IMPERIAL COLLEGE LONDON

Department of Earth Science and Engineering
Centre for Petroleum Studies

Shale gas - How does it affect the Gas market?

By

Yogesh Gupta

A report submitted in partial fulfilment of the requirements for the MSc and/or the DIC.

September 2011

DECLARATION OF OWN WORK

I declare that this thesis

“Shale gas - How does it affect the Gas market?”

is entirely my own work and that where any material could be construed as the work of others, it is fully cited and referenced, and/or with appropriate acknowledgement given.

Signature:..

Name of Student: Mr. Yogesh Gupta

Name of Supervisors: Dr. Velisa Vesovic
Dr. Nicolas Riesco

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Shale Gas - How does it affect the Gas market?

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Abstract

The knowledge of shale gas is spreading into other continents, after showing its dominance in United States. It is not only providing new resource of energy, but for some it is also providing energy independence and creating jobs. Gas is already known to be a cleaner fuel than other energy resources such as coal and oil; with shale gas, the amount of gas available to our energy hungry world is immense. This can be very well observed from the recent land acreage in Poland, for its shale gas exploration.

Some countries largely depend on one particular energy resource, like France having around 80% (Trading Economics, 2011) of its energy coming from nuclear, whereas Poland relies almost 93% (Trading Economics, 2011) on coal energy. Both of these European countries have nearly 180 trillion cubic feet (Tcf) of shale gas resources and this makes it interesting, how the governments of these two countries will tackle the need of new resources and the issues associated with shale gas development.

Though the shale gas revolution of United States has affected many businesses, but this thesis will try and cover the effect, shale gas revolution has on the gas market and how different countries are trying to capitalize on the shale gas resources at their own advantage. We will also see how shale gas may help United States to become a major exporter of gas; how the political decisions of France and Poland are going to affect their gas market and particularly in case of Poland it may provide independence from import of gas from Russia, whereas help reduce the dependency on one particular energy resource like France, to have a broader portfolio of energy in the country and lastly how India and China would use their shale gas resources to boost their economy and meet their growing energy needs.

Introduction

Gas Reserves

We require energy regularly, to heat our homes or cook our food, and generate electricity. It is this need for energy that has elevated natural gas to such a level of importance in our society, and in our lives. Natural gas is colourless, shapeless and odourless in its pure form, but combustible and abundant. The combustion of natural gas emits significantly lower levels of key pollutants, including carbon dioxide (CO2), nitrogen oxides, and sulphur dioxide, than does the combustion of coal or oil. When used in efficient combined-cycle power plants, natural gas combustion emits 22% (BG Group, 2011) less carbon dioxide than oil and 40% (BG Group, 2011) less than coal. The worldwide community consumes about 90 trillion cubic feet (Tcf) of natural gas each year (Small, 2005).

After crude oil and hard coal, gas accounts for about 24% (BGR, 2011) of the world's primary energy consumption. The consumption of natural gas in the world also reached its highest level in 2008, of about 3.1 trillion cubic metres (BGR, 2011), before the world economic downtrend. Russia has the largest reserves of natural gas in the world, with Iran and Qatar having the next most abundant gas reserves as seen in Figure 1. Gas market was initially shaping mainly due to gas demand from Japan and other Asian countries such as Taiwan and South Korea. But with many countries especially in Europe moving strongly towards a decarbonisation mindset, the concept of Carbon Capture and Storage (CCS) may be coupled with gas dependent energy to have a sustainable future in Europe. Though the use of CCS has been most successful, (Van Dusan, 2011) in places where the carbon dioxide itself can serve a purpose, such as injection into depleted wells to enhance production. This is not going to be a huge concern or the deciding factor in fast developing countries like China and India with their relaxed environmental laws. Hence gas exporters may target their gas ships towards Asia for long term contracts. The gas that is being transported currently comes from conventional gas.

Apart from these conventional gas reserves, there are large quantities of unconventional gas reserves in form of coal seam gas, gas hydrates, shale gas and tight gas. Shale gas is the same gas as conventional gas except for the fact that it is found in different geologic formations. These formations need advance technologies or special treatments to be able to extract the gas from these formations. Shale gas has played minor role in meeting world energy demands till date but shale gas is the most talked topic today in the energy industry. The recent advancements in drilling technique such as horizontal drilling and production technique such as hydraulic fracturing have completely revolutionized the energy market.

Hydraulic fracturing is a procedure that can increase the flow of oil or gas from a well. It is done by pumping liquids down a well into subsurface rock units under pressures that are high enough to fracture the rock. The goal is to create a network of interconnected fractures that will serve as pore spaces for the movement of oil and natural gas to the well bore.

Horizontal drilling has been used to reach targets beneath adjacent lands, reduce the footprint of gas field development, increase the length of the "pay zone" in a well, deliberately intersect fractures, construct relief wells and install utility service beneath lands where excavation is impossible or extremely expensive. These techniques when combined have the magic to convert the unproductive unconventional gas reservoirs into profitable producers of gas.

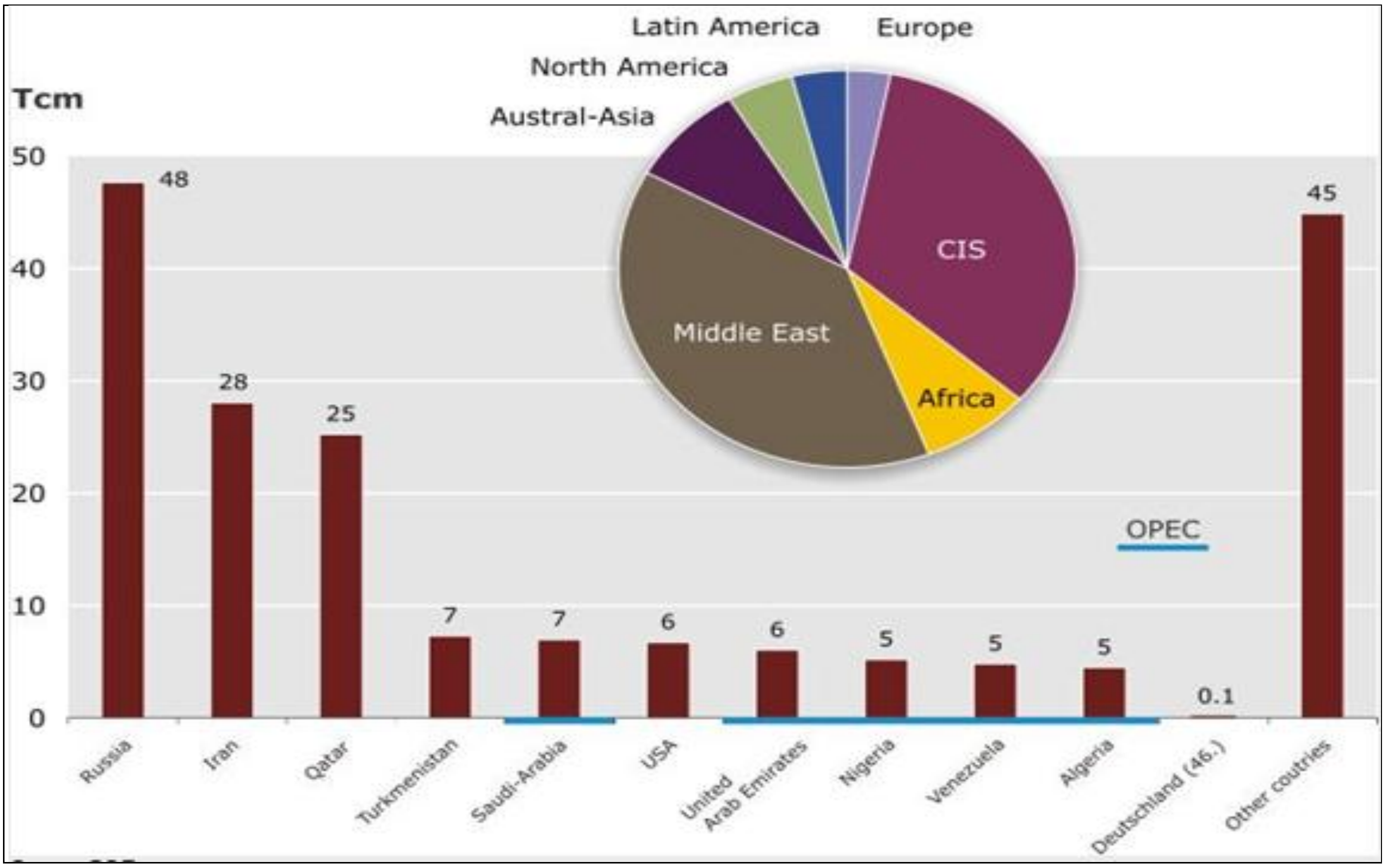

Figure 1: Conventional Gas Reserves (Trillion cubic meter) in 2008 [Source: BGR]

Amongst all the unconventional resources, shale gas has clearly gained lot of attention lately with the US being able to unfold huge amounts of gas from its shale formations using horizontal drilling and hydraulic fracturing techniques. The increase in its shale gas contribution helped US become the largest producer of gas with 624 billion cubic metres (bcm) against Russia’s 582 bcm (Kefferputz, 2010).

Natural gas is much more environmental friendly and abundant in nature. But natural gas is not easy to handle because it is in gaseous state and handling huge volumes of gas is difficult. In past the natural gas associated with the crude oil was flared as waste product, as the markets for natural gas were distant and transporting this natural gas can be challenging. So how is natural gas transported?

Gas Transport

The world is energy hungry to grow and develop its land to accommodate more human beings. Some countries are more energy hungry, as they wish to grow faster than others. But the energy present in the world is not evenly distributed. Some countries have small population and huge amount of energy resources which makes them energy exporters to the countries where resources are less than required. This transfer of energy in case of natural gas can take place with a pipeline or in the liquefied form, also called (LNG) Liquefied Natural Gas.

To transfer long distances of natural gas on land, the most convenient method is a pipeline. Some pipeline like the ‘Nord Stream Pipeline’ is 759 miles long, which starts in Russia and ends in Germany and some pipeline like ‘West-East Pipeline’ is 5410 miles long, which starts in Xinjiang province of China and ends in Shanghai, China (Pentland, 2011). On the other hand LNG has played a vital role in meeting world’s energy demand and till date the countries with largest conventional gas reserves such as Russia, Iran and Qatar were believed to be dominating the natural gas market supply and also dictating pricing. This is about to change in decades to come, as new sources of gas such as Coal Bed Methane, Shale gas and Gas hydrates are showing fast development.

Present Gas Market

Liquefying of natural gas gave confidence to think that transportation of this fuel across geographical barriers was possible. In January 1959, (Dominion, 2011) the first LNG tanker made a journey from Lake Charles, Los Angeles to Canvey Island, United Kingdom. This demonstrated that large quantities of liquefied natural gas could be safely transported across regions. Following this success in 1964, (Dominion, 2011) the British Gas Council started importing LNG from Algeria, starting the first trade of LNG. After the concept was seen working in the United Kingdom, more LNG import and export terminals started. But in 1979, the LNG market saw a brief setback after the demand in United States declined, primarily due to deregulation of gas industry (which increased the domestic production) and the price dispute with Algeria; saw some gas receiving terminals in United States shutting down (Warren, 2008).

After this brief setback, towards 1990's, gas was recognized as more environmentally friendly fuel over coal and oil, which saw the demand for gas growing incrementally. In 1999, the first gas liquefaction plant came on line in Trinidad and Tobago. This event together with the increasing demand for electric power in United States saw the rusting gas receiving terminals in United States come back to life (Dominion, 2011).

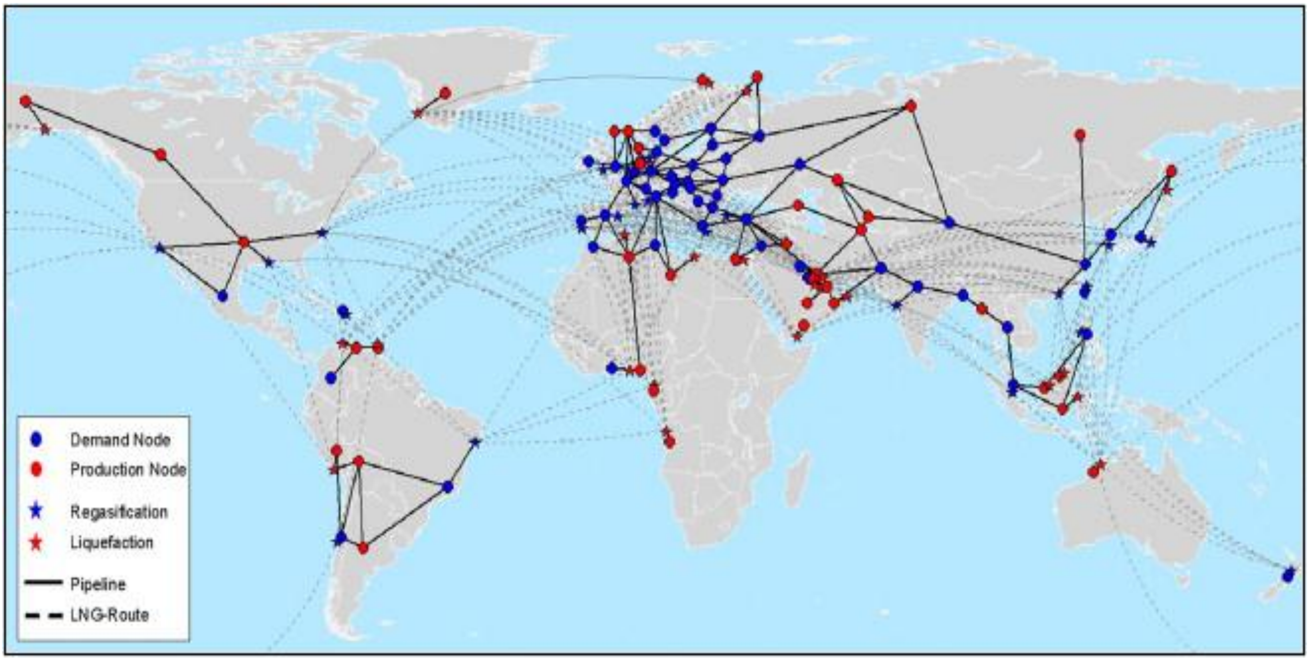

Figure 2: Current world LNG and pipe gas trade [Source:Stefan et al, 2009]

By the end of the 20th century, it had become very clear to the global natural gas industry that the moving of natural gas in liquefied state had the potential for overcoming the regional and other geographic barriers (Dominion, 2011). With new suppliers from Australia, Qatar and West Africa coming into action, the gas market has grown significantly. The present network of gas transport with pipelines and LNG from one continent to other can be seen in Figure 2.

Shale Gas Worldwide: Selecting Countries

Conventional gas reservoirs are created when natural gas migrates toward the earth's surface from an organic-rich source formation into highly permeable reservoir rock, where it is trapped by an overlying layer of impermeable rock. In contrast, Shale gas resources form within the organic-rich shale source rock. The low permeability of the shale greatly inhibits the gas from migrating to more permeable reservoir rocks. No two shales are alike. Shales vary aerially and vertically within a trend, even along the wellbore (George, 2010). Without horizontal drilling and hydraulic fracturing, shale gas production would not be economically feasible because the natural gas would not flow from the formation at high enough rates to justify the cost of drilling.

We can see the worldwide distribution of shale gas based on initial assessments and expert's estimates from Figure 3. For this thesis we will consider the following five countries with shale gas potential, namely US, Poland, France, India and China, as these are the only countries with some appreciable shale gas action taking place in the country and also to limit the scope of this thesis.

United States has already proven the feasibility of shale gas and hence will lead the discussion in this thesis to show the revolution it can bring to a country's economy. Poland and France are in Europe and both have similar (180 Tcf) shale gas reserves and give an excellent opportunity to show the political interference and environmental challenges shale gas will face in Europe. China and India are the two fast developing countries, also major economies today and both have large shale gas potential and it will be interesting to see how these two major economies will pursue shale gas developments.

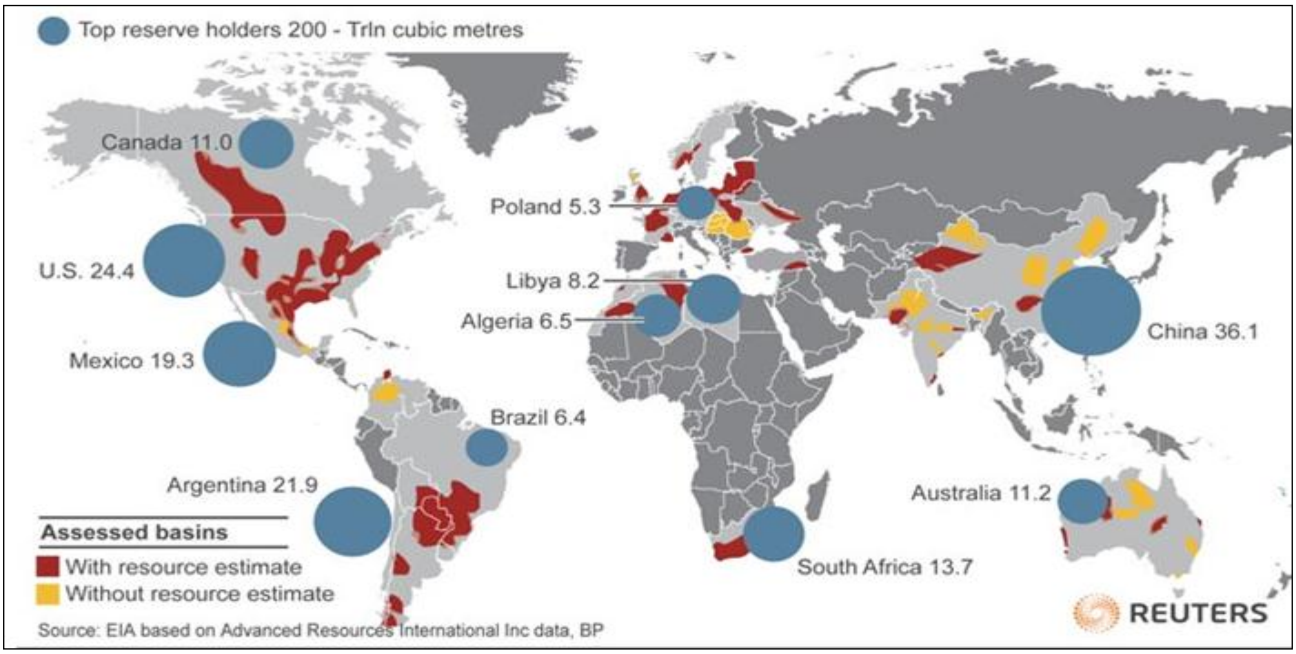

Figure 3: Worldwide Shale gas potential (Light grey areas indicate areas included in study; dark grey areas are not)

Shale Gas: Advantages and Shortcomings

Energy Profile of Selected Countries

Let us take a look at the diverse profile of energy use in the following countries we had selected. This can be illustrated in Figure 4. It is clearly seen that coal has been a widely used energy resource in all these countries with an exception of France, which largely depends on nuclear energy. Coal is abundant and cheaper energy resource but it is also highly polluting. Similarly shale gas has some advantages and disadvantages, which are discussed in the next section.

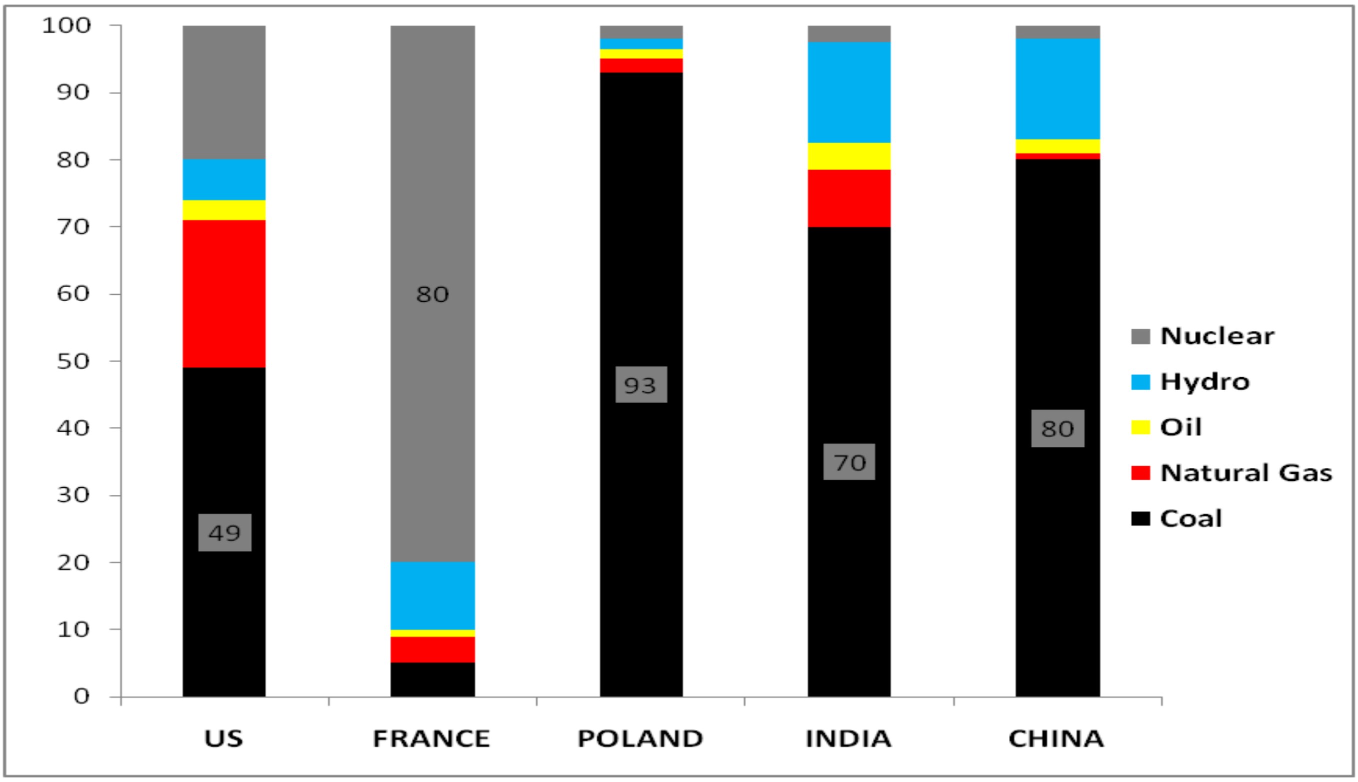

Figure 4: Source of Energy Production in % [Data source: Tradingeconomics, 2011]

ADVANTAGES

Reducing CO2 Emissions:

Shale gas will make more gas available in the market and if US, China and India include more gas into their energy profile, these carbon emissions (mentioned below) may be reduced significantly.

The method of growth in the developing countries like China and India is completely different. China, relying on its abundant coal resources (which are very high in CO2 emission) overtook United States in 2007 to lead the chart for CO2 emissions. The emissions have increased alarmingly by almost 300% (From Table 1) in 10 years. It can be seen from Table 1 that United States has been leading the CO2 emission chart until 2007. In European countries, as environmental norms are very strict, the CO2 emissions are much lower. This is also due to low population figures compared to US, India and China.

Table 1: Total CO2 Emissions (Million metric tons) [Source: www.TradingEconomics.com]

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
United States	5,861.819	5,753.702	5,801.170	5,850.634	5,968.495	5,991.466	5,913.676	6,018.131	5,833.133	5,424.530
France	401.651	405.635	401.727	408.383	410.914	413.962	416.368	423.056	428.539	396.652
Poland	292.564	276.418	274.239	284.789	292.186	287.589	299.146	295.949	294.776	285.785
China	2,849.750	2,969.576	3,464.843	4,069.239	5,089.780	5,512.703	5,817.144	6,256.704	6,800.468	7,706.826
India	1,002.954	1,025.677	1,015.845	1,032.067	1,125.836	1,183.283	1,282.681	1,368.383	1,463.304	1,591.126

Job Creation and Economy Boost:

Development of shale gas will need well trained workforce (see example 1below) to harness the large amounts of energy available in the shale formations. This shale gas revolution may help create new jobs and an opportunity to reduce the unemployment in the country. This may also contribute to the economy and boost the growth of the country.

For example:

1. In 2008, 33 states (United States) had at least 2,000 workers directly involved in natural gas activities, with 21states of the 33 having at least 4,000 people directly involved in natural gas activities (ANGA, 2009; Markey, 2010).
2. Activity in the Marcellus, Haynesville, and Fayetteville shale plays of US has created an estimated 80,000 jobs (ANGA, 2009; Markey, 2010).
3. Over the next two decades, shale gas production in US is expected to create 300,000 new jobs (Markey, 2010; Tillerson, 2010).
4. In 2008, natural gas production contributed $385 billion to the national economy of US and helped support more than 2.8 million jobs (ANGA, 2009; Markey, 2010).

SHORTCOMINGS

To understand the issues related to shale gas, let us understand the difference between the conventional gas production and shale gas production methods. As seen in Figure 5, a conventional gas well produces from a reservoir rock that has gas trapped in it due to a seal rock on top of this reservoir rock, preventing the gas to escape from this rock or may be reach surface. As the permeability of this rock is high enough, the gas can flow naturally into the well and may require minimum or no hydraulic stimulation in its whole life cycle. On the other hand, shale gas well produces from a very low permeability rock, hence regular hydraulic fracturing is required to keep the gas flowing at economic volumes.

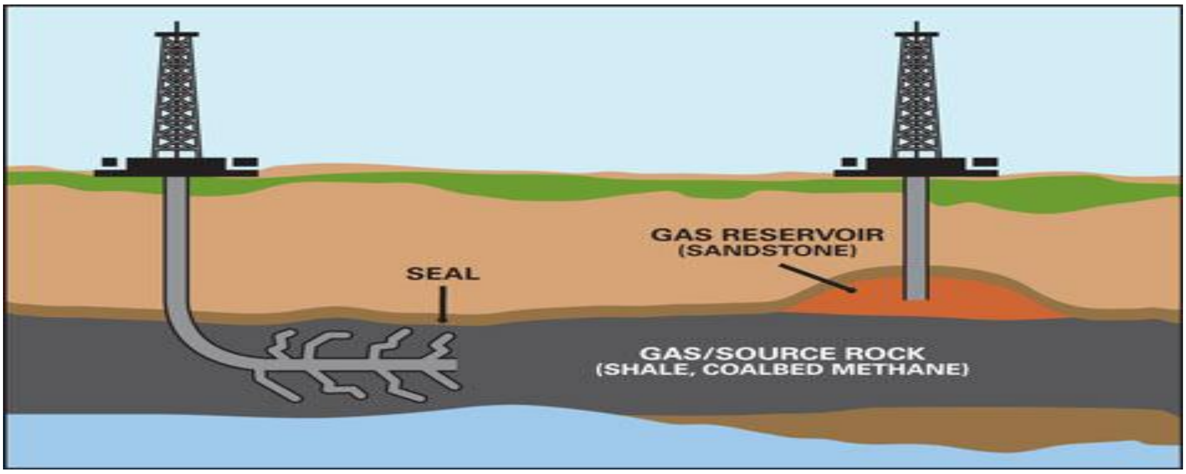

Figure 5: Conventional and Shale gas well [Source: Waterengnet]

Though shale gas is proving to be very resourceful and economic in the present scenario; it also has some environmental issues associated with it. The main issues associated with shale gas development are linked with hydraulic fracturing. For hydraulic fracturing large amounts of water is required along with other chemicals to create fractures, which allows economic amounts of gas to flow from these gas rich shales. Large amounts of water with chemicals and sand are pumped into the well to create artificial fractures; the water along with the chemicals allow to initiate these fractures at high pressures and the sand keeps the fractures open once the pressure is removed. The new fracture network makes higher volume of gas to be extracted and hence the project becomes economical.

At the blending stage the chemicals and other additives are added to the freshwater and pumped down hole to make the hydraulic fracture and after the operation, the remaining fluids are flown back and stored temporarily before it is sent for further treatment and disposal. The treated water may then be disposed according to the regional regulation.

The issues in this shale gas development process are:

Water availability:

Large amount of water is required for hydraulic fracturing treatments but not all drilling sites are close to water resources and in such case, this volume of water required for the treatment may come from other location with dozens of trucks or from groundwater in the area. In both cases the water required for other purposes in the area would be affected.

Mismanaged hydraulic fracturing:

As this operation is controlled by humans, the scope of error is always high. From Figure 5, we can see that if the seal rock during hydraulic fracturing is damaged, the gas from the reservoir rock or shale rock can escape to shallow depths and pollute the groundwater zones (MIT, 2011) or in worst case reach the surface, destroying crops, etc. This may make the groundwater useless for other purposes such as drinking or irrigation.

Polluting shallow water zones:

Even if the hydraulic fracturing is managed properly and the seal remains intact, the chemicals used in the hydraulic treatment may leak into the shallow water zones (MIT, 2011) if the well cementation or zone isolation is substandard. This may pollute the groundwater zones and local population and animals which may be consuming this water or using it for agriculture would be affected.

Wastewater disposal and treatment:

The water used in the hydraulic treatment is accompanied with chemicals and when it is flowed back to surface post treatment, it cannot be disposed into the water bodies without treatment. If the local resource of water is used for drinking by local communities, the disposal of treated water into this fresh water resource may not be accepted. Even if, all the regulations are in place, to define the acceptable level of pollutants in the disposed water, the human factor is always going to be large.

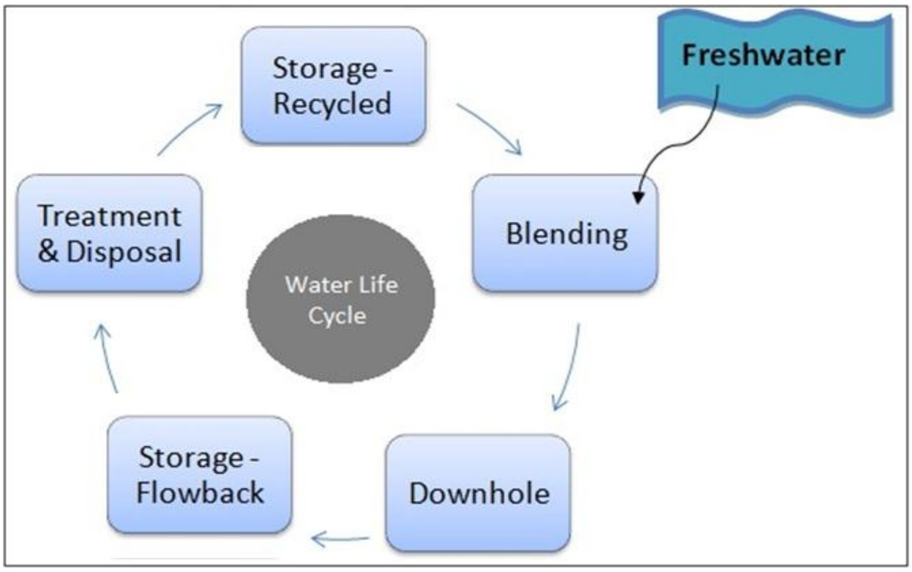

Figure 6: Water life Cycle in Shale Gas development

All the stages in the life cycle of water, related to shale gas development; from acquiring the fresh water for the hydraulic fracturing treatment to recycling wastewater are equally important and high standards must be met at all stages of this cycle. Let us now see how shale gas development is taking place in our selected countries and as United States has started this revolution, we will first see the shale gas affect on United States.

Shale Gas: Approach of Selected Countries

UNITED STATES

A very significant amount of activity is currently taking place in the United States to explore, develop and produce its shale gas plays with the increase in gas prices. In past decades production of natural gas from shales was not economical but together with recent technological advancements of hydraulic fracturing and horizontal drilling, natural gas from shales has become economical. The production of natural gas from shales has renovated the natural gas market of United States.

Shale Gas Potential

Taking the decade long production (From Figure 8) from Barnett Shale in United States has brought tremendous experience of shale gas production has brought improvements in other shale gas prospects of the country. In 2009, 87% of natural gas consumed in the United States was produced domestically. At the 2010 rate of consumption of United States (24.1Trillion cubic feet (Tcf) per year), the 2543 Tcf shale gas resource is enough to supply for 100 years (EIA-2, 2011). The most important basins in United States are the Barnett and Marcellus. Since 1998 natural gas production from unconventional sources has increased to 8.9 Tcf/year in 2007 from 5.4 Tcf/year (Yost, 2010).

Few years ago it was thought that United States was going to experience a short fall in its natural gas supply and was all set to become the largest importer of Liquefied Natural Gas (LNG). The natural gas production was on decline and imports from foreign land were increasing, and to accommodate the large imports, new LNG import terminals were planned. But with some operators being able to unlock the huge resources of natural gas from shales at low costs changed the game altogether. The investment planned for LNG import terminal was now diverted to build LNG export terminals. In Figure 7 below we can see the various shale gas plays of United States and the benefits of horizontal drilling with hydraulic fracturing, compared to vertical drilling.

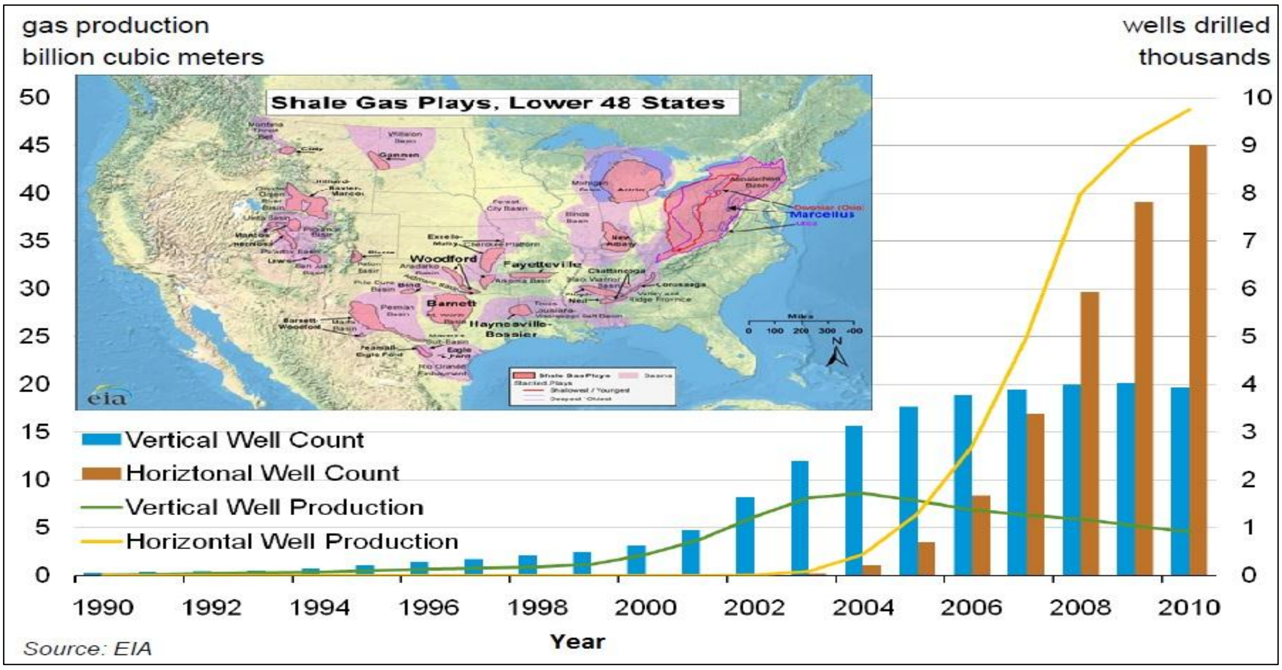

Figure 7: Shale Gas plays in United States and Barnett Production [Modified from Source: EIA-4, Newell]

Effect on US LNG Market:

Around 75% (EIA, 2008) of US LNG supply comes from Trinidad & Tobago. Other countries like Egypt, Norway, Nigeria and Qatar have also been supplying some of the requirements from US. The falling imports can be seen in Figure 9.

Though US have been importing gas from various countries, it has also been exporting gas to Mexico and Japan for a long time (EIA, 2008). It has one LNG exporting or liquefaction terminal located in Kenai, Alaska. The supply of LNG to other Asian countries is also considered and the fact can be proved with three new LNG liquefaction projects being proposed in the same area as seen in Figure 8.

United States-A Major LNG Exporter?

While it is not a surprise that, United States is an LNG exporter, as it has been exporting LNG from its Kenai LNG terminal located in Alaska; mainly to Tokyo Electric and Tokyo Gas in Japan (EIA, 2008). But we would like to know, when United States with its huge resources of Shale gas, would become a major LNG exporter. In the Figure 8, I have tried to project the year when this may happen.

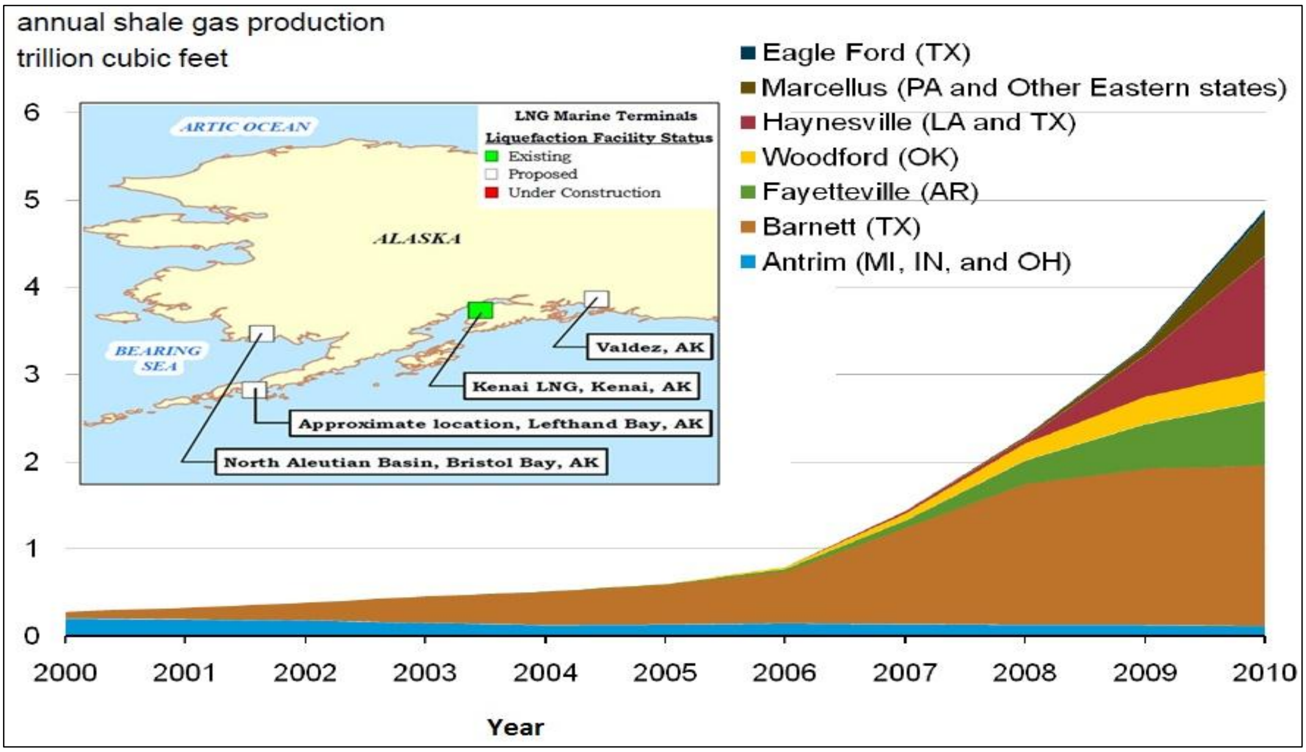

Figure 8: New LNG exporting terminals proposed in Alaska [Modified from Source: CEA-2, Newell, EIA-4]

I believe that with the current debt crisis, United States might try and cut its expenditures and bring reforms in their spending. Hence the demand for energy in United States may stay very modest, while the advancements in Shale gas technologies may help produce faster and recover more from its reservoirs. As consumption may increase modestly and the production may increase much more steeply; it may approximately exceeds its demand by the year 2015-2017 (Based on last trend seen in the graph and rough estimation of the countries strategy).

The import strategy is difficult to predict, as this will depend on the approach United States will adopt. It can continue to import gas when it is cheaper in the market (depending on the gas price fluctuation) compared to its own gas price or completely stop its import of gas. If we consider the above prediction, they may be able to completely stop its imports by 2015-2017 and may become one of the largest gas exporting countries.

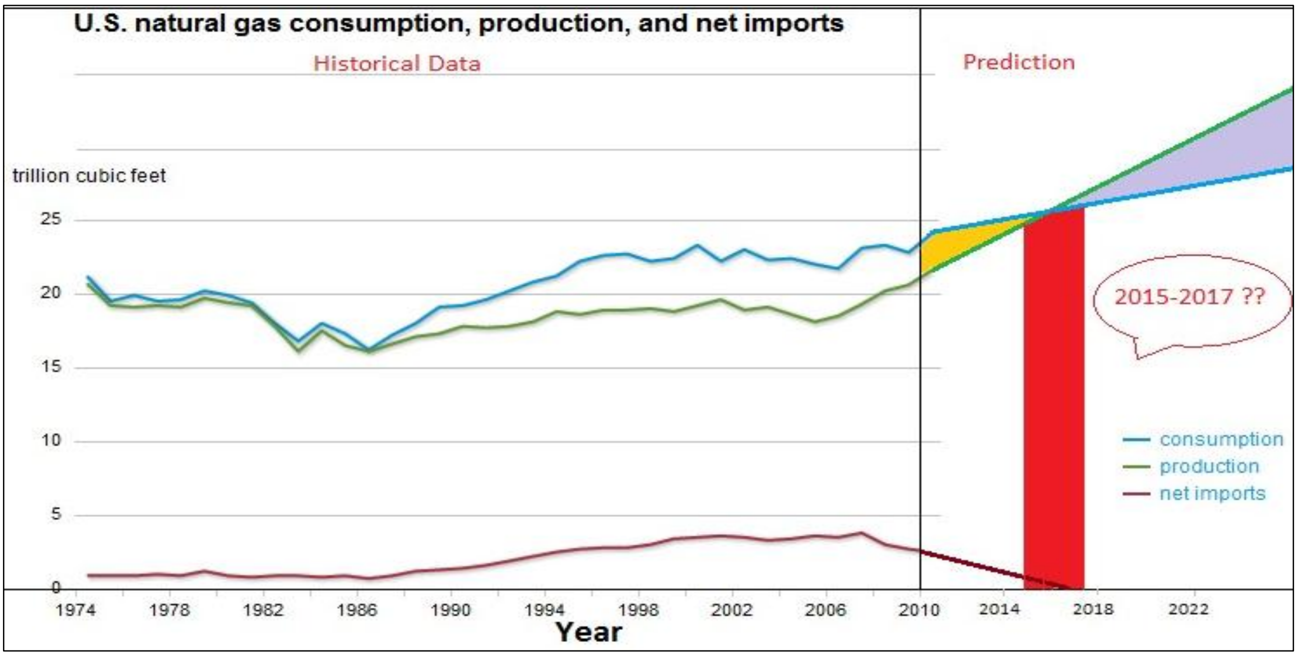

Figure 9: US natural gas consumption, production and imports [Modified from Source: EIA-3]

FRANCE and POLAND

Shale Gas Potential

After shale gas revolution in United States, the interest of many international and national oil companies has increased in shale gas prospects outside United States. Though the unconventional gas resources in Europe have not been explored actively till date but recent efforts in exploration have given the indication of significant potential of shale gas in Poland and France.

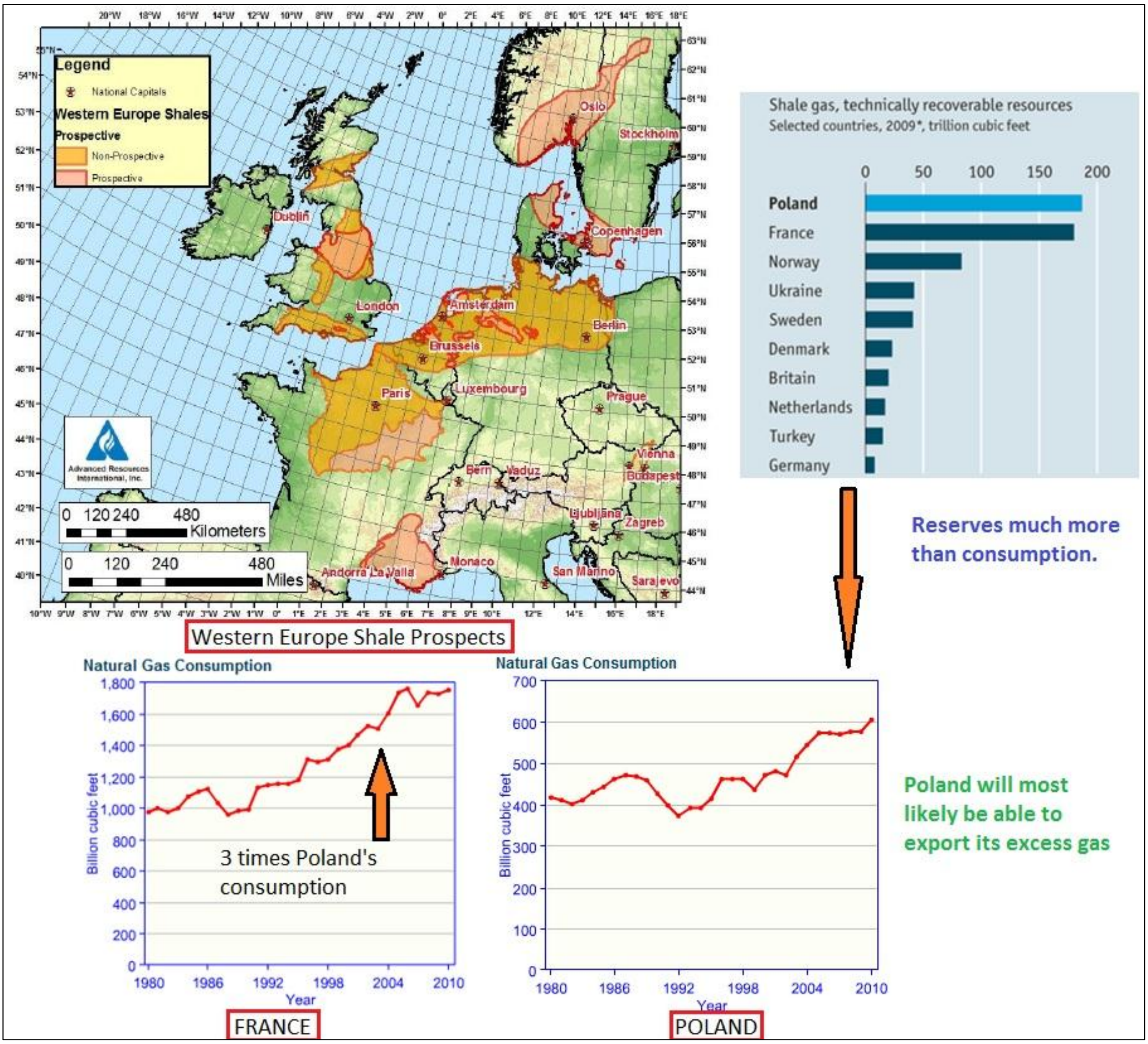

Figure 10: Shale Gas Effect on Poland and France [Modified from Sources: EDI, EIA-5, EIA-6]

*'Poland's Prime Minister Donald Tusk called shale gas a **"great opportunity"** for Poland. The unconventional gas industry, while still in its infancy in Poland, could create thousands of jobs and, eventually, generate export revenue. If it turns out to be economically viable to extract, it may free Poland from dependence on Russian natural gas supplies'* (Sobczyk, 2011).

*'On Thursday 30 June, the French Parliament **banned** the use of the technique of hydro fracturing for exploration and exploitation of gas and shale oils, under the pressure of strong mobilization of the people concerned.' France became the first country in the world to prohibit the use of this technique **considered highly polluting**-* (LeMonde.fr, June 2011). Hence the political stance of these two countries in Europe is completely opposite.

Poland and France are believed to have almost similar shale gas reserves (From Figure 10) but consumption of gas in France is three times that of Poland (From Figure 10). So, are the above decisions going to change the gas market in these two countries? This will be covered in the next section.

Effect on Gas Market and Future Plans

To understand the effect on gas market in these two countries, let us look at the volume of gas imported and the origin it comes from, as seen in Table 2.

Table 2 Gas Imports of Poland and France (Mode of transport and Country) [Access at: EDI]

Imports by transport type - Poland

By transport type (in mcm)	2006	2007	2008	2009
Pipeline imports	10922	10124	11202	9954
LNG imports	-	-	-	-
Total	10922	10124	11202	9954
c = confidential; - = nill; ..= not available	-	-	-	-
Source: IEA Natural Gas Information 2009	-	-	-	-

c = confidential; - = nill; ..= not available

Imports by country - Poland

By country of origin (in mcm)	2006	2007	2008	2009
Russia	7525	6855	5719	8166
Other former USSR*	2480	2407	2513	5
Germany	537	862	906	1084
Total	10922	10124	11202	9954

c = confidential; - = nill; ..= not available

* Other former USSR consists of Turkmenistan, Kazachstan or Uzbekistan

Source: Natural gas information 2010 & OECD/IEA, 2010

Imports by transport type - France

By transport type (in mcm)	2006	2007	2008	2009
Pipeline imports	32599	32566	36219	37052
LNG imports	12902	11250	10227	10068
Total	45501	43816	46446	47120

c = confidential; - = nill; ..= not available

Imports by country - France

By country of origin (in mcm)	2006	2007	2008	2009
Norway	12286	13683	14653	14142
Netherlands	9420	8837	9073	8262
Russia	7311	5955	6772	6400
Algeria	6827	7254	7044	7038
Nigeria	3966	2929	2245	1159
Egypt	2109	1067	938	1416
Qatar	-	-	-	445
Other	3582	4091	5721	8248
Total	45501	43816	46446	47120

c = confidential; - = nill; ..= not available

In Poland the gas imports account for 61% (Calculated from Table 2) of gas volumes consumed and 82% (Calculated from Table 2) of these imports come from Russia alone via pipeline. Poland has been troubled by the political issues of the gas supply from Russia, which comes with a pipeline passing Ukraine. There have been issues since 2005 with gas prices, debts and supplies (BBC, 2006). Poland may want to gain independence from Russia's gas supply by increasing its domestic supply from shale gas developments. At current consumption rate of 600 Bcf (From Figure 10) Poland has resources for 300 years. It has also proposed its first LNG regasification terminal to open up its gas imports via LNG, which shows they are keen on transition to gas.

In France there are three (From Figure 11) LNG regasification terminals currently operating and in addition to these four new LNG regasification terminals have been proposed. This expansion is also seen due to two main reasons: 1) France currently relies around 80% (From Figure 4) on nuclear energy and the possible scenario of 'energy mix' after the nuclear tragedy of Japan may be possible. It is estimated that the new share of nuclear energy could be 60-70% from the current 80% (LeMonde.fr, July 2011). 2) After announcing a ban on Shale gas development in France (LeMonde.fr, June 2011), it may continue importing gas from the international gas market.

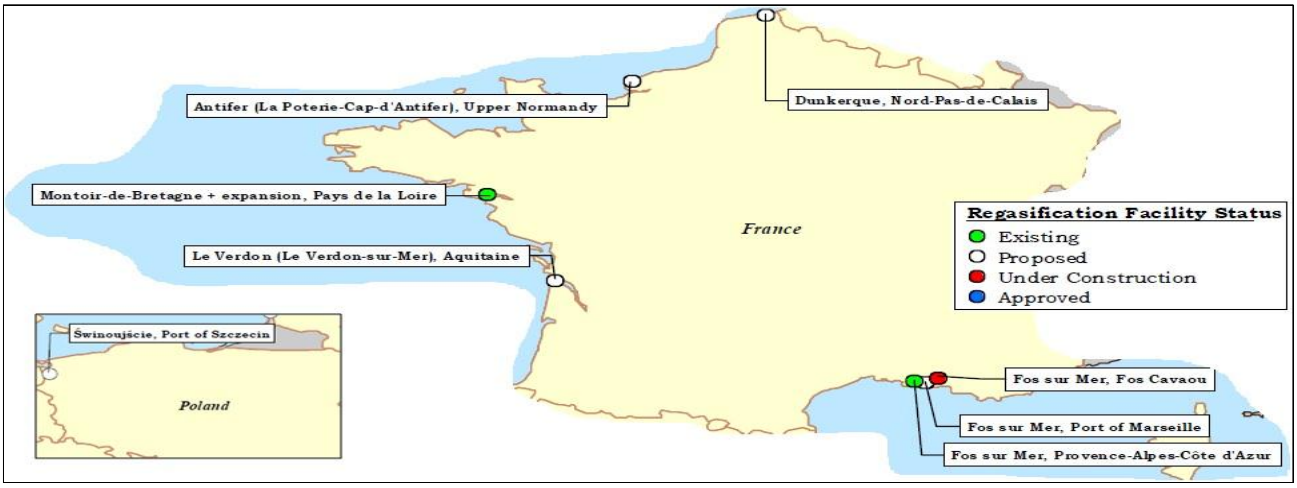

Figure 11: Existing & Proposed LNG facilities of Poland and France [Source: CEA-3]

INDIA and CHINA

Shale Gas Potential

India and China are considered as the future destination for next shale gas boom with its technically recoverable estimated resources exceeding 1000 trillion cubic feet (Xiuli et al, 2011). In China, shale gas resources are estimated to be about 1084 to 3530 Tcf (Xiuli et al, 2011). While the Chinese government believes that commercial shale gas production could start in early 2011 in southwest China; the Indian government is planning to auction its first shale gas blocks by the end of 2011. In early 2011, ONGC (Oil and Natural Gas Corporation) India completed a pilot shale gas well in West Bengal and shale gas estimated resources are in the range of 600-2000 (PacWest, Sharma) trillion cubic feet. Both countries have signed various memorandums with the US government for assistance in its shale gas developments. Both Chinese and Indian oil companies are buying stakes in US shale gas plays to understand and gain valuable shale gas operating experience.

Though the shale gas development is in its primary stages in both the countries, both the governments have shown clear intentions of developing shale gas resources (Initial basin evaluation seen in Figure 12) to boost its domestic supply. India is clearly lagging behind China (as mentioned above) in tapping shale gas resources but at the same time India uses much less energy compared to its huge population (From Figure 14).

India may struggle to catch up with China, as China is seen to invest largely in its gas pipeline network in the country. China plans to triple its pipeline network from current 36000 Kilometre to 100,000 Kilometre (China Daily, 2010). The volume of shale gas available to recover technically and economically will be clearer in coming years, when the operating companies start exploration and development of these basins (In Figure 12) and also new prospects may be discovered.

Figure 12: Some Shale gas prospect basins of India and China [Source: PacWest]

Demand of Gas

Both, China and India depend on imports of oil and gas to meet the energy requirements of the huge population in the country. From Figure 13, we can see that the population growth is estimated to be similar but less severe for China due to its birth control policies. India is believed to become the most populated country in the world by adding around 400 million more people in next 25 years to its count and on the other hand, China is believed to add around 300 million more people in next 25 years (From Figure 13). Even though both countries may have almost similar population in the next 10-15 years (From Figure 13); the total energy demand of China is believed to be 4 times that of India (From Figure 14).

For natural gas, from Figure 13 we can say that China's natural gas consumption is believed to increase at a much faster rate than India. China, from less than 1.6 Tcf per year consumption of natural gas in 2005, is believed to touch around 10 Tcf per year (From Figure 13) of natural gas consumption by 2035. On the other hand India is believed to take a slow transition to natural gas from around 1 Tcf per year in 2005 to around 4.4 Tcf per year of natural gas consumption (From Figure 13). These statistics match with the fact that the Chinese government is pushing hard to develop its shale gas resources to increase its domestic gas supply.

Reducing CO2 Emissions: Coal and Nuclear Consumption

China and India are actively pursuing shale gas exploration, as gas can provide a cleaner source of energy for economic development. Let us look at the historical CO2 emissions of these two fast growing economies below to understand the different economic growth models adopted by these two fast emerging economies. (China and India are ranked 2nd and 4th largest economies of the world - IMF, 2011)

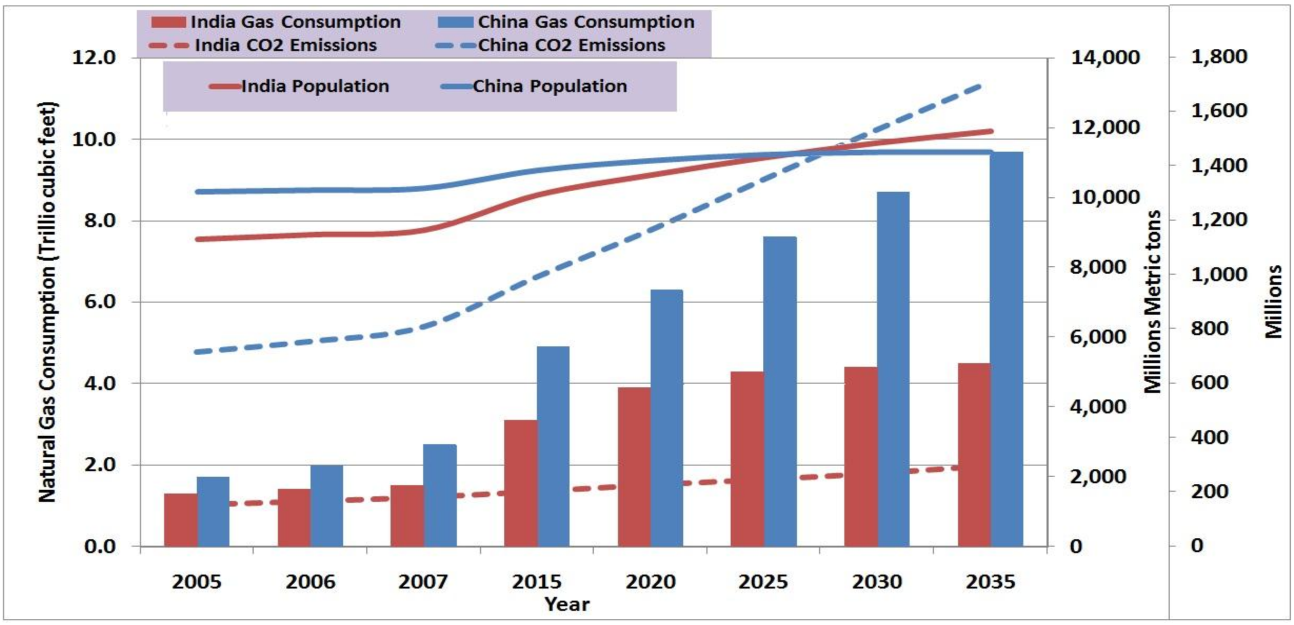

Figure 13: Natural Gas Consumption and Population (Data Source: EIA-7)

It is clearly evident from Figure 14Figure 13 that China needs to cut down its CO2 emissions drastically. This would mean reducing its reliance on coal and bringing more natural gas in its energy profile. As seen from Figure 13 and Figure 14, China is believed to still continue its mass usage of coal and also increase its nuclear energy use to meet its energy demand, which is believed to increase to nearly 180 Quadrillion Btu (British thermal units) (From Figure 14). To meet this growing energy demand it is also going to increase its use of natural gas and shale gas may play a major role in improving its domestic supply and energy profile to more environment friendly one.

India has shown readiness in committing steps towards cutting down its CO2 emissions at the Copenhagen Climate Summit (BBC, 2009). India's low per-capita emissions are, in part, a result of the fact that there are 400 million Indians who do not have access to commercial electricity today (Saran, 2009). But the good news is that India might be able to reduce its use of coal by keeping the use to its current level in future and increasing its reliance on nuclear and natural gas and again shale gas may boost its domestic supply of gas to help reduce its gas imports.

It is yet not clear the exact amount of shale gas reserves existing in these countries, but the Chinese government are announcing ambitious shale gas projects. In November 2010, President Barack Obama and President Hu Jintao of China announced a US-China Shale Gas Resource Initiative aimed at promoting "environmentally sustainable development of shale gas resources" and in July 2010, the state-owned China National Petroleum Corporation announced that it aims to produce 500 million cubic meters of shale gas by 2015 (Westervelt, 2010)

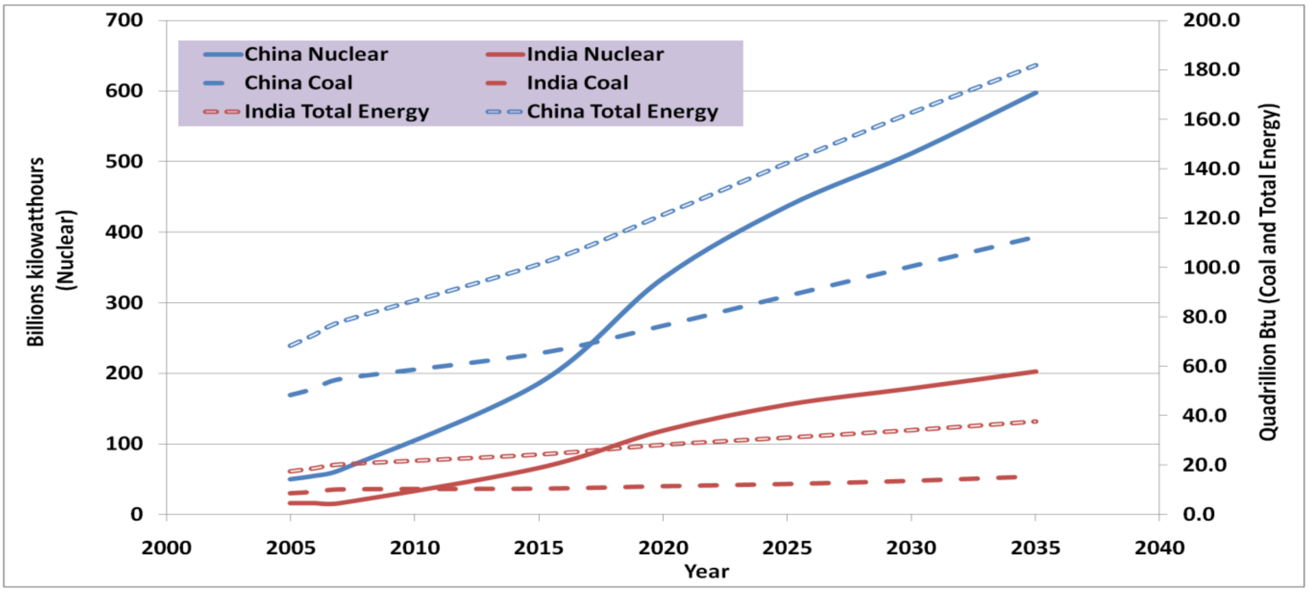

Figure 14: Nuclear and Coal Consumption of India and China (Source: EIA-7)

Summary

Shale gas has been a huge success in North American continent but almost 75% (Wilczynski et al, 2010) of shale gas resources lie outside North America. Operators planning to take the share of shale gas pie outside North America need to find alternative approach to reduce their risks. The infrastructure and logistic capabilities available in North America are not so well developed in Asia or Middle East. On the other hand, the environmental norms are stricter in Europe which can pose great difficulties for operators to carry out their work smoothly. It is evident from the decision of France to not exploit shale resources due to pressure from environmental groups and the fear amongst locals about the side effects of shale gas, that environment issues are complicated in Europe with high density of population directly in the vicinity of the exploration sites.

Another major concern in many shale gas locations is the access to large amounts of water required for hydraulic fracturing and the facilities to handle these massive volumes and treating them before releasing them back to the environment. But on the other hand countries like China and India, who majorly depend on coal will need to keep a check on their CO2 emissions and the only way to reduce the reliability on coal is to diverse the energy portfolio of the country by using more gas energy. This may see the demand for gas increasing in these countries. China also has tremendous reserves of shale gas and if the shale gas success story of North America can be replicated in China, the domestic supply of gas would improve drastically. This will reduce the large bills for imports of gas and make gas available locally which will also ensure supply security. The gas market has already seen a ripple effect from North America which forced the gas exporters to find new market for its gas loaded ships.

Shale gas can have a positive impact in the region (as in the case of North American gas market) or it can have a negative impact in the region (as in the case of gas exporters to North America). Operators are buying huge land acreage from Argentina to Poland to China, hoping that they could replicate the North American shale gas story in other continents. The task is not straightforward and poses many hurdles in doing so. There are different environmental concerns, operational and logistic challenges, lack of experience, water availability, political hindrances and access to land are some major challenges posed in front of operators hoping to take this challenge at hand. Some challenges have the ability to turn the project uneconomical and the risks can be high enough for investors to shy away from financing such an adventure. The rewards on the other hand are highly lucrative with the volumes of gas available, if captured successfully.

Conclusions

There are three main conclusions derived from this study:

1. The United States may become a gas exporting country by 2015-2017, with steep increase in production from shale formations and demand staying modest with the current debt crisis.

2. France with its new LNG import terminals is set to increase its gas importing strategy and reducing its reliance on nuclear energy. With elections of France in 2012, it will be interesting to see the strategy of the new government on shale gas resources. As Poland is ready to unleash its shale gas development in the coming years, will France be able to digest sitting on shale gas resources and buy gas internationally?

3. India and China, the two major economies of the world, have shown clear intentions of developing their shale gas resources and the international environmental groups are happy to see these developments in these countries as these economies rely on coal for their energy, which is much more hazardous to the existing 'Global Warming' issue.

Nomenclature

Bcm: Billion cubic metres
Bcf: Billion cubic feet
Btu: British thermal units
Mcf: 1000 cubic feet
Tcf / Tcm: Trillion cubic feet / Trillion cubic metres

Conversions

1 feet (ft) = 0.3048 metre (m)
1Trillion cubic feet (Tcf) = 10^{12} cubic feet (cf) = 28.32 billion cubic metre (bcm)
1cf = 0.0283 cubic metre (m^3)
1Metric Ton (MT) = 10^3 Kg
1Million Metric Ton (MMT) = 10^6 MT
1British thermal unit (Btu) = 35.32 m^3
1 Million British thermal units (MMBtu) = 10^6 Btu
1 quadrillion Btu = 10^{15} Btu = 1 Tcf = 20.53 MMT
1 million = 10^6 ; 1 billion = 10^9 ; 1 trillion = 10^{12} ; 1 quadrillion = 10^{15}
1 Watt hour (Wh) = 3600 Joules; 1kilowatthour (kWh) = 10^3 Wh

References

ANGA (America's Natural Gas Alliance), "The Contributions of the Natural Gas Industry to the U.S. National and State Economies "(2009)

BBC, 2006, Available at http://news.bbc.co.uk/1/hi/world/europe/4573572.stm, last visited on 24/08/2011.

BBC, 2009, Available at http://news.bbc.co.uk/1/hi/sci/tech/8278973.stm, last visited on 23/08/2011.

BG Group, Available at http://www.bg-group.com/OurBusiness/OurBusiness/Pages/NaturalGas.aspx, last visited on 19/08/2011.

BGR (Bundesanstalt für Geowissenschaften und Rohstoffe) in Hannover, http://www.bgr.bund.de/EN/Themen/Energie/Erdgas/erdgas_node_en.html;jsessionid=CD08B3D4684FA4296055516202322DF6.1_cid137, last visited on 11/08/2011

CEA-1 (The California Energy Commission), http://www.energy.ca.gov/lng/international.html; last visited on 10/08/2011

CEA-2 (The California Energy Commission), http://www.energy.ca.gov/lng/worldwide_united_states.html, last visited on 09/08/2011.

CEA-3(The California Energy Commission), http://www.energy.ca.gov/lng/international.html; last visited on 10/08/2011.

China Daily 2010, Available at http://www.chinadaily.com.cn/business/2010-10/20/content_11435212.htm, last visited on 23/08/2011.

Dominion, available at http://www.dom.com/business/gas-transmission/cove-point/history-of-lng.jsp ; last visited on 11/08/2011

EIA, 2008 (U.S Energy Information Administration), available from http://www.lngfacts.org/About-LNG/Diversifying-Energy-Portfolio.asp, last visited on 16/08/2011

EIA-1 (U.S. Energy Information Administration), http://www.eia.gov/oiaf/analysispaper/global/importers.html; last visited on 10/08/2011

EIA-2 (U.S Energy information Administration); Available at http://www.eia.gov/energy_in_brief/about_shale_gas.cfm, last visited on 09/08/2011

EIA-3(U.S Energy information Administration); Available at http://www.eia.gov/naturalgas/, last visited on 09/08/2011

EIA-4 (U.S Energy information Administration); Available at http://www.eia.gov/analysis/studies/usshalegas/pdf/usshaleplays.pdf, last visited on 09/08/2011

EIA-5 (U.S Energy information Administration), available at http://www.eia.gov/countries/country-data.cfm?fips=FR#ng (France), last visited on 20/08/2011

EIA-6 (U.S Energy information Administration), available at http://www.eia.gov/countries/country-data.cfm?fips=PL#ng (Poland), last visited on 20/08/2011

EIA-7 (U.S Energy information Administration), available at http://www.eia.gov/analysis/projection-data.cfm#intlproj, last visited on 20/08/2011

EDI (Energy Delta Institute), http://www.energydelta.org/mainmenu/edi-intelligence-2/our-services/Country-gas-profiles, last visited on 14/08/2011.

Geology, An article on liquefied natural gas (LNG), Available at http://geology.com/articles/lng-liquefied-natural-gas/, last visited on 18/08/2011

George E. K (2010), Apache Corporation: "Thirty Years of Gas Shale Fracturing: What Have We Learned?" paper SPE 133456-MS presented at SPE Annual Technical Conference and Exhibition, 19-22 September 2010, Florence, Italy.

IMF (International Monetary Fund) - Data and Statistics, 2011. Available at http://www.imf.org/external/data.htm, last visited on 25/08/2011.

Kefferputz .R (2010), "Shale Fever: Replicating the US gas revolution in the EU? Article from Centre For European Policy Studies (CEPS), June 2010

LeMonde.fr- June, "Gaz de schiste: le Parlement interdit l'utilisation de la fracturation hydraulique", article from LeMonde.fr on 30/06/2011. Available at http://www.lemonde.fr/planete/article/2011/06/30/gaz-de-schiste-le-parlement-interdit-l-utilisation-de-la-fracturation-hydraulique_1543252_3244.html, last visited 14/08/2011.

LeMonde.fr-July, "Electricité: Besson prône deux tiers de nucléaire à l'horizon 2050", article from LeMonde.fr on 08/07/2011. Available at http://www.lemonde.fr/politique/article/2011/07/08/energies-a-l-horizon-2050-besson-prone-2-3-de-nucleaire_1546332_823448.html, last visited on 24/08/2011

Markey .E (2010), Chairman, House Subcommittee on Energy and Environment, "Fact Sheet - Shale Gas: Creating American Jobs", IOGCC Shale Gas Directors Task Force (2010). January 20, 2010. Available at http://groundwork.iogcc.org/sites/default/files/FINAL%20JOBS%20FACT%20SHEET.pdf, last visited 25/08/2011.

MIT, Energy Initiative (2011): "The Future of Natural Gas: An Interdisciplinary MIT Study", available at http://web.mit.edu/mitei/research/studies/documents/natural-gas-2011/NaturalGas_Chapter%201_Context.pdf, last visited 25/08/2011.

Newell .R (2011), Administrator: "Shale Gas and the Outlook for U.S. Natural Gas Markets and Global Gas Resources", Organization for Economic Cooperation and Development (OECD), June 21, 2011, Paris, France. Available at http://www.eia.gov/pressroom/presentations/newell_06212011.pdf, last visited 14/08/2011.

PACWEST Consulting Partners: Available at http://www.pacwestcp.com/global.php, last visited on 15/08/2011

Pentland .W (2011), Contributor at Forbes, available at http://www.forbes.com/sites/williampentland/2011/06/17/worlds-longest-natural-gas-pipelines/, last visited on 18/08/2011.

ProPublica, http://www.propublica.org/special/hydraulic-fracturing-national, last visited on 15/08/2011

Saran .S (2009), Special Envoy to the Prime Minister for Climate Change, "India's Climate Change Initiatives: Strategies for a Greener Future", speech at Carnegie Endowment for International Peace, March 2009. Available at http://carnegieendowment.org/files/Saran_Speech%20at%20Carnegie.pdf, last visited on 26/08/2011.

Sharma S.S, Kulkarni P.K, SPE, Joshi Technologies International Inc. (2010): "Gas Strike in Shale Reservoir in Dholka Field in Cambay Basin", paper SPE 129082-MS presented at SPE Oil and Gas India Conference & Exhibition, 20-22 January 2010, Mumbai, India

Small .D (2005), National Gas Company: "The Global LNG Industry - Changed Market Dynamics", paper WPC 18-0959 presented at 18th World Petroleum Congress, September 25 - 29, 2005 , Johannesburg, South Africa

Sobczyk M (2011): "Resistance to Poland's Shale Gas Exploration Plans Emerging", article for 'The Wall Street Journal', August 5, 2011. Available at http://blogs.wsj.com/emergingeurope/2011/08/05/resistance-to-poland%e2%80%99s-shale-gas-exploration-plans-emerging/, last visited 14/08/2011.

SPM (Special Piping Material) 2011, (LNG section). Available at http://www.specialpiping.com.au/lng.html, last visited on 18/08/2011.

Stefan .L, David .B (2009): "The development of natural gas supply costs to Europe, the United States and Japan in a globalizing gas market—Model based analysis until 2030", Energy Policy 37 (2009) 1518-1528.

Tillerson R. W. (2010), (Chairman and CEO, ExxonMobil Corp).The ExxonMobil-XTO Merger: Impact on U.S. Energy Markets, Subcommittee on Energy and Environment, Committee on Energy and Commerce, 111th Cong., 101 (2010)

Trading Economics, India: Available at http://tradingeconomics.com/india/co2-emissions-metric-tons-per-capita-wb-data.html, last visited on 15/08/2011

Trading Economics, China: Available at http://tradingeconomics.com/china/co2-emissions-metric-tons-per-capita-wb-data.html, last visited on 15/08/2011

Trading Economics, US: Available at http://tradingeconomics.com/united-states/co2-emissions-metric-tons-per-capita-wb-data.html, last visited on 15/08/2011

Trading Economics, France: Available at http://tradingeconomics.com/france/co2-emissions-metric-tons-per-capita-wb-data.html, last visited on 15/08/2011

Trading Economics, Poland: Available at http://tradingeconomics.com/poland/co2-emissions-metric-tons-per-capita-wb-data.html, last visited on 15/08/2011

Van Dusan M. (2011)- Txchnologist, 2011, article on "Carbon Capture and Storage: A Long-Term Solution for Natural Gas?". Available at http://www.txchnologist.com/2011/carbon-capture-and-storage-a-long-term-solution-for-natural-gas, last visited on 24/08/2011.

Warren R. T. (2008): "Overview of World LNG Industry", paper OTC 19662-MS presented at Offshore Technology Conference, 5-8 May 2008, Houston, Texas, USA

Waterengnet, 2011: Available at http://waterengnet.com/2011/water-issues-with-shale-gas-development/, last visited on 24/08/2011

Westervelt A. (2010) -Contributing Writer:"Shale Gas Booming Globally, Despite Chemical Dangers", an article from SolveClimate (Aug 9, 2010). Available at http://solveclimatenews.com/news/20100809/shale-gas-booming-globally-despite-chemical-dangers?page=2, last visited on 15/08/2011.

Wilczynski H. (2010), Muqsit Ashraf and Mohammed Saadat, an opinion "Shale Gas: a risk worth taking" at The Petroleum Economist Ltd, 2010. Available at http://www.sbc.slb.com/Our_Ideas/SBC_News/~/media/Files/Articles/2010_Dec_Shale%20Gas%20A%20Risk%20Worth%20Taking.ashx, last visited on 28/08/2011.

Xiuli W; XGas and TianJiao W. (2011), Xi'an Petroleum University: "The Shale Gas Potential of China", paper SPE 142304 presented at the SPE Production and Operations Symposium held in Oklahoma City, Oklahoma, USA, 27-29 March 2011.

Yost C. (2010): "SPECIAL Report US gas market well-supplied: LNG or shale gas?" OIL & GAS JOURNAL Volume: 108 Issue: 10 Pages: 46-50 Published: MAR 15 2010 (Available from: http://www.istockanalyst.com/article/viewiStockNews/articleid/4031146, last visited on 15/08/2011

APPENDICES

Appendix A: Literature Review

MILESTONES (Table of Content)				
Paper Number	**Year**	**Title**	**Author(s)**	**Contribution**
WPC 18-0959	2005	"The Global LNG Industry - Changed Market Dynamics"	David Small	Understanding the LNG industry before the economic recession and shale gas revolution.
SPE 133456-MS	2010	"Thirty Years of Gas Shale Fracturing: What Have We Learned?"	George E. King	Understanding complexities of shale gas production in US
SPE 129082-MS	2010	"Gas Strike in Shale Reservoir in Dholka Field in Cambay Basin"	Sharma S.S, Kulkarni P.K	Understanding the Shale Gas developments and existence in India.
OTC 19662-MS	2008	"Overview of World LNG Industry"	Warren R. True	Understanding the global LNG capacities and facilities.
SPE 142304	2011	"The Shale Gas Potential of China"	Xiuli Wang, XGas and TianJiao Wang, Xi'an	Understanding the shale gas developments in China.

WPC 18-0959, presented at 18th World Petroleum Congress, September 25 - 29, 2005, Johannesburg, South Africa

Title: "The Global LNG Industry - Changed Market Dynamics"

Author(s): David Small

Contribution to this thesis: Understanding the LNG industry before the economic recession and shale gas revolution.

Objective of the paper: To examine the underpinnings of the evolutionary changes that the global LNG market has been experiencing over the past few years

Methodology used: Geographic level evaluation of LNG industry comparing Atlantic and Pacific basin.

Conclusion(s): 1990's being the period of maximum LNG industry growth. LNG business is facing challenging times ahead.

Comments: This also shows the unexpected recession and shale gas revolution has affected the way LNG industry will operate.

SPE 133456-MS, presented at SPE Annual Technical Conference and Exhibition, 19-22 September 2010, Florence, Italy

Title: "Thirty Years of Gas Shale Fracturing: What Have We Learned?"

Author(s): George E. King, Apache Corporation

Contribution to this thesis: Understanding complexities of shale gas production.

Objective of the paper: A summary of the lessons learned in shale fracturing.

Methodology used: A survey of around 350 shale completion, fracturing and operations publications.

Conclusion(s):

- No two shales are alike. Shales are aerially and vertically within a trend, even along the wellbore.
- Shale "fabric" differences, combines with in-situ stresses and geologic changes are often sufficient to require stimulation changes within a single well to obtain best recovery.
- Understanding and predicting shale well performance requires identification of a critical data set that must be collected to enable optimization of the completion and stimulation design.
- There is no optimum, one-size-fits-all completion or stimulation designs for shale wells.

Comments: Does not contribute to the paper with its detailed work but gives an understanding of complexities faced in shale gas developments and production.

SPE 129082-MS presented at SPE Oil and Gas India Conference & Exhibition, 20-22 January 2010, Mumbai, India

Title: "Gas Strike in Shale Reservoir in Dholka Field in Cambay Basin"

Author(s): Sharma S.S, Kulkarni P.K, SPE, Joshi Technologies International, Inc.

Contribution to this thesis: Understanding the Shale Gas developments and existence in India.

Objective of the paper: Case study of the accidental gas strike in shale section of the reservoir.

Methodology used: This was an accidental gas strike; the operations were for its complex oil field in Cambay basin.

Conclusion(s): Presence of gas in Shale reservoir has been established. This gives new frontier for exploration in the basin.

Comments: This is a significant shale gas find in one of its basin and the ongoing ONGC shale gas pilot project with Schlumberger is going to take note of this major finding in the basin.

OTC 19662-MS presented at Offshore Technology Conference, 5-8 May 2008, Houston, Texas, USA

Title: "Overview of World LNG Industry"

Author(s): Warren R. True

Contribution to this thesis: Understanding the global LNG capacities and facilities.

Objective of the paper: Overview of global LNG capacities- production, shipping and regasification till early 2008.

Methodology used: Review the ongoing and planned projects of different regions and summarizing them.

Conclusion(s): Addressing issues the industry faces with liquefaction capacities and slow growth in some regions. The increasing Asian demand for LNG is making the LNG supplies tight and hence tightening the pricing policies. The issues of LNG industry may be sorted by end of 2008 as the industry increases its capacities and demands are met with more suppliers coming into picture.

Comments: Does not directly contribute to the paper with its LNG industry details but helps in understanding the complexities and issues the LNG industry faces with demand and pricing pressure.

SPE 142304 presented at the SPE Production and Operations Symposium held in Oklahoma City, Oklahoma, USA, 27-29 March 2011

Title: “The Shale Gas Potential of China”

Author(s): Xiuli Wang, XGas and TianJiao Wang, Xi’an Petroleum University

Contribution to this thesis: Understanding the shale gas developments in China.

Objective of the paper: Investigate the status of China’s shale gas development and assess its accumulations.

Methodology used: Developments on shale gas assessed and predictions made in accordance with China’s less environmental restrictions.

Conclusion(s): The author is convinced that with the government’s incentives and lenient environment laws for shale gas drilling, once the technology is applied in China; the exploration and production of shale gas will be economical and attractive. This will play a significant role in the countries future energy needs.

Comments: This paper helps in understanding the eagerness and positive signals of Chinese government for quick development of its shale gas resources to contribute in its local gas supply.

Appendix B: Information on LNG

What is LNG - Liquefied Natural Gas? (Source: Geology)

LNG is natural gas that has been temporarily converted into a liquid. This is done to save space - 610 cubic feet of natural gas can be converted into 1 cubic foot of LNG. Converting natural gas into LNG makes it easier to store and easier to transport where pipelines are not available.

A refrigeration process is used to condense natural gas into LNG by cooling it to a temperature of minus 260 degrees Fahrenheit. This refrigeration process is usually accompanied by treatments that remove water, carbon dioxide, hydrogen sulphide and other impurities. To maintain this low temperature during storage and transport, LNG must be placed into cryogenic tanks - heavily insulated tanks equipped with refrigeration units.

When a shipment of LNG reaches its destination or when LNG is being removed from storage it must be regasified. This is done by heating the LNG and allowing it to evaporate back into natural gas. Regasification is usually done at a facility where the gas can be placed into storage or directly into a pipeline for transport.

Journey of LNG market

Liquefaction of natural gas was experimented in the 19th century, but through most of the last half of 20thcentury, the use of natural gas as a fuel, has been restricted to regional use. Since the market for natural gas could not reach the global market due to geographical constraints, it was usually flared as a consequence. Efforts were made in 1912 and the first liquefied natural gas plant was built in West Virginia, but the first commercial liquefaction plant was built in 1941 at Cleveland, Ohio. (Dominion)

LNG Importers and Exporters

Currently there are 26 existing export terminals in 15 different countries and 60 existing importing terminals in 18 different countries. These numbers may not sound very significant but with approximately 65 new export terminals and 181 new import terminals proposed or under construction does give a fair idea about the growing LNG market. (EIA-1)

The countries that export LNG are: Algeria, Australia, Brunei, Guinea, Egypt, Indonesia, Libya, Malaysia, Nigeria, Norway, Oman, Qatar, Trinidad and Tobago, United Arab Emirates and United States of America. (CEA-1)

The countries that import LNG are: Belgium, China, Dominican Republic, France, Greece, India, Italy, Japan, Mexico, Portugal, Puerto Rico, South Korea, Spain, Taiwan, Turkey, United Kingdom and United States of America. (CEA-1)

Japan, South Korea, Spain, France, Italy and Taiwan import large volumes of LNG due to their shortage of Energy. In 2005, Japan imported 58.6 million tons of LNG representing some 30% of the LNG trade around the world that year (SPM, 2011). As of 2010, Japan has around 20 existing regasification terminals, 1 approved regasification terminal to be constructed and 2 regasification terminals under construction.

Liquefaction and Regasification Terminals (Source: Geology)

There are two types of LNG terminals:

1) Terminals that convert natural gas into LNG
2) Terminals that convert LNG back into natural gas.

These are called liquefaction terminals and regasification terminals, respectively. Liquefaction terminals are on the export side of transactions and regasification terminals are on the import side of transactions.

Liquefaction terminals generally receive natural gas by pipeline from a well field. Before it is liquefied the gas must be cleaned of water, carbon dioxide, hydrogen sulphide and other impurities that might freeze, become corrosive or interfere with the liquefaction process. Once liquefied the LNG is sent by pipeline to a LNG carrier ship or into storage to await transport.

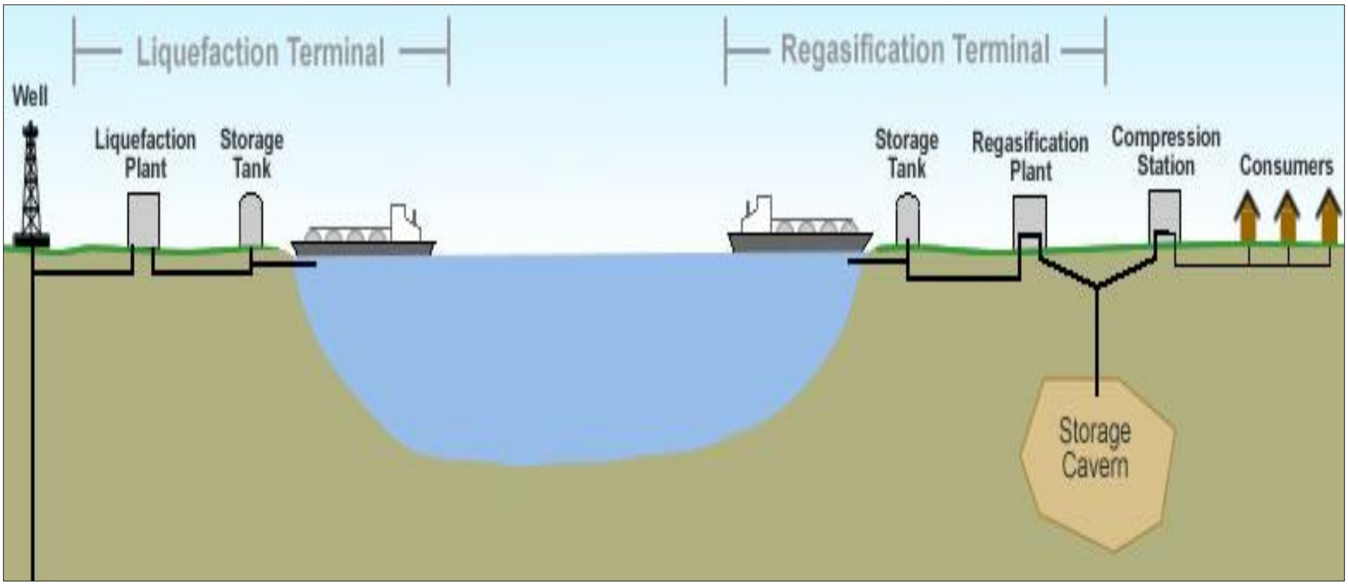

Figure B1: LNG transport chain [Source: Geology]

Regasification terminals receive natural gas - usually by ship - from other areas. At a regasification terminal the LNG might be temporarily stored or sent directly to a regasification plant. Once regasified it is sent by pipeline for distribution or placed in temporary storage until it is needed.

What is environmental impact of LNG? (Source: Geology)

Natural gas has a much lower environmental impact when it is burned than other fossil fuels. It emits less carbon dioxide, less particulate matter and produces less ash. Although LNG is burned in the form of natural gas it has a greater environmental impact than natural gas that has not been liquefied. This is because LNG requires an expenditure of energy to liquefy, transport and regasify.
After these impacts are considered, LNG has a greater environmental impact than natural gas but generally has a lower impact than burning coal or oil. If one considers that the LNG might have been flared at the source as a waste product the environmental impact is lowered.

Factors affecting natural gas prices

Natural gas prices are a function of market supply and demand. It is a very volatile market as major economies switch from one energy resource to other according to fluctuating in prices.

Factors affecting the supply side include:

1) Variations in natural gas production
2) Net imports or storage levels
3) Excess supply means low prices
4) Decrease in supply means high prices.

Factors on the demand side include:

1) Economic growth
2) Weather changes
3) Oil price variation
4) Higher demand means higher prices
5) Lower demand means lower prices.

--End of Report--