"Shale Gas: The future fuel": A Review on its Practicality and Viability

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Abstract:

Crude Oil reserves are estimated to run out in the next few decades. There is an urgent need to look at alternative sources of energy so that mankind does not descent into darkness. One of the most promising solutions to this quandary is 'Shale Gas'. Shale gas is an unconventional source of natural gas that is extracted from the sedimentary rock having the same name. Like conventional Natural Gas it is a mixture of gases that contains a high proportion of methane. It is estimated that the untapped reserves could last many years till a permanent renewable solution is found. Shale gas extraction has been made viable by recent advancements in technology and with further research promises to solve the energy needs of the future. Shale gas is extracted by a process called hydraulic fracture or fracking in which a mixture of water, chemicals and sand at high pressures induce fissures into the rocks enabling the gas to escape easily and thus extract it. Shale Gas has only been used commercially by the US and Canada. It is said to have a huge potential worldwide and especially in countries like India, Indoneasia, China and Poland. Through this paper we try to comprehend the credibility of these claims.

Keywords: Shale Gas; Hydraulic Fracking; Natural Gas; Horizontal Drilling; Alternative Energy.

1. INTRODUCTION:

Without Energy mankind would be catapulted right back into the middle ages. Much of this energy is provided by the fossil fuels: Coal and Petroleum. However due to the requirements of man, coal and petroleum reserves have been diminishing quickly.

Shale gas has seen widespread adoption in the United States since the turn of the 21st century. This methods dependence and viability has thus been tested. The current renewable sources require huge capital investments and are susceptible to seasonal and climate variations making them unviable for industrial use. In contrast, shale gas is independent of climatic and geographic variation and can be used to give continuous dependable supply to give uninterrupted power supply. Shale gas extraction has been made viable by recent advancements in technology and with further research promises to solve the energy needs of the future. There are fears that shale gas extraction may lead to detrimental effects on the environment. The assessment of these claims is an additional objective of this paper.

2. WORLD SCENARIO

With advancing technologies and more liberal energy usage, the consumption of fuels has increased manifold over the last two decades and is expected to go up even further. Almost 80% of the world's power needs are fulfilled through fossil fuels, mainly consisting of oil, coal and natural gas.

As it can be seen from the table, the energy consumption has only been increasing. Even with the tedious attempts to increase fuel efficiency and productivity, the need for fuel has been increasing exponentially. The thirst for better amenities can only be fulfilled by advancements in technologies and that involves more processing. This will in turn consume more fuel. According to International

Energy Agency (IEA) data from 1990 to 2008, the average energy used by one person rose 10% but the world population increased by 27% and overall global consumption rose by 39% (Iea, 2012)

Table.1 World Energy Consumption dynamics based on source (Terawatt-hour) (Tabell, 2011)

Year	**Fossil Fuel**	**Nuclear Energy**	**Renewable Energy**	**Total**
1990	83,374	6,113	13,082	102,569
2000	94,493	7,857	15,337	117,687
2008	117,076	8,283	18,492	143,851
Change (2000-2008)	+23.9%	+5.4%	+20.6%	+22.2%

*1 terawatt-hour (TWh) = 1 billion kilowatt-hours (kWh) = 10^{12} watt-hours

The present energy consumption of the world is largely dependent on fossil fuels like crude oil and natural gas. The other major contributor is coal. The contribution of crude oil is the largest, though it has been steadily decreasing and it is expected to run out in the near future. It may result on an overdependence on coal which itself is destined to run out in the near future. This will drastically change the energy dynamics of the world. Energy security is expected to become a major political standpoint in the future. It has become imperative to find an alternative solution to meet the increasing energy demands. Present substitutes do not have the capacity, reliability or the flexibility to replace fossil fuels, especially for industrial use where requirements are huge and flexibility is desired (Iea, 2012).

3. OTHER ALTERNATIVES:

Present and upcoming alternatives mainly constitute Renewable energy sources and Nuclear energy. The contribution of these energies is about 10% of the total energy consumption (WEC, 2013).

3.1. RENEWABLE ENERGY:

Renewable energies include source which can be replenished by their natural cycles in short periods of time for man to put to use. These include geothermal, solar, wind, tidal and hydro energy.

For all its advantages, hydroelectricity has many pitfalls. Damming rivers may destroy or disrupt wildlife and other natural resources. At the same time hydroelectricity needs a specific set of geographical conditions; a minimum water flow, minimum velocity, a minimum depth etc. Wind energy involves high capital expenditure and high geographical dependence; hence use of wind energy is impractical in most cases. Biofuels have good flexibility in application, but the calorific value of biofuel is too less for practical applications.

Geothermal energy is said to be sustainable, but has historically been limited to areas near tectonic plate boundaries. Drilling and exploration for deep resources is very expensive. (International Geothermal Association) IGA projects growth to 18,500 MW by 2015. The present generation of geothermal power is negligible in the world context and there is inadequate growth in the same. The practicality of it purely speculative and has no concise base. Technically solar power is abundant and easily available, but exploitation of this resource has been very limited. Attempts to generate electricity on a small scale from it have been partially successful. Due to high climate and seasonal dependence, high capital expenditure and very high loss during storage it has not been exploited.

The problems plaguing all these renewable sources are high seasonal, climate and geographical dependence. Need for electricity storage, which is impractical on a large scale and involve huge transmission losses.

3.2. NUCLEAR ENERGY

The main problem associated with nuclear power is the handling and disposal of spent radioactive material. Since the activity of radioactive material never seizes completely it poses a great difficult for its handling and storage .Moreover, reactor design imperfections, earthquakes, human error can cause the reaction to go out of control and result in a monumental disaster as seen in Chernobyl(1979) and Fukushima(2011). Also the risk to people in direct contact with its operations is not ascertained. The transportation of radioactive materials has also been made difficult due to political insecurities.

4. ENERGY OF THE FUTURE

As it has been mentioned, the world's energy requirement is only increasing. An all-encompassing solution which can address the energy concerns of the globe is the need of the hour. Such a solution has to be flexible in use, should not have storage and transportation issue and should be independent of factors like climate, season and geography. It should ideally have a minimum effect on the environment. It should also have enough resources to last a significant time span.

Energy security is the basis for industrial development and the augmentation of human life. Energy is essential to attain any defined aim in any sector that man wishes to excel in any field. Hence, energy security is imperative and for that we are in the need of a resource which will satiate the growing energy needs of the world and be reliable. Its availability should not be hostage to political and environmental constraints. Hence its extractable reserves and amount should be predefined to attain energy security. The known reserves of fossil fuels are depleting. In this situation, the world needs a reliable alternative to quench its power requirements.

5. WHY SHALE?

With the recent advents in technologies, natural gas sources which were previously unrecoverable can be recovered using hydraulic fracking. These sources are called Unconventional Natural Gas (UNC) consisting of Shale gas, tight gas and coalbed methane. Conventional gas is the natural gas that is extracted by conventional drilling techniques. According to the International Energy Agency (IEA), the volume of shale gas, tight gas and coalbed methane resources estimated at 380,000 billion cubic meters (Gm3), equivalent to about 50% of global gas resources. Shale gas accounts for the biggest share of these resources. The unconventional gas has extremely high potentiality which should extend lastingly the petroleum industry's capacity to meet global demand especially the foreseeable growth in natural gas's share in electric power generation. Shales or the rocks which are sources of the unconventional resource are present considerably on every continent which broadens their outlook in exploration. Shale gas has come up as a promising alternative to solve the energy requirements. Reserves are estimated to represent between 120 and 150 years' worth of natural gas supply at the current rate of consumption (Iea, 2012).

As of 2013 only US, Canada, and China were found to produce commercial quantities of shale gas and of them only US and China had significant production of shale gas.

No	Country	Estimated technically recoverable shale gas (trillion $feet^3$)	Proven natural gas reserves of all types (trillion $feet^3$)
1	China	1,115	124
2	Argentina	802	12
3	Algeria	707	159
4	United States	665	318
11	Indonesia	580	150
5	Canada	573	68
6	Mexico	545	17
7	South Africa	485	-
8	Australia	437	43
9	Russia	285	1,688
10	Brazil	245	14

Table.2 Shale gas reserves in comparison with conventional Natural Gas (Administration, 2013).

As it can be seen the shale gas estimations are promising and are large enough to take the burden of the world's energy requirement. It is important to note that India is expected to have high Shale gas reserves in the North Indian plains, no official estimates are available. However, shale gas exploration has been started by Oil and Natural Gas Corporation (ONGC) in Gujurat in 2014 ("Shale gas," 2012). Shale gas emerged as an important natural gas source in the United States from the augment of this century, and interest has dispersed to crucial gas sales in the other parts of the world. In 2000 shale gas could produce only 1% of U.S. natural gas; by 2010 it provided more than 20% and the U.S. government's Energy Information Administration (EIA) foresees that by 2035, 46% of the natural gas supply in United States' would comprise of shale gas. As it can be seen, shale gas has been tested and practically proven. Its commercial viability has been tested and it has already been integrated in USA and Canada. Its reliability is proven. Its transportation and storage is similar to that of conventional natural gas. It is not largely affected by climate or seasonal changes. It is a viable, tested and proven resource which has great promise to gift energy security to the globe.

While being still developing, it is a pragmatic solution to our energy needs and hence truly an "Energy for the Future".

6. EXTRACTION:

Hydraulic fracturing is a key technique that has enabled the economic production of natural gas from shale deposits. Shale is a sedimentary rock with low permeability which limits the flow of the gas which is entrapped within pores and fractures. Hydraulic fracturing is the method commonly used to connect these pores and allow the gas to flow. The process of producing natural gas from shale deposits involves many steps in addition to hydraulic fracturing, all of which involve potential environmental impacts. The term is often incorrectly used to describe all the steps involved in the extraction of Shale Gas. These steps include road and well pad construction, drilling the well, casing, perforating, hydraulic fracturing, completion, production, abandonment, and reclamation (Clark, Burnham, Harto, & Horner, 2013).

6.1. ROAD AND WELL PAD CONSTRUCTION

A well requires a prepared area on the surface, called a pad, that provides a stable base for a drilling rig, retention ponds, water storage tanks, loading areas for water trucks, associated piping, and pumping and control trucks. The size of the pad depends on the depth of the well and the number of wells to be drilled on the site. More land is required to construct a road that will service the pad (Clark et al., 2013).

6.2. DRILLING

Most shale gas resources are located at depths of 6,000 feet or more below ground level, and can be relatively thin. The efficient extraction of gas from such a thin layer of rock requires drilling horizontally through the shale. This is accomplished by drilling vertically downward until the drill bit reaches a distance of around 900 feet from the shale formation. At this point, a directional drill is used to create a gradual 90-degree curve, so that the wellbore becomes horizontal as it reaches optimal depth within the shale. The wellbore then follows the shale formation horizontally for 5,000 feet or more. Multiple horizontal wells accessing different parts of the shale formation can be drilled from a single pad. Thus, horizontal drilling reduces the footprint of these operations by enabling a large area of shale to be accessed from a single pad (Clark et al., 2013)

6.3. CASING AND PERFORATING

At various stages in the drilling process, drilling is stopped and steel casing pipe is installed in the wellbore. Cement is pumped into the annulus, or void space between the casing and the surrounding mineral formation. After the wellbore reaches a depth below the deepest freshwater aquifer which is a subsurface zone that provides economically crucial amounts of water to wells. Aquifer resembles closely with water-bearing formation. An aquifer may be porous rock, fractured rock, unconsolidated gravel or cavernous limestone (Clark et al., 2013). Extra Casing and cement are installed to protect the water from contamination due to the drilling process. Additional casing and cementing along the entire wellbore occurs after the well has reached its full horizontal length. This process is intended to prevent leakage of natural gas from the well to the rock layers between the shale formation and the surface, as well as to prevent the escape of natural gas to the surface through the annulus. The casing surrounding the horizontal section of the well through the shale formation is then perforated using small explosives to enable the flow of hydraulic fracturing fluids out of the well into the shale and the eventual flow of natural gas out of the shale into the well (Clark et al., 2013).

6.4. HYDRAULIC FRACTURING AND COMPLETION

The process depends on the geology of the respective region. In order to avoid the exposure of shale to water, the fracture can be preferably made with a non-aqueous fluid like gelled propane/butane, nitrogen, or liquid carbon dioxide depending on the reservoir (Jackson, Pearson, Osborn, Warner, & Vengosh, 2011). A horizontal well section can vary from 1.0 to 3.0 kilometres depending on local geological conditions. To maintain a high rate of injection for fracturing the shale which surrounds the entire horizontal well length efficiently through many ports in a single operation is difficult, so the fracturing is carried out in stages, usually starting from farthest of the head of the well and traversing toward the heel of the well, by means of one of different methods.

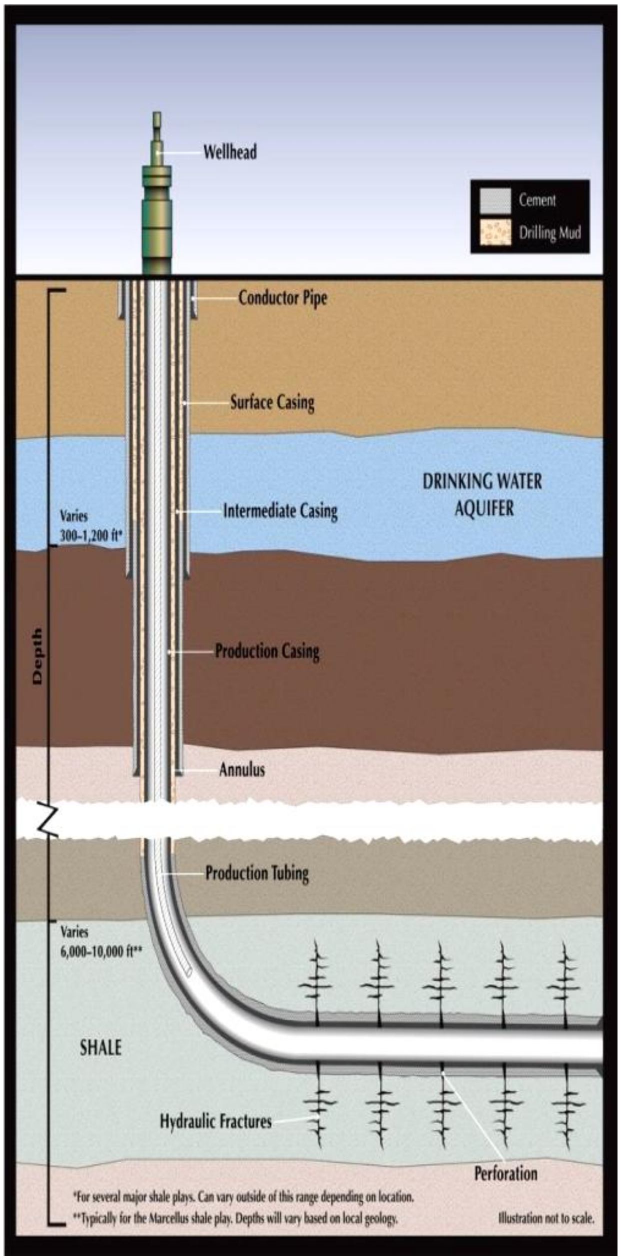

Fig.1 Horizontal Drilling (Clark et al., 2013).

One of the methods involve perforating a limited length of the well casing at regular intervals which executes a fracture in a small section of the well termed as a stage furthermore installing a drillable packer which isolates the fractured section and perforating another interval which is closer to the heel, and the process gets repeated. The distance between fracture stages is influenced by local conditions or the operator's priorities. It is normally in the range of 100-300 metres and along the length having 15 to 30 stages. The injection time may vary between 20 minutes to more than 4 hours for each fracture stages. The specifications of the fracturing treatment and the changes taking place during the operations will vary with the formation and the operator. In order to "prop open" the fracture propping agents or proppants are required when the fracture begins to collapse on shutting down of the pumps. The novel propping agent must be resistant to corrosion, strong, resistant to crushing, have a low density, and must be readily available at low cost. The products like silica (sand), ceramic and resin-coated sand (RCS) proppants fulfil the above mentioned properties (Holditch, Jennings, Neuse, & Wyaman, 1978).

Proppants and chemical substances are added to the fracturing fluid during different stages of the fracturing process. The viscosity of the fracturing fluid is reduced because of addition of additives in fracturing fluid which allows easy penetration of the existing natural fractures in the formation. Initially the fracturing fluid takes away only clay stabilizers, friction reducers, or other additives to enhance its flow. After the fractures in the shale are made, granular materials are added to prop open the fractures. Gelling agents like xanthate or guar gum are incorporated at this stage to enhance the viscosity of the fluid which would enable them to carry the proppants into the fractures. The role of breakers in the gelling agents is to get activated after the embedding of proppants in the fractures perpetuating the gel to liquefy thereby promoting back flow and recovery of the fracturing fluid which remains at the surface, and henceforth allowing oil or gas to flow through the natural and induced fractures. The before mentioned proppants resemble 6 to 9 per cent of the total volume injected with the chemical additives which represent 0.5 to 2 per cent (Gottardo, Amenta, Mech, & Sokull-Klüttgen, 2013).

These chemicals typically include acids to "clean" the shale to improve gas flow, biocides (e.g.- Bromine, Naphthalene and methanol) to prevent organisms from growing and clogging the shale fractures, corrosion and scale inhibitors to protect the integrity of the well, gels or gums that add viscosity to the fluid and suspend the proppant, and friction reducers that enhance flow and improve the ability of the fluid to infiltrate and carry the proppant into small fractures in the shale.

To improve the efficacy of the gas extraction processes all injection parameters (e.g., rate, pressure, compositions, temperature, and density) were monitored continuously — particularly in the first wells. Slickwater, water with a viscosity reducing agent such as polyacrylamide are commonly used as the fracturing fluids. The fracturing fluids travel into the rock fractures with lower pressure losses, and gelled (viscosified) water, thereby carrying proppant into the rock. Recently slickwater treatments were carried out where low viscosity fluids were pumped at high rates and narrow, complex fractures were generated with propping agent having low concentrations (0.2-5 lbm proppant added (PPA) per gallon).Rates of pumping must be high so as to prevent premature screenout (SO), to enable efficient transport of proppant over long distances before entering the fracture. To get conventional wide-biwing fractures, it was seen that carrier fluid must be adequately viscous such that transportation of higher proppant concentrations (1-10 PPA per gallon) is enabled. Often these treatments are pumped at low pump rates which might lead to wider fractures (normally 0.2 to 1.0 inch).

An alternative to water-based fracturing fluids, *Energized fluids*, includes carbon dioxide and nitrogen gases, foams, propane or butane-based liquefied petroleum. Hydraulic fracturing based on gas leads to decreased recovery time and thereby formation damages are reduced but it is not cost effective. Propane being flammable makes the treatment slightly more dangerous. The amount of water being utilized for most fracturing operations can lead to considerable quantity usage of chemicals.

After the completion of a hydraulic fracturing stage, the injected fluids are flowed back till the commencement of next fracturing stage. Flowback of fracturing fluids takes place slowly and at a decreasing rate as the well is producing. The natural gas that is accompanied by flowback fluid can be collected, vented, or flared from the first few wells, before actual production commences.

On the completion of a single fracture stage, the necessary modifications are carried out before moving on to next stage, and this fracturing process is repeated until the well is finished. Flowback fluid is a fusion of the returning hydraulic fracturing fluid and water from the formation. According to a general rule, 30 to 40 per cent of injected fluids can be recovered from hydraulic fracturing. The well pads are used to store the flowback water that is removed at each stage, which is treated and reused in the next stage (Mair et al., 2012).

6.5. PRODUCTION, ABANDONMENT, AND RECLAMATION

The gas recovered from the well during production is sent to small-diameter gathering pipelines that connect to larger pipelines which collects gas from a network of production wells. As the large-scale shale gas production has started very recently, the lifetime of the shale gas production wells is not well settled. As compared to conventional natural gas production, the production of shale gas declines faster. In the Fayetteville play in north-central Arkansas, it has been determined that half of a well's lifetime production, occurs within its first five years. When the well stops producing at an economic rate, the wellhead is removed and the wellbore is filled with cement so as to ensure that there is no leakage of gas into the air and the surface is reclaimed. The site is abdicated to the holder of the land's surface rights (Council of Canadian Academies, 2014).

7. ENVIRONMENTAL CONCERNS

While Shale Gas has shown great promise, the drilling methods consume large amounts of chemicals and are feared to have adverse environmental effects. Apart from the aspect of pollution, there are concerns about the possibility of the drilling triggering earthquakes or tsunamis. Though no such link has been established, there is no denying the necessity to be extremely careful while dealing with Hydraulic Fracking.

7.1. ENORMOUS USE OF WATER FOR HYDRAULIC FRACTURING

There are two important issues that are involved with fracking , first issue is the use of a huge quantity of fresh water that becomes contaminated which cannot be reused by plants, animals or human for any purpose unless treated while other issue is the necessity to protect surface water and underground water tables from getting contaminated by migrating gas flows and/or fracking fluids. In some water-scarce areas it could lead to potential water shortage.

Water is also needed for the drilling operation itself, before any hydraulic fracturing can take place; this is typically less than 10 per cent of the total requirement. The amount of water depends on the types of drilling fluids used and the depth and horizontal extent of the wells. It is claimed by the industry that many gas wells have an efficient useful production life of 20-40 years, and they must be re-fractured after every 3-5 years to maintain an economically viable production flow which indicates that the total volume of fresh water usage during the lifetime of a well is several times the volume required for one fracking operation. Thus the total water requirement for a well during its entire lifetime can be anywhere between 24,000 m3 and 500,000 m3. Water availability is the biggest obstacle to extracting Shale Gas (Rahman & Rahman, 2010), (Amoco, 1986).

7.2. GROUNDWATER CONCERN

Low permeability natural gas resources are in geological formations located at depths of 450-4,500 m below the surface, with natural gas wells averaging 2,000 m. Water aquifers typically lie about 30-100 m below the ground surface. Fracking wells pass through the aquifers and this is a major concern. There is stringent need to protect the aquifers from the well and thus there needs to be a good casing. Several different pathways for migration have been proposed but the risks vary. One potential pathway is through the casing/wellbore ring like structure when there is poorly cemented casing around the wellbore as it passes through and beneath potable water aquifers. In this situation, the drilling of new shale wells could connect deeper natural gas bearing formations with shallower aquifers, and in the presence of sufficient pressure differential, cause natural gas to reach the water zone.

Another pathway could be through poorly cemented wellbores from long-abandoned “orphan” wells. Higher pressure gas from deeper formations could potentially find a path behind poorly cemented casing to a shallower, lower pressure zone of past production, which in turn communicates with an even shallower aquifer via the abandoned wellbore. Flowback (returned) water, in addition to fracking chemicals, can also contain brine, heavy metals and radioactive contaminants in addition to the methane that is released. It is with the often expensive handling of this flowback that many people are concerned. It is a point in the fracking cycle where extraction companies may be tempted to take shortcuts to reduce costs.

If properly treated, returned water can be reused in other fracking operations. The leakage potential is also a serious concern because water supplies can be contaminated by exposure to methane which is a powerful climate change gas, many times more potent at trapping heat than carbon dioxide.

Another major concern, possibly associated with the disposal of fracking wastewater in deep injection wells, a common practice, is the possibility of triggering small earthquakes (Issue, n.d.).

7.3. AIR QUALITY

Any oil and gas drilling operation impacts air quality. The emissions include primarily ozone precursors like NO_x and non-methane volatile organic compounds (VOC), and particulates.

Air quality is also influenced by methane emissions during the well completion process when wells are flowed back or tested. This can include emissions from flares used to burn off excess natural gas. Still another source of air pollution is non-combustion particulates, both from gravel roads constructed for drill pad access as well as from silica dust from proppant handling during hydraulic fracturing. The silica sand can lodge in lungs and cause silicosis (Howarth, Santoro, & Ingraffea, 2012).

Equipment used during the gas and liquids production process can also create harmful emissions, including inadvertent methane releases from valves, compressor blowdown, and VOCs such as BTEX (Benzene, Toluene, Ethylbenzene and Xylenes) that escape from condensate or oil tanks (Issue, n.d.).

7.4. GREENHOUSE GAS EMISSIONS AND CLIMATE CHANGE

Natural gas has less than half the carbon footprint of coal and emits only about two-thirds as much CO_2 as oil when combusted. Therefore it has been seen as a more favourable energy source. The truth of the matter is, however, that it still remains a fossil fuel and releases CO_2 when burned.

Extraction of gas from shale formations may eventually also produce significantly more methane than conventional wells and could have a larger carbon footprint than other fossil fuel development due to uncontrolled leakage (Klemow, Ph.D. & Fetcher, Ph.D., 2011).

It should be noted that Hydraulic fracking and horizontal drilling are new technologies which have recently been implemented. So, technological advancement and optimization of resources is to be expected with further research and advents in technologies. The major disadvantages related to shale gas extraction are related to technological constraints. With further research these restrictions can be overcome to give a safer and environment friendly energy source (Issue, n.d.).

8. HEALTH AND SOCIAL ISSUES

There has long been speculation that fracking can pose risks to human health and the environment when additives included in the fracking fluid leak into the surrounding environment. Reports are emerging from locations close to fracking sites of people being affected and falling ill from contaminated water or air contact with fracking chemicals.

However there are an increasing number of scientific studies that provide systematic evidence which supports suspicions of the possible health dangers of fracking. The US House of Representatives Committee on Energy and Commerce released a list of fracking chemicals in 2011, many of which are considered toxins, including xylene, naphthalene, methanol, formaldehyde, ethylene glycol, hydrochloric acid, sodium hydroxide, benzene, ethyl benzene, toluene and many others. Some of the chemicals named in the report have also been identified as endocrine disruptors (affecting the endocrine system), able to block hormones and disrupting bodily functions. Recent work by the University of Missouri involving testing known fracking chemicals identified as endocrine disruptors, as well as collecting ground and surface water samples from known fracking sites, yielded many telling results. Among twelve tested chemicals the researchers found that an overwhelming majority were in fact hormone-disrupting and higher than average endocrine disrupting activities could be detected in water samples collected from drilling sites compared to low activities in samples taken from sites not associated with fracking activities (Issue, n.d.).

9. INDIAN PERSPECTIVE

India's growing demand for energy can be fulfilled by unlocking domestic shale gas reserves thereby decreasing its dependence on expensive energy imports. Moreover, it can prove a boon to our economy. This emerging industry thus has to be promoted by economic benefits balanced with social issue and environmental issue.

9.1. ADVANTAGES OF SHALE GAS

The growing energy demand of India can be met by unlocking of domestic shale gas, thereby reducing its dependence on the energy import bill and expensive energy imports. It can be seen from the US's impact of shale gas development that developing this sector can enhance government revenues and employment opportunities which will increase economic activity in the country. The prices of shale gas are not economically feasible for power and fertilizers industries as there the prices of end products are regulated and price hikes are not viable to pass on to customers. But it can be efficiently used as an alternative to expensive liquid fuels in sectors such as transportation, refineries and steel.

9.2. SHALE GAS PROSPECTS OF INDIA

It is estimated that India has 63 trillion cubic feet (tcf) of recoverable shale gas reserves, however a downward change has been observed recently in the estimates. Like US, it is possible that India's shale gas reserve potential could be boosted with further exploratory drilling. The Krishna Godavari, Cauvery, Cambay and the Damodar valley are the most important sedimentary basins to carry out shale gas activities in the country. The Krishna Godavari basin which is located in eastern India holds the largest shale gas reserves in the country. It is extended over 7,800 square miles in gross area, with a potential area of around 4,340 square miles. The basin has a series of organically rich shales, containing around 27 tcf of technically recoverable gas. The Cambay basin located in Gujarat is the largest basin in the country which spread across 20,000 gross square miles, with a potential area of 1,940 square miles. Around 20 tcf of gas has been classified as technically recoverable reserves in the basin ("Shale gas," 2012).

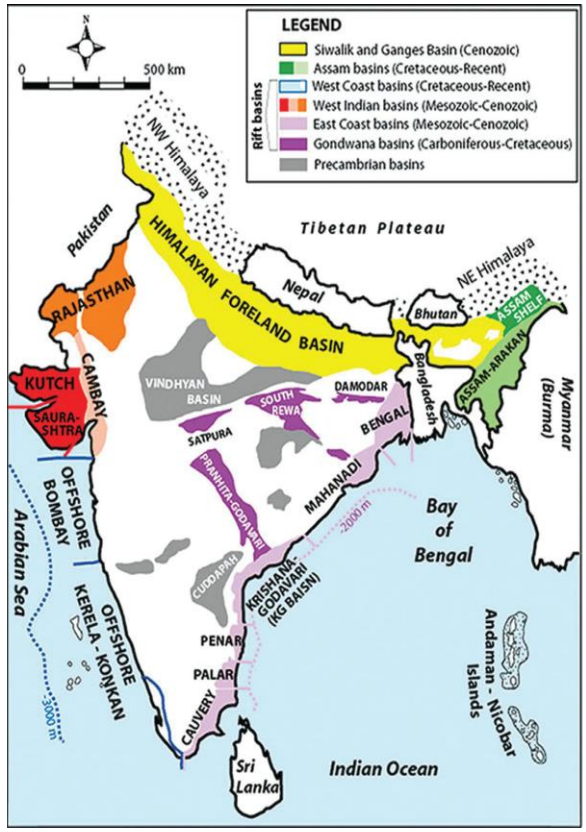

Fig.2. Estimated Shale reserves in India (Deloitte, 2010)

9.3. LATEST DEVELOPMENTS

The Government of India, along with Indian companies, is undertaking various initiatives to accelerate the development of shale gas reserves in the country. As a part of this initiative, the government has set up a Multi-Organizational Team (MOT) comprising the Directorate General of Hydrocarbons (DGH), Oil and Natural Gas Corporation (ONGC), Oil India Limited (OIL), and GAIL (India) Limited for analyzing the existing data set and suggesting a methodology for shale gas development in the country. ONGC and OIL are aggressively implementing pilot projects which can assess the shale gas potential in the country. In addition, Reliance Industries Limited (RIL) and GAIL have entered the US shale industry to gain technical expertise and may apply that expertise in developing shale gas reserves in India.

In January 2011, first pilot shale gas drilling venture was discovered by ONGC in the Damodar basin. Further, the company plans to explore shale gas potential in other promising basins in the country ("Shale gas," 2012).

10. SCOPE AND CONCLUSION:

Shale gas is a new and promising technique. It has been already commercialized in the United States and Canada. A working model is already present, hence its practicality and commercial viability have already been tested. Having said that, it is still a developing technique and further insights are necessary to optimize this process. The use of various chemicals and water has to be moderated. The various environmental concerns expressed need to be addressed and further refining in technology is required to address these concerns. The horizontal drilling component is extremely delicate and utmost care should be taken to ensure no environmental damage takes place. However, all these constraints are technological and with improvement can be overcome.

With the promise that this technology has shown and its proven viability, it is imperative that further research be carried out to develop a more refined, green and effective process.

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