case has been reported in Oklahoma. Although these seismic events were small, they have generated a considerable amount of concern in the general public, and so cannot be discounted. A National Research Council Study concluded that earthquake events from fracking would be small, and over a very limited spatial area. There is a greater risk of earthquakes from disposing of fracturing waste in injection wells, but this is similar to the disposal of waste water from conventional drilling activities.

Groundwater Contamination

Groundwater contamination is by far the most serious risk associated with hydraulic fracturing and this issue has attracted a huge amount of attention from the media and environmental organizations.

The main ways in which the fracking process could contaminate groundwater are as follows: first, during fracking the fracturing fluid might travel from the shale layer into water wells and aquifers; second, gas released by fracking might travel into water wells and aquifers; third, drilling vibrations might disturb contaminants at the bottom of a water well; and, fourth, used fracturing fluid from the drilling process might be disposed of improperly and it may pollute the groundwater.

Because these risks are primarily associated with fracking (as opposed to conventional oil and gas drilling), and because they form the essential basis for states and local communities (and even countries) to restrict or ban hydraulic fracturing they will be discussed in more detail below.

Migration of Fracturing Fluid from Fracturing into Aquifers

Fracturing fluid is 99.5% water and sand but the other 0.5% contains toxic chemicals. Since the goal of fracking is to create cracks in the underground shale formations (to allow oil and gas to come out), the question of whether the fracturing fluid can migrate through these cracks into water wells and aquifers is a very real one, and this one of the most commonly perceived risks by the public [8].

However, geological studies suggest that this risk is remote since the hydraulic fracturing of shale beds typically takes place 1.5 – 2 miles below the surface while the water table is typically only 500 – 1,000 feet down. In between the shale beds and the water table are multiple layers of rock and clay, some of which are highly impermeable. Toxic chemicals would have to migrate upwards 1 mile or more through highly compressed soil and rock formations to contaminate groundwater. According to a 2011 DOE Study, the risk of fracturing fluid leaking into groundwater through fractures made in the deep shale reservoirs is remote [8]. This conclusion is shared by the 2011 MIT Study [7].

However, there are four other (more realistic) ways that fracturing fluid could enter water supplies [9]. These are outlined below:

- Fracturing chemicals might accidentally be spilled on the surface, either before or after the drilling process, and then might seep down into the water table. Fracturing fluid should be transported and stored carefully according to EPA regulations but the sheer volume of fracking operations throughout the US makes a small number of spills inevitable, which is similar to the issues faced by many industrial processes.
- When shale cracks, the gas that is released pushes some fluid back up to the surface, which is known as "flow-back". In addition, water that had accumulated naturally in the shale formation is also pushed up. Both the fracturing fluid and this produced water must be caught at the surface so that it does not seep into the water table.
- There is a risk that the well itself may crack at or above the water table, allowing fluid to leak into nearby wells or aquifers. If there is a crack in the "well casing" (the layers of concrete and steel encasing the well) then what is inside the wellbore – fracturing

fluid, gas or oil – could leak out. Therefore, proper well casing design is essential for safe operations (similar to conventional drilling).

- If the energy company encounters an unexpected pocket of gas when drilling then the subsequent pressure surge can cause a blowout, which is a dangerous, uncontrolled release of gas or fluid. Blowouts are also a familiar issue in conventional drilling and they can usually be prevented by using thick and deep well casings and with a "blowout preventer" which is an assembly of valves on top of the well which close automatically in the event of a pressure surge.

The overall magnitude of these risks is uncertain. However, they are caused by enginering and management problems and are associated with the well design and operating procedures of the energy companies rather than with the hydraulic fracturing process itself.

Contamination of Water Wells with Methane

The natural gas itself that is released by the fracking process, predominantly methane, can also contaminate the groundwater. There have been several reported incidents of methane contamination in water wells [7]. Since methane can leak out through cracks in vertical well pipes that pass through aquifers (see Figure 3), the best response is to ensure that the thickness and depth of the well casing is sufficient to prevent contamination [7]. This problem can also occur in conventional wells, however the additional risk presented by fracturing is the possibility that methane might migrate from the fractured shale seam through fissures created or enlarged by fracturing into aquifers above or near the shale seam.

Disturbance of Sludge or Other Residues in Water Wells

The vibrations and pressure pulses caused by fracturing can bring iron, manganese, and other contaminants up from the bottom of the well into the water. This phenomenon offers one explanation as to why some wells near drilling sites appear dirty but do not test positive for fracturing chemicals. However, it is important to note that hydraulic fracturing stirs up the contaminants that are already present in the water well and does not introduce any new contaminants into it.

Unsafe Disposal of Used Fracturing Fluid and Other Waste

Energy companies need to dispose of used fracturing fluids and the produced water which is a by-product of oil and gas production. The volume of used fracturing fluid for disposal may be significantly reduced by recycling. Another practice is to store used fluid and produced water underground in "injection wells" that are specifically drilled for this purpose and regulated by the EPA. To ensure that injection wells do not pose a risk to the water table their casings must be sufficiently thick and deep and the total well depth should be deep enough to ensure that the waste is far below the water table.

THE STATUS OF HYDRAULIC FRACTURING IN THE USA

The Impact of Banning Fracking in the U.S.

As discussed in the previous section, hydraulic fracturing is opposed by many individuals, politicians and environmental and community organizations. This opposition is due to concerns about the risks associated with fracking activities outlined above.

While some opponents of hydraulic fracturing recommend an increase in state/federal regulatory oversight, others advocate a complete halt to all fracking activities and a cessation in the production of unconventional gas. In order to rationally address this question, it is necessary to investigate the economic and environmental impacts of shutting down all U.S. shale gas production [10].

The Importance of Shale Gas Production

There has been a ten-fold increase in U.S. shale gas production since 2006, and shale gas production is now up to about 28 Bcf (Billion cubic feet) of gas per day as shown in Figure 7. It can be seen that shale (natural) gas production in the Marcellus (PA and WV), Haynesville (LA and TX) and Barnett (TX) areas currently accounts for approximately 2/3 of the total U.S. shale gas production.

The EIA Annual Energy Outlook for 2013 [12] forecasts that shale gas production will continue to increase over the next few decades while conventional gas production is expected to continue its long-term decline as shown in Figure 8. Shale gas production is projected to double between 2012 and 2040, and supply about 50% of the total U.S. gas production by that time. Tight gas, coal bed methane, and Alaska (conventional) gas production are also expected to increase but at a slower rate.

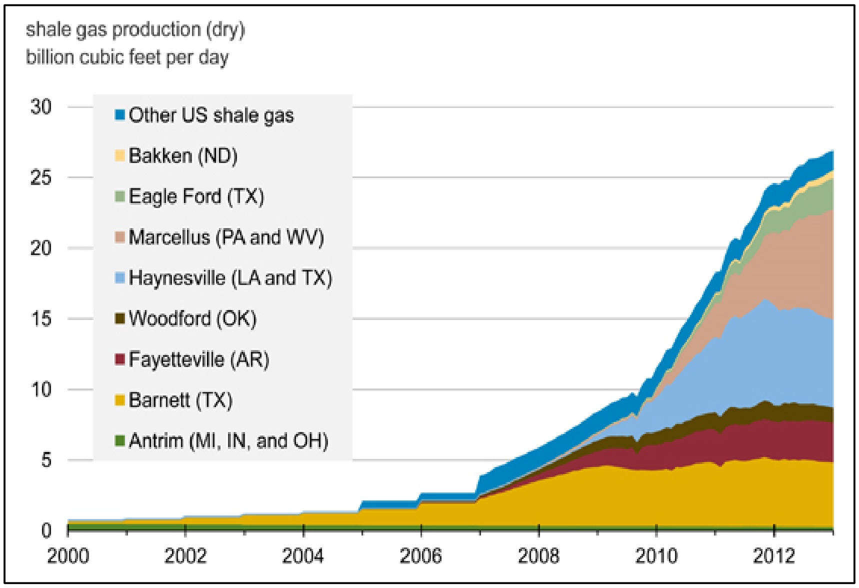

Figure 7: US Shale Gas Production (Bcf/day) from Different Regional Plays [11].

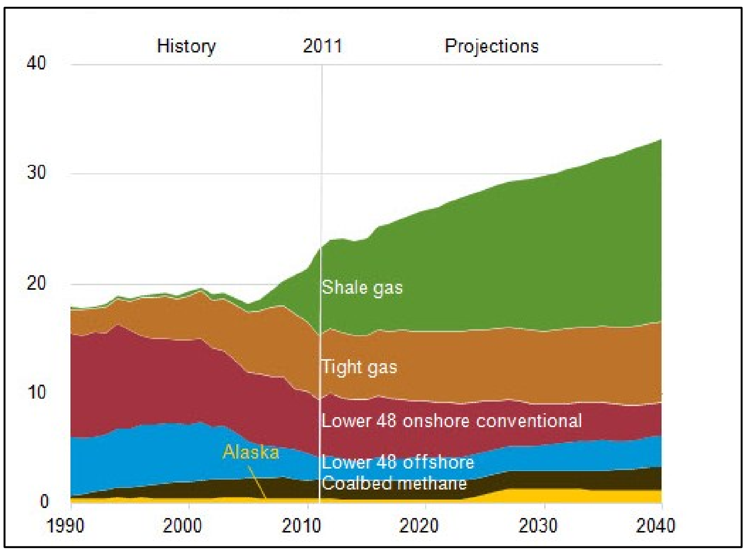

Figure 5.2: US. Historic and Projected Natural Gas Production (Tcf) by Source [11].

Finally, it should be recognized that shale gas has also become a major source in the world natural gas supply, and its contribution is projected to increase. Figure 9 shows that the total world natural gas production is expected to increase by almost 70 Tcf (Trillion cubic feet) per year, or by about 60% between 2012 and 2040. Most of this increase is expected to come from Non-OECD states such as Russia and the Middle East countries. However, a very large part (12%) of the increased world natural gas production is projected to come from growing US shale gas production and in 2040 U.S. shale gas is expected to account for 9% of the total world natural gas supply.

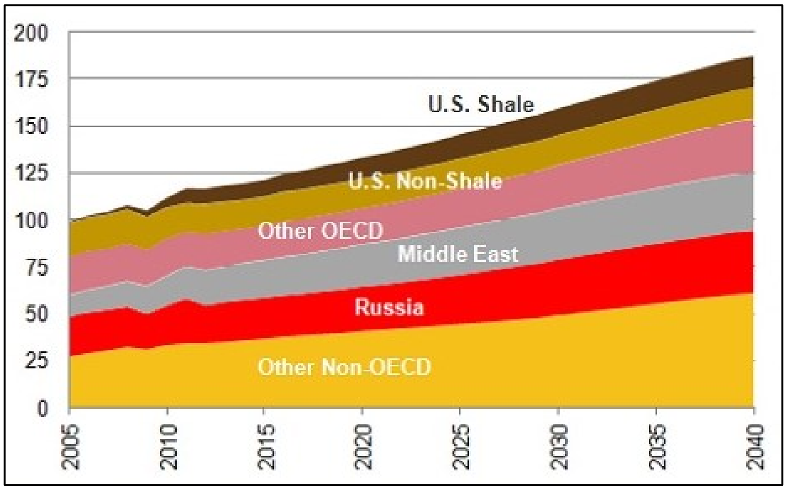

Figure 9: Historic and Projected Natural Gas Production (Tcf) by Region [11].

Impacts of Shutting Down U.S. Fracking and Shale Gas Production

Shutdown of all U.S. shale gas production will dramatically impact domestic and international markets. A loss of all U.S. shale gas will cause a significant reduction in total world supply which will adversely impact market prices and the economy, energy security, fossil fuels mix and carbon emissions.

Based on the growth in U.S. shale gas production over the last 10 years the Federal government has approved the building of several LNG 'export' terminals. The projected increase in shale gas is expected to create an over-supplied US market, justifying the export of excess domestic production and allow taking advantage of economically attractive world LNG markets, based on regional differences in world natural gas prices (see Figure 10). However, if all shale gas production were shut down this excess domestic supply would disappear.

In 2012, U.S. net natural gas imports were 1.5 Tcf, which is roughly 6% of consumption. All of these net imports come from Canada, which is the most secure source of U.S. energy imports. Based on the latest EIA data [12], net U.S. gas imports are projected to decline to zero in 2020 and 'net exports' are projected to increase up to 3.5 Tcf by 2040 as shown in Figure 11. This figure also shows that if all U.S. fracking operations and shale gas production were to be shut down at the end of 2013 that U.S. net imports would immediately increase to 10 Tcf in 2014 and 13 Tcf by 2040. These levels of natural gas imports represent 40-45% of total U.S. consumption over the period 2014-2040. This level of U.S. natural gas consumption supplied from imports is 2-3 times previous historic highs.

As well as changing the U.S. from a projected net exporter of natural gas to a continuing gas importer, shutting down shale gas production will have a significant effect on the price of natural gas and the U.S. economy as a whole. The U.S. has one of the lowest average prices for natural gas compared to other OECD countries [12].

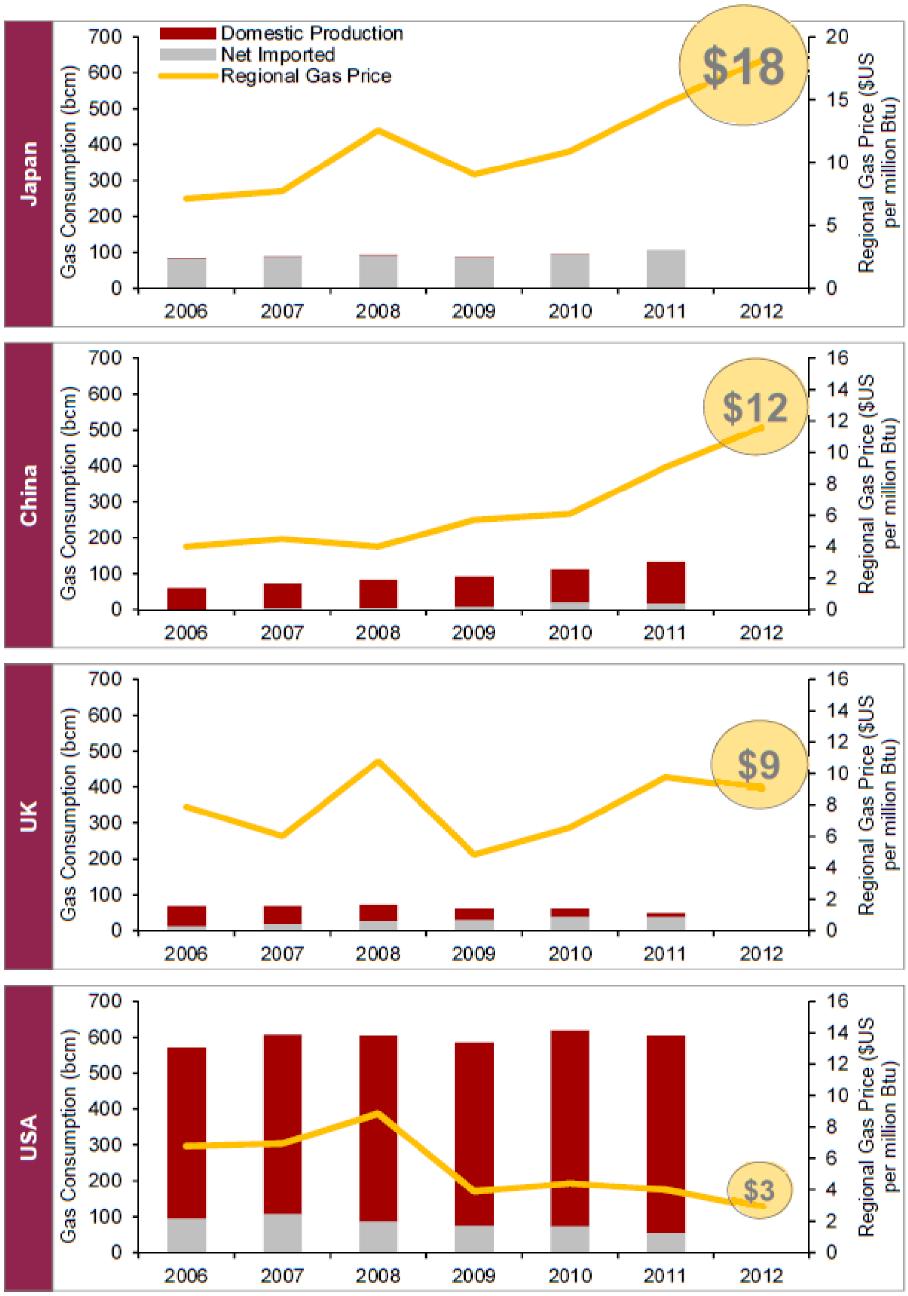

Figure 10: Historical Differences in Regional Natural Gas Prices [12].

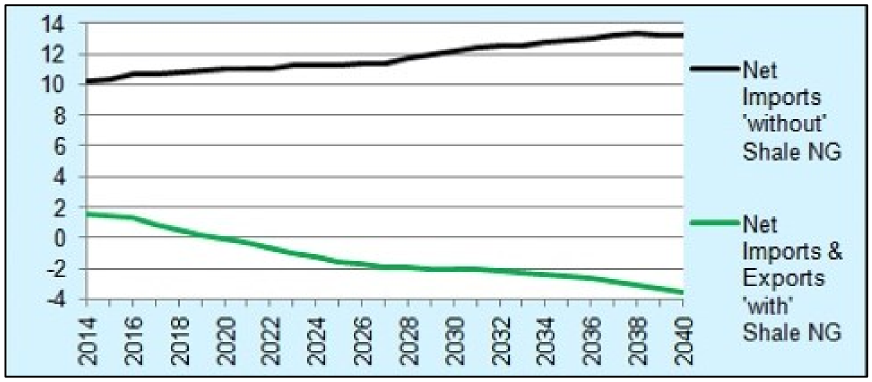

Figure 11: U.S. Projected Exports and Required Imports (in Tcf) from Shutting Down Shale Gas Production [10].

The shutdown of U.S. shale gas production would also have a huge negative impact on employment and the overall economy. According to the IHS [5], shale gas currently supports over 600,000 workers, and contributes more than $200 Billion/year to the GDP and more than $50 Billion/year to State and Federal tax revenues. Banning hydraulic fracturing, and effectively shutting down U.S. shale gas production would result in the loss of these economic benefits, and would result in paying foreign countries outside North America more than $100 Billion/year for natural gas imports.

As stated previously, shale gas provides a means for the U.S to obtain energy security. If the U.S. were to ban hydraulic fracturing and cease all shale gas production net imports would increase up to about 45% of total consumption, which would cause an enormous decline in current U.S. energy security.

Shutting U.S. shale gas production will have a large impact on the world energy mix. The subsequent increase in natural gas heating fuel costs will generally result in consumers switching to less-expensive coal. Reduced natural gas supplies and increased costs will encourage developing countries to increase their coal consumption. Without U.S. shale gas, total world coal consumption could increase by at least 11% in 2040 and switching to coal will result in an increase of carbon emissions of at least 2.3 Billion metric tons per year in 2040. This is equivalent to increasing total world carbon emissions by 5%, leading to a negative effect on the planet's climate.

Alternatives to Banning Hydraulic Fracturing in the U.S.

From the above discussion, it can be seen that banning fracking in the US and production of shale gas will have a large negative impact on U.S. and World economies, energy security and carbon emissions. Instead of adopting potentially destructive legislation and/or regulations, more evaluation of current unconventional gas development operations should be taken [10].

The basic requirements for developing an environmentally responsible and profitable hydraulic fracturing industry are solid scientific data, balanced regulation, and transparency of operations. These are discussed in more detail below:

- A lot of the scientific data opposing hydraulic fracturing is based on a relatively small sample size, statistically biased, or is of short duration. However, the contamination of groundwater is a highly emotional and sensitive topic. However, solid scientific evidence, based on large datasets gathered over extended periods by distinguished researchers will go a long way towards lowering the temperature of the argument and providing a sensible framework on which to base regulatory policy.
- Each US state possesses a framework for the regulation of oil and gas drilling activities, and for the monitoring of hydraulic fracturing of wells. However, there is considerable variability between the states. The goal should be to create a balanced regulatory environment that addresses the legitimate concerns of the local population yet makes the responsible development of these important resources possible.

- Transparency of operations, both to the local community and the various regulatory agencies is an essential step in building public trust in oil and gas drilling operators as responsible developers of natural resources, and of hydraulic fracturing as a safe and reliable process. A lot of progress has been made in this regard, with websites such as ***FracFocus*** (www.fracfocus.org), which is managed by two entities: the Ground Water Protection Council and Interstate Oil and Gas Compact Commission. The missions of these two organizations involve environmental conservation and protection. The site provides the public access to reported chemicals used for hydraulic fracturing within their area. It is emphasized that the site's main purpose of this site is to give factual information on groundwater protection as it relates to fracking activities and not to debate the use of hydraulic fracturing technology or to give a science-based analysis of the associated risks. It is currently being used by 10 states as a means of officially disclosing chemical contents (CO, LA, MS, MT, ND, OH, OK, PA, TX, UT).

ASSESSMENT OF ECONOMIC AND EMPLOYMENT IMPACTS ON STATE AND LOCAL COMMUNITIES

Recently, there has been a considerable amount of interest in attempting to quantity the economic and employment impacts of allowing unconventional gas developments, i.e., gas production from shale, tight sands and coal bed methane (CBM), and the associated hydraulic fracturing process. Data has been gathered on a state-by-state level, and within those states that are involved in unconventional gas production, data is available on a county-by-county basis. The basic assumption in discussing much of this data from the present perspective is that the production of unconventional gas resources is intrinsically linked to the hydraulic fracturing process and so the level of unconventional gas production may be seen as the level of fracking activity, both at the state and county levels.

It is noted in [13] that coalbed methane extraction doesn't usually involve fracking in the early years of a development. Large amounts of water are pumped out of the coal seams to reduce the pressure. However, if gas flows reduce then the well may be fracked to increase productivity". Up to 40% of coalbed methane wells in Australia are hydraulic fracturing at some stage of their development cycle [13].

Projected Economic and Employment Impacts on State Economies

Recently, in 2012, IHS carried out a study to forecast the economic and employment contributions of natural gas development in state economies over the period up to 2035 [4]. The economic gains generated by increased unconventional gas production (and hydraulic fracturing) were presented as contributions to employment, GDP, and federal, state and local government revenue. Much of the discussion below is based on that report (IHS is a major US consulting company in the United States that specializing in advising giving advice to private companies and govenments on energy industry trends and business strategy).

The distribution of the unconventional gas plays in the lower 48 states is presented in Figure 12. Most of the economic activity generated by unconventional gas production will take place in the 16 states with natural gas resources – the so-called "Producing States"; however, by 2015 it is predicted that many economic benefits will occur in states that do not have any unconventional gas production activity – the "Non-Producing States" who will benefit from the purchases of services and supplies.

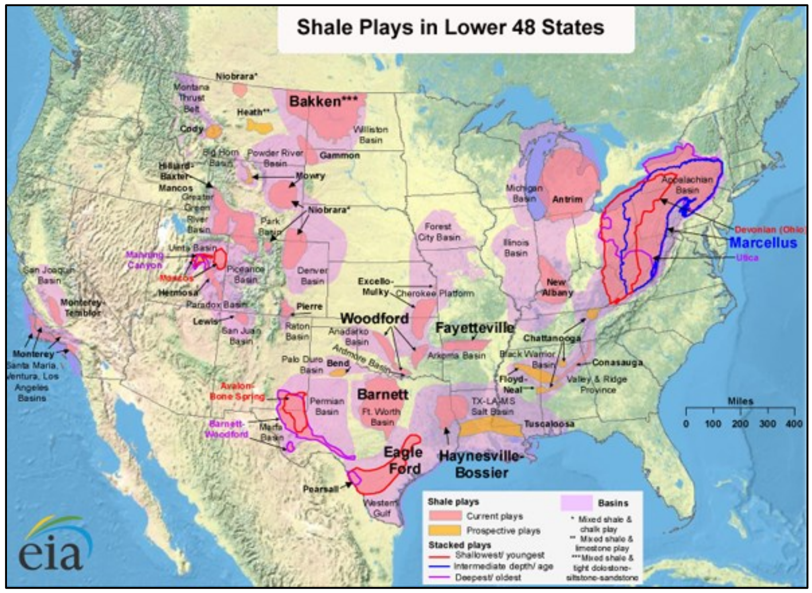

Figure 12: Shale Plays in Lower 48 States [1].

The 16 producing states are Arkansas, California, Colorado, Kansas, Louisiana, Mississippi, Montana, New Mexico, North Dakota, Ohio, Oklahoma, Pennsylvania, Texas, Utah, West Virginia, and Wyoming. The 32 "Non-Producing States" are Alabama, Arizona, Connecticut, Delaware, Florida, Georgia, Idaho, Illinois, Indiana, Iowa, Kentucky, Maine, Maryland, Massachusetts, Michigan, Minnesota, Missouri, Nebraska, Nevada, New Hampshire, New Jersey, New York, North Carolina, Oregon, Rhode Island, South Carolina, South Dakota, Tennessee, Vermont, Virginia, Washington and Wisconsin. The geographic distribution of the producing and non-producing states is shown in Figure 13 [4].

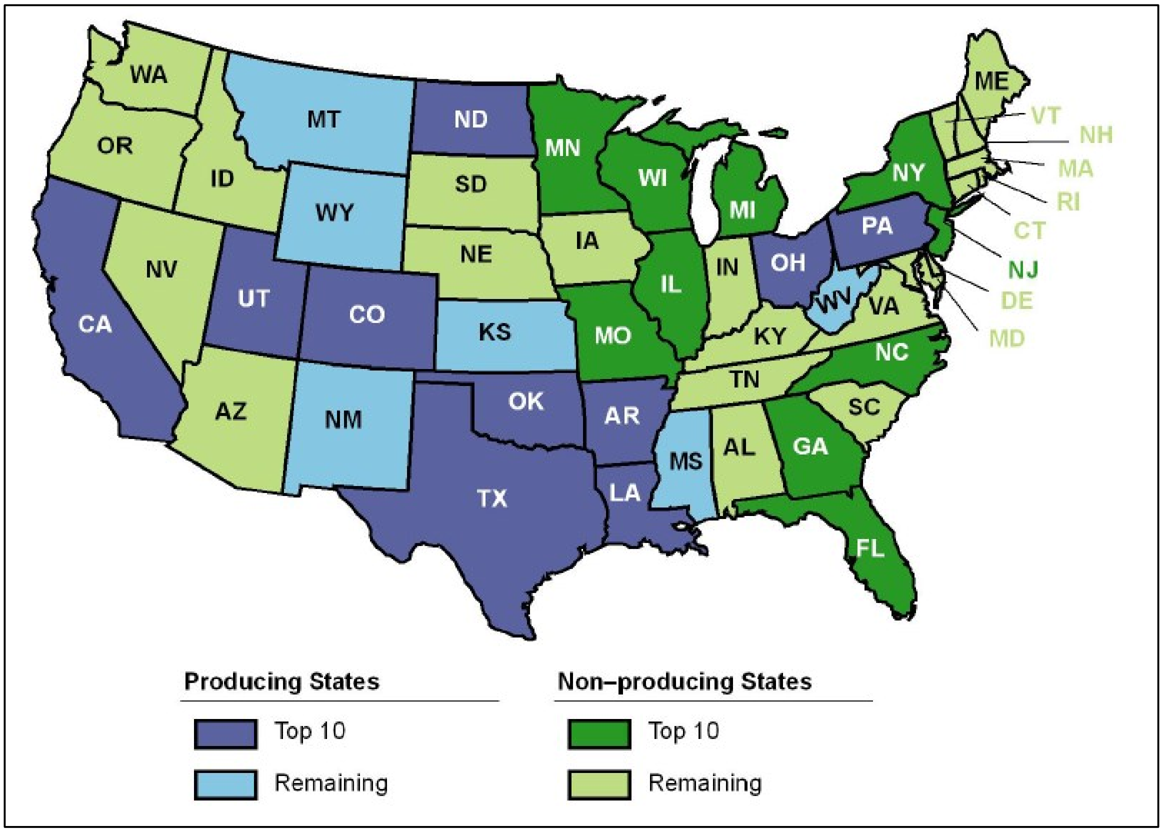

Figure 13: Geographic Distribution of Producing and Non-Producing States [4].

Although the non-producing states currently have no unconventional gas wells, nor are they currently projected to engage in unconventional gas drilling during the next 25 years, it does not mean that these states lack the potential for resource development; rather their current position is that they will not be engaging in unconventional gas drilling and development (and hydraulic fracturing) in the foreseeable future. In coming up with this delineation between producing and non-producing states, IHS [4] states that "the current policies of state governments toward unconventional oil and natural gas production are assumed to continue through the forecast horizon". As an example, today's policy against unconventional oil and natural gas production in New York is assumed to continue. Therefore, New York was considered a non-producing state in terms of the IHS study.

Finally, it should be noted that major economic contributions may be made by states like California, which is anticipated to have unconventional oil production from the emerging Monterey Formation but has no current production. Although unconventional oil production in California is not expected to begin until quite late in the forecast period, it is anticipated that the large volume of its goods and services that feed into the unconventional oil and gas supply chain will make California one of the largest producing states in terms of GDP, employment, and government revenues.

The forecasted economic gains generated by unconventional oil and gas developments using hydraulic fracturing techniques will be presented in terms of their contributions to (1) Employment; (2) Gross State product (Value-Added); and, (3) Federal, State and Local Government revenues. For each category of economic contribution, the data will be presented in terms of comparisons between producing and non-producing states [4].

Contributions to Employment

Clearly, the majority of US economic activity generated by the unconventional oil and gas industry will take place in the 16 states directly involved in production. In 2012, the 10 producing states that generated the most jobs from unconventional activity were responsible for creating nearly 1.2 million jobs. The IHS study [4] forecasts that these top 10 states will add nearly 900,000 additional jobs between 2012 and 2020, growing to over 2 million total jobs, as shown in Table 1.

Table 1: Employment Contributions from Unconventional Oil and Gas in Producing and Non-Producing States [4].

Producing v Non-Producing	Number of Workers		
	2012	2020	2035
Producing States	1,274,486	2,168,612	2,543,203
Non-Producing States	474,144	816,563	955,491
US Total	1,748,630	2,985,176	3,498,694

In terms of individual states, it is forecast that the producing states of Texas, Pennsylvania and California will lead the top 10 in job creation through 2020. By 2035, it is forecast that Ohio and Oklahoma will join the top five states, ranked by employment, behind Texas and Pennsylvania and will move ahead of California.

The non-producing states will also see significant employment gains, reaching more than 816,000 jobs in 2020. New York and Illinois will lead the top 10 in job creation among non-producing states over the forecast horizon. This data is shown in Table 2, where the rank for years 2020 and 2035 is shown based on the 2012 ranking.

Table 2: Top 10 Employment Contributions from Unconventional Oil and Gas in Producing States [4].

Producing States	Number of Workers		
	2012	2020	2035
Texas	576,084	929,482	733,179
Pennsylvania	102,668	220,635	387,360
California	96,553	153,658	187,270
Louisiana	78,968	97,418	150,903
Colorado	77,622	121,398	175,363
North Dakota	71,824	114,240	57,267
Oklahoma	65,325	149,617	225,387
Utah	54,421	51,859	67,052
Ohio	38,830	143,595	266,624
Arkansas	33,100	52,539	56,418
Top 10 Total	**1,195,396**	**2,034,442**	**2,306,822**
All Producing States Total	**1,274,486**	**2,168,612**	**2,543,203**
All US Total	**1,748,630**	**2,985,176**	**3,498,694**

The corresponding data for the non-producing states is shown in Table 3. There are two mechanisms by which jobs can be created in non-producing states: (1) purchases of capital goods for use in producing states that are manufactured in the other states; (2) expenditures made in producing states will result in cross-state contributions (leakages) from direct and supply chain industries. These cross-state contributions include purchases of services, such as financial and insurance services. It can be seen that although New York has banned all unconventional gas developments (including the hydraulic fracking process) it lies at the top of the list of non-producing states. For example, in 2012 and 2020, more than 17,000 and 28,000 jobs are contributed by the financial, insurance and other related services sectors respectivelyas a result of unconventional oil and gas activity.

Table 3: Top 10 Employment Contributions from Unconventional Oil and Gas in Non-Producing States [4].

Non- Producing States	Number of Workers		
	2012	2020	2035
New York	44,429	74,007	78,645
Illinois	38,652	66,604	82,817
Michigan	37,848	64,551	78,632
Missouri	37,716	64,228	70,794
Florida	36,532	65,063	79,499
Wisconsin	19,760	33,112	35,976
New Jesrey	19,753	34,455	40,537
Minnesota	19,103	34,815	42,691
North Carolina	18,665	32,477	37,439
Georgia	18,505	32,458	38,771
Top 10 Total	**290,963**	**501,771**	**585,801**
All Non-Producing States Total	**474,144**	**816,563**	**955,491**
All US Total	**1,748,630**	**2,985,176**	**3,498,694**

A comparison of the numbers in Tables 2 and 3 indicates that the jobs concentration is much more heavily weighted to the top producing states (more than 90% of the jobs are in the top 10 states) while job creation in the non-producing states is much broader (60% in the top 10 states). Most significantly, roughly four jobs are created in a producing state for every one job that is created in a non-producing state.

Contributions to GDP

Gross domestic Product (GDP) is the sum of the value added across all products and services produced in the United States. Value added is the total value of workers' incomes, corporate profits, indirect business taxes paid, and depreciation.

The relative value added contribution due to unconventional oil and gas developments in the producing and non-producing states is presented in Table 4. It can be seen that the annual value added from unconventional oil and gas activities was more than $237 billion in 2012. By 2020 it is projected to surpass $416 billion, with a further increase to $475 billion by 2035.

Table 4: Contributions to GDP (Value Added) from Unconventional Oil and Gas in Producing and Non-Producing States [4].

Producing v Non-Producing	Millions of US$		
	2012	**2020**	**2035**
Producing States	188,391	331,963	373,457
Non-Producing States	49,293	84,588	101,527
US Total	237,684	416,551	474,985

According to the IHS study, in 2012, the 10 producing states providing the greatest value added contribution to GDP contribute nearly $178 billion. This accounts for 75% of the total US value added from unconventional oil and gas activity nationwide, as shown in Table 6.5. By 2020, it is projected that these top 10 states will add another $134 billion to GDP, increasing their combined contribution to over $312 billion. By 2035, unconventional oil and gas activity nationwide will add almost $475 billion to US GDP, with 71% of that coming from the 10 producing states that generate the most economic activity. By far the largest individual value added contributor to GDP is the state of Texas. However, it is noted that the relative contribution of Texas to the total of the Top 10 producers is actually forecasted to decline from 57% in 2012, to 50% in 2020, and finally to 37% in 2035. Again, in Table 5 the rank for years 2020 and 2035 is shown based on the 2012 ranking.

Table 5: Top 10 Contributions to GDP (Value Added) from Unconventional Oil and Gas in Non-Producing States [4].

Producing States	Millions of US$		
	2012	**2020**	**2035**
Texas	101,633	168,558	125,701
Pennsylvania	14,113	26,714	49,022
Colorado	11,647	17,605	26,675
Louisiana	10,727	12,829	19,718
California	10,455	16,647	21,631
Oklahoma	8,911	24,454	38,061
North Dakota	6,808	13,046	6,630
Utah	5,618	8,195	9,430
Ohio	4,103	17,960	35,292
Arkansas	3,818	6,409	6,876
Top 10 Total	**177,832**	**312,418**	**339,038**
All Producing States Total	**188,391**	**331,963**	**373,457**
All US Total	**237,684**	**416,551**	**474,985**

The corresponding data for the top 10 value added contributions to GDP from the non-producing states are presented in Table 6. Again it should be noted that in the table the rank for years 2020 and 2035 is shown based on the 2012 ranking. It can be seen that the non-producing states account for about 21%, on average, of the total value added contribution to US GDP during the entire forecast period (25 years). While the share of labor income from the non-producing states is in line with their employment share, their contribution to GDP is smaller than that of the producing states. This is because producing states are heavily influenced by the oil and gas sector, which has high value added (mostly non-labor income).

Table 6: Top 10 Contributions to GDP (Value Added) from Unconventional Oil and Gas in Non-Producing States [4].

Non- Producing States	Millions of US$		
	2012	2020	2035
New York	5,033	8,171	8,836
Illinois	4,228	7,315	9,434
Florida	3,669	6,346	7,814
Michigan	3,658	6,570	8,363
Missouri	3,322	6,035	6,886
New Jersey	2,353	4,184	5,430
Georgia	2,037	3,494	4,202
North Carolina	2,010	3,360	3,855
Minnesota	1,996	3,743	4,717
Virginia	1,991	3,426	4,298
Top 10 Total	**30,298**	**52,643**	**63,834**
All Non-Producing States Total	**50,382**	**86,974**	**105,687**
All US Total	**237,684**	**416,551**	**474,985**

Contributions to Government Revenue

In 2012, the IHS study [4] estimated $63 billion in annual federal, state and local government tax receipts was derived from unconventional oil and gas activity. It is forecasted that total annual receipts will approach $113 billion by 2020 and exceed $125 billion by 2035, essentially double the levels for 2012. On a cumulative basis, between 2012 and 2035 unconventional oil and gas activity is projected to contribute over $2.5 trillion in total revenues. The projected contributions to government revenues from the producing and non-producing states are shown in Table 7. It can be seen that the producing states provide approximately 75-78% of the total revenue throughout the forecast period.

Table 7: Contributions to Government Revenue from Unconventional Oil and Gas in Producing and Non-Producing States [4].

Producing v Non-Producing	Millions of US$			
	2012	2020	2035	2012-2035
Producing States	50,776	92,539	102,513	2,094,083
Non-Producing States	12,239	20,404	23,142	460,834
US Total	63,015	112,943	125,655	2,554,917

Table 8: Top 10 Contributions to Government Revenue from Unconventional Oil and Gas in Producing States [4].

Producing States	Millions of US$			
	2012	2020	2035	2012-2035
Texas	22,168	38,538	28,656	790,984
North Dakota	5,758	10,159	5,363	202,392
California	2,987	4,615	5,773	108,383
Pennsylvania	2,980	5,623	9,869	146,689
Colorado	2,935	4,748	7,147	121,542
Louisiana	2,553	3,070	5,181	82,685
Oklahoma	2,432	7,016	11,123	178,512
Utah	2,401	2,989	2,636	60,650
New Mexico	1,473	1,931	3,597	53,299
Ohio	1,448	6,744	12,672	177,956
Top 10 Total	**47,135**	**85,433**	**92,016**	**1,923,092**
All Producing States Total	**50,776**	**92,539**	**102,513**	**2,094,083**
All US Total	**63,015**	**112,943**	**125,655**	**2,554,917**

In terms of the producing states, the IHS study [4] forecasted that for 2012, the 10 states generating the most government revenues provide 75% of total revenues from unconventional oil and gas activity, as shown in Table 8. These revenues derive not only from personal, corporate, federal, state, and local taxes but also from severance, ad valorem, and bonus and royalty payments, which are specific to the unconventional oil and gas industry [4]. By 2020, these top 10 states, led by Texas, North Dakota and Oklahoma, will generate over $85 billion in revenues or 76% of total tax receipts. By 2035, the top 10 producing states will generate over $92 billion in taxes or 73% of the total government revenues from all unconventional oil and gas activity..

The IHS study also forecasts a considerable amount of government revenue from the non-producing states, the data for the top 10 non-producing states in terms of contributions to government revenue is presented in Table 9. It forecast that the non-producing states will contribute a total of over $12 billion in 2012 tax revenues associated with unconventional oil and gas activity; that is projected to exceed $20 billion by 2020. By 2035, the contribution from all of the non-producing states will reach nearly $23 billion.

Table 9: Top 10 Contributions to Government Revenue from Unconventional Oil and Gas in Non-Producing States [4].

Non- Producing States	Millions of US$			
	2012	2020	2035	2012-2035
New York	1,648	2,573	2,598	56,274
Illinois	1,012	1,710	2,099	39,332
Michigan	919	1,612	1,948	37,244
Missouri	740	1,316	1,437	29,495
Florida	651	1,112	1,337	25,536
Wisconsin	590	993	1,028	22,018
New Jesrey	561	975	1,196	22,443
Minnesota	526	956	1,133	21,870
Georgia	520	867	985	19,577
North Carolina	486	792	860	17,655
Top 10 Total	**7,654**	**12,906**	**14,621**	**291,444**
All Non-Producing States Total	**12,239**	**20,404**	**23,142**	**460,834**
All US Total	**63,015**	**112,943**	**125,655**	**2,554,917**

Among the non-producing states, the top 10 in terms of government revenues account for a significant share of the total coming from all of the non-producing states. In 2012, these 10 states contributed more than $7 billion or over 62% of all government revenues generated by the non-producing states. It is forecast that by 2020, that will increase to nearly $13 billion, or about 63% of the non-producing state total. This large projected increase will be associated with more supply chain activities in the producing states. It must be noted that government revenues in non-producing states are comprised of personal and corporate taxes paid to federal, state and local governments. Since there is no exploration or extraction in the non-producing states, the associated taxes exclude all oil and gas related taxes and payments by the industry.

Historical Economic and Employment Impacts on Local Economies

Beyond the state level, in the producing states data for unconventional oil and gas developments is available at the county (or equivalent) level. Therefore, for these states it is possible to compare the **historical** economic and employment effects of hydraulic fracturing on a county-by-county basis. This data is most meaningful for those producing states that were part of the "first wave" of the shale gas revolution so that the industry and the local communities have had time to reach some sort of economic equilibrium. In selecting a state for further analysis it is also beneficial to choose one that has a large degree of overall unconventional oil and gas production and a comparable number of producing and non-producing counties so the data is not skewed unduly by cyclical production rates and/or statistical outliers. It is for the above reasons that the Commonwealth of Pennsylvania was chosen for a historical county-by-county analysis.

The Commonwealth of Pennsylvania

The Pennsylvania Department of Environmental Protection provides data on the number of horizontal, hydraulically fractured wells [14] for each of the state's 67 counties. This data is presented in Table 10. It can be seen that the number of unconventional wells across the state was low until 2007. For this reason 2007 can be considered the "base year" for the economic and employment analysis for this state.

Table 10: Unconventional Wells Drilled in Pennsylvania by County and Year.

County	Year										Total	Group
	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011		
Adams	0	0	0	0	0	0	0	0	0	0	**0**	**1**
Allegheny	0	0	0	0	0	0	1	3	0	5	**9**	**2**
Armstrong	0	0	0	0	3	2	7	19	37	34	**102**	**3**
Beaver	0	0	0	0	0	0	0	1	1	6	**8**	**2**
Bedford	0	0	0	0	0	0	0	0	1	0	**1**	**2**
Berks	0	0	0	0	0	0	0	0	0	0	**0**	**1**
Blair	0	0	0	0	0	0	0	0	4	2	**6**	**2**
Bradford	0	0	0	1	2	2	24	160	378	399	**966**	**4**
Bucks	0	0	0	0	0	0	0	0	0	0	**0**	**1**
Butler	0	0	0	0	3	12	11	10	35	34	**105**	**3**
Cambria	0	0	0	0	0	0	0	2	1	3	**6**	**2**
Cameron	0	0	0	0	0	0	3	2	3	7	**15**	**2**
Carbon	0	0	0	0	0	0	0	0	0	0	**0**	**1**
Centre	0	0	0	0	1	1	4	7	41	8	**62**	**3**
Chester	0	0	0	0	0	0	0	0	0	0	**0**	**1**
Clarion	0	0	0	0	0	3	1	3	3	10	**20**	**3**
Clearfield	0	0	0	0	0	1	6	24	39	58	**128**	**3**
Clinton	0	0	0	0	0	0	4	9	35	39	**87**	**3**
Columbia	0	0	0	0	0	0	0	0	1	2	**3**	**2**
Crawford	0	0	0	0	0	0	0	0	0	0	**0**	**1**
Cumberland	0	0	0	0	0	0	0	0	0	0	**0**	**1**
Dauphin	0	0	0	0	0	0	0	0	0	0	**0**	**1**
Delaware	0	0	0	0	0	0	0	0	0	0	**0**	**1**
Elk	0	0	0	1	1	6	8	6	16	22	**60**	**3**
Erie	0	0	0	0	0	0	0	0	0	0	**0**	**1**
Fayette	0	0	0	0	2	6	20	57	44	54	**183**	**3**
Forest	0	0	0	0	0	0	0	5	1	0	**6**	**2**
Franklin	0	0	0	0	0	0	0	0	0	0	**0**	**1**
Fulton	0	0	0	0	0	0	0	0	0	0	**0**	**1**
Greene	0	0	0	0	2	14	67	101	103	122	**409**	**4**
Huntingdon	0	0	0	0	0	0	0	0	1	0	**1**	**2**
Indiana	0	1	0	0	0	0	5	6	7	21	**40**	**3**
Jefferson	0	0	0	0	0	0	3	3	8	15	**29**	**3**
Juniata	0	0	0	0	0	0	0	0	0	0	**0**	**1**
Lackawanna	0	0	0	0	0	0	0	1	0	1	**2**	**2**
Lancaster	0	0	0	0	0	0	0	0	0	0	**0**	**1**
Lawrence	0	0	0	0	0	0	0	0	0	2	**2**	**2**
Lebanon	0	0	0	0	0	0	0	0	0	0	**0**	**1**
Lehigh	0	0	0	0	0	0	0	0	0	0	**0**	**1**
Luzerne	0	0	0	0	0	0	0	0	2	0	**2**	**2**
Lycoming	0	0	0	0	0	5	12	23	119	300	**459**	**4**

Table 10: Continued.

County	Year										Total	Group
	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011		
McKean	0	0	0	0	2	1	5	7	22	19	**56**	**3**
Mercer	0	0	0	0	0	0	0	0	0	0	**0**	**1**
Mifflin	0	0	0	0	0	0	0	0	0	0	**0**	**1**
Monroe	0	0	0	0	0	0	0	0	0	0	**0**	**1**
Montgomery	0	0	0	0	0	0	0	0	0	0	**0**	**1**
Montour	0	0	0	0	0	0	0	0	0	0	**0**	**1**
Northampton	0	0	0	0	0	0	0	0	0	0	**0**	**1**
Northumberland	0	0	0	0	0	0	0	0	0	0	**0**	**1**
Perry	0	0	0	0	0	0	0	0	0	0	**0**	**1**
Philadelphia	0	0	0	0	0	0	0	0	0	0	**0**	**1**
Pike	0	0	0	0	0	0	0	0	0	0	**0**	**1**
Potter	0	0	0	0	0	8	6	8	36	12	**70**	**3**
Schuylkill	0	0	0	0	0	0	0	0	0	0	**0**	**1**
Snyder	0	0	0	0	0	0	0	0	0	0	**0**	**1**
Somerset	0	0	1	0	0	1	0	7	4	7	**20**	**3**
Sullivan	0	0	0	0	0	1	0	0	22	19	**42**	**3**
Susquehanna	0	0	0	0	1	2	33	88	125	205	**454**	**4**
Tioga	0	0	0	0	0	0	15	124	276	274	**689**	**4**
Union	0	0	0	0	0	0	0	0	0	0	**0**	**1**
Venango	0	0	0	0	0	0	0	0	0	2	**2**	**2**
Warren	0	0	0	0	0	2	0	0	0	1	**3**	**2**
Washington	1	1	0	5	19	45	66	101	166	156	**560**	**4**
Wayne	0	0	0	0	0	0	1	0	4	0	**5**	**2**
Westmoreland	0	2	1	1	0	4	33	39	49	59	**188**	**3**
Wyoming	0	0	0	0	0	0	0	2	24	71	**97**	**3**
York	0	0	0	0	0	0	0	0	0	0	**0**	**1**
PA Total	1	3	2	6	22	69	171	399	849	1,127	4,897	-

In order to present a meaningful analysis of the economic data the counties were divided into groups based on the number of unconventional wells drilled between 2002 and 2011. Four groups were defined as follows [15]:

- Group 1 – Counties with no unconventional wells (30 counties fit this criterion).
- Group 2 – Counties with minimal participation defined as less than 20 wells (15 counties fit this criterion).
- Group 3 – Counties with between 20 and 200 wells, indicating a significant level of fracking activity (16 counties fit this criterion).
- Group 4 – Counties with more than 200 wells, indicating a high level of fracking activity (6 counties fit this criterion).

The group designation of each county according to the above definitions can be found in the last column of Table 10. The geographical distribution of the counties within each group can be seen in Figure 14.

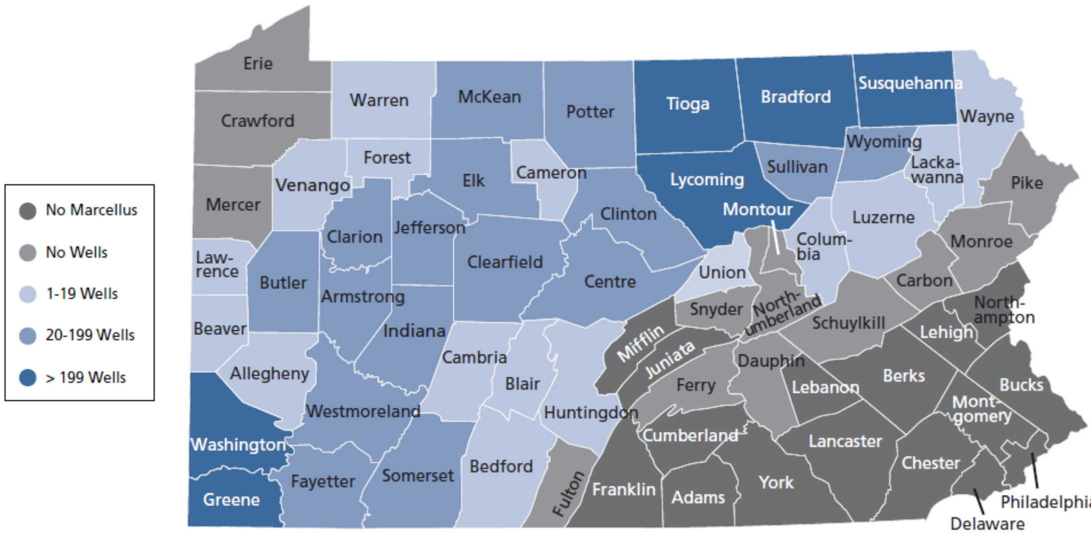

Figure 14: Distribution of Unconventional Wells by County in Pennsylvania [16].

A historical analysis of the economic and employment effects of unconventional gas drilling (hydraulic fracturing) between 2007 and 2011 is carried out. Three variables were chosen to measure economic growth on a county-by-county basis: the total number of jobs, per-capita personal income, and the unemployment rate. Economic data was collected from the Bureau of Economic Analysis website [16], while unemployment data was collected from the Bureau of Labor Statistics website [17].The data was post-processed according to the county group assigned in Table 10 based on the level of unconventional drilling, and the results are presented below.

Table 11: Total Number of Jobs by PA County Group from 2007 to 2012.

County	JOBS BY YEAR						CHANGE
	2007	2008	2009	2010	2011	2012	2007-2012
4	241,873	245,032	238,380	242,116	250,044	255,186	**13,313**
3	672,814	679,356	658,916	656,139	663,410	671,256	**-1,558**
2	1,263,221	1,272,405	1,236,981	1,229,271	1,239,081	1,255,590	**-7,631**
1	3,876,227	3,908,090	3,764,027	3,727,016	3,739,989	3,791,375	**-84,852**

Table 12: Average Per-Capita Income by PA County Group from 2007 to 2012.

County	PER CAPITA INCOME BY YEAR						CHANGE
	2007	2008	2009	2010	2011	2012	2007-2012
4	30,673	31,798	32,050	33,761	36,673	38,772	**8,099**
3	31,838	33,076	33,005	34,190	36,284	37,376	**5,538**
2	31,635	32,749	32,771	33,690	35,488	36,453	**4,819**
1	36,522	37,501	37,148	37,915	39,771	40,887	**4,364**

Table 13: Average Unemployment Rate by PA County Group from 2007 to 2012.

County	UNEMPLOYMENT (%) BY YEAR						% CHANGE
	2007	2008	2009	2010	2011	2012	2007-2012
4	4.9	6.0	9.1	8.5	7.7	7.8	**2.9**
3	4.8	5.8	8.7	8.7	8.0	8.1	**3.3**
2	4.5	5.6	8.6	8.6	7.8	7.8	**3.3**
1	4.7	5.8	8.6	8.8	8.3	8.2	**3.5**

Looking at Table 11 it can be seen that the largest employment growth over the period 2007 – 2012 occurred in Group 4 which has the greatest number of unconventional wells per county (more than 200). The counties within this group experienced an average 5.2% increase in jobs over this period. In Group 2, with 20 – 200 wells per county, job growth was flat over the sample period with less than 1% change in the total number of jobs. Group 3 which contained counties with a low level of unconventional oil and gas activity lost about 1% of their jobs while counties with no activity (Group 1) lost 2.2% of their jobs on average. This data provides clear historical evidence of the correlation between the extent of unconventional oil and gas development activities (or equivalently hydraulic fracturing activities) and job growth.

Table 12 shows that the largest percentage increase in average per-capita income occurred in Group 4 where there are the largest concentration of unconventional wells, between 2007 and 2012 average per-capita income rose 21% for this group. In Group 3 the corresponding increase was 15%, with 13% in Group 2 and finally 11% in Group 1. Again, this is clear historical evidence of the correlation between the extent of unconventional oil and gas development activities (or equivalently hydraulic fracturing activities) and prosperity.

Between 2007 and 2009 unemployment rates throughout the US increased due to the financial crisis and the global recession. The country is still recovering and Pennsylvania is no exception. The unemployment rates for the county groups over the 2007 – 2012 periods are presented in Table 13. Using 2007 as the base year, the average unemployment rate in Group 1 counties increased by 3.5% by 2012. However, for groups with higher levels of drilling/fracking activity the increase in the unemployment rate is progressively less as drilling increases until the corresponding change for Group 4 is only 2.9%.

SUMMARY AND CONCLUSIONS

This thesis has addressed the question of the economic and employment benefits of unconventional oil and gas developments which use the controversial hydraulic fracturing technique.

As background to discussing this issue, an overview of the hydraulic fracturing process has been presented and the economic and strategic benefits of US shale gas production have been outlined. The perceived risks associated with the hydraulic fracturing process have been discussed in detail, in particular the potential for groundwater contamination. While this is a highly emotive topic there does not seem to be a consistent body of scientific evidence to support the fears that are expressed by some segments of the public.

The status of the fracking debate and legislative efforts in different states has been reviewed. The consequences of shutting down US shale gas production have been addressed and are found to involve severe economic penalties and an overall reduction in energy security.

The economic and employment impacts on state and local communities of allowing unconventional oil and gas development (i.e., hydraulic fracturing) have been discussed in detail through two different approaches:

- An analysis of published projections of economic and employment contributions to state's economies over the next 25 years overwhelmingly supports unconventional oil and gas development using the hydraulic fracturing process. By 2035 this industry is projected to create almost 3.5 million jobs in the US and contribute $475 billion to the GDP. Between 2012 and 2035 it is projected to yield over $2.5 trillion in government revenue. These benefits are projected to be overwhelmingly concentrated in the producing states.
- A county-by-county analysis of the historical (from 2007 to 2012) economic and employment benefits of allowing unconventional oil and gas developments

in a single state: Pennsylvania. This analysis was accomplished by post-processing downloadable US government data (BEA, BLS). It was found that employment growth, increased per-capita income and lower unemployment rates were all concentrated in those counties with high degrees of unconventional oil and gas development activities.

It has been demonstrated that the benefits associated with the development of unconventional oil and gas reserves are simply too huge to ignore, and the negative economic consequences of banning hydraulic fracturing are simply too severe for the US economy. Therefore, a rationally planned program involving the gathering of solid scientific data, coupled with a balanced legislative agenda, and transparency of operations to build public trust should be adopted to allow these resources to be developed in a safe and profitable manner.

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