A STUDY ON NATURAL GAS AS AN ALTERNATE FUEL FOR ELECTRICITY GENERATION IN INDIA

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Abstract*—India's population is expected to surpass China as the world's largest by 2022, reaching approximately 1.4 billion people, creating greater demand for energy. India has the potential to be a much larger producer and consumer of natural gas. Competing political and economic factors have limited the government's effectiveness in changing the country's energy mix, which is heavily weighted toward natural gas, coal and oil.In India installed capacity for power generation is 199.87 Gigawatt (GW) as of March 2012; the world's fifth largest, of which approximately 30,000 MW running idle due to shortage of fuel supply. The International Energy Agency estimates that estimates India will add between 600 GW to 1200 GW of additional new power generation capacity before 2050. Due to acute shortfall in domestic coal production to meet demand and higher exchange rate is severely affecting power sector in India. Exploration of huge shale gas reserve of USA and China and natural gas have changed prospective of fuel supply. Indian coal is of high ash content and low sulfur content. Its contribution to power sector is around 56.4% and natural gas contribution to power sector is around 9.2% of total power generation. Our objective is the scope of natural gas as an alternate fuel for electricity in India. Due to higher prices of coal and petroleum, substitutively fuel demand can be met by natural gas. Natural gas demand is continuously increasing and furcating is done at different scenarios of growth rate. There are three options for natural gas- domestic natural gas, piped natural gas and imported liquefied natural gas. Domestic gas production in India is continuously falling down is not viable option. Presently we have a country wide network of 12,000 km of gas pipeline and having capacity to transport 230 mmscmd of gas. Study of natural gas pricing method in India and factors affecting natural gas pricing and scope of new pricing method pool pricing in India and Shale Gas. Demand from different sectors i.e. fertilizer, city gas sector and power sector. And scope of shale gas exploration and production.

***IndexTerms*—Natural gas, Gas pipe lines, LNG, Regasification Capacity, Pool Pricing Mechanism, Shale Gas.**

I. INTRODUCTION

Energy can be defined in a number of ways. In the broad sense, energy means the capacity of something – a person, an animal, or a physical system (machine) – to do work and produce change. It can be used to describe someone doing energetic things such as running, talking, and acting in a lively and vigorous way. It is used in science to do describe the part of the market where energy itself is harnessed and sold to consumers.

Today, energy is the primary input for almost all economic activities and has become vital for improvement in the quality of life. Infact, the whole infrastructure rests upon energy. The energy consumption of a nation now-a-days is usually considered as an index of its development. About 24 percent of energy consumed globally, is used for transportation, 40 percent for industries, 30 percent for domestic and commercial purposes and the rest 6 percent for other uses including agriculture.

India is the 3rd largest consumer of energy in the world. Globally, natural gas contributes approximately 24% to the primary energy mix.1 However, in India; natural gas has a nominal share of 6.5% market share. As a part of its "Intended Nationally Determined Contributions" (INDC), India has committed to reducing its carbon emissions intensity to GDP by 33%–35% by 2030 from 2005 level.2 to meet this commitment while at the same time supporting its economic growth trajectory, India needs to add cleaner sources of energy to its fuel mix.

With a burgeoning population, we have to recognize that resources are scarce and plan accordingly. End use efficiency, reduction of wastage and accountability has great potential for improvement. Investment in coal base electricity needs critical appraisal because of availability, land requirement, pollution, green house gas emission and ash disposal and increasing cost of environment needs critical appraisal. Natural gas based electricity generator are generally not approved because of lack of domestic availability of natural gas besides domestic gas sector has received a thrust with shale gas and Hydraulic fracking technology in US. A relook into fuel import i. e. import of coal vis a vis import of natural gas is a national imperative in view of the need for electricity keeping in view all other collateral concerns. Diesel generator can be replaced by natural gas plant- In India electricity generated by DG set- 1200 MW at cost of Rs. 12/kwh and grid power at cost of Rs 3/kwh. This market will grow at the rate of 20% for coming years. Natural gas can be used for distributed power generation-Due to heavy distribution and transmission losses (around 30%) distributed generation by natural gas is better option as it can be produced at cost of Rs. 6 to 7 per kwh.

The main aim of this paper to find out viable option for fuel supply to set new power plant on India. Study of power sector in India and all available fuel supply option for electricity generation in India to find out scope of natural gas as an alternate fuel for electricity generation. Electricity demand projection in India at different growth rate scenarios. Natural gas supply option as domestic natural gas reserve and natural gas import. Study of piped natural gas and LNG import. To find out viable natural gas supply option while keeping in mind price, gas reserve, infrastructure requirement and time period required to be operational. Natural gas as a fuel for distributed power generation to reduce transmission losses and replacement of DG sets by natural gas based turbines. Natural gas price mechanism in India and in different regional gas market and impact of globalization of gas market.

II. NATURAL GAS IN INDIA

Current Natural Gas Scenario in India

India is the world's seventh largest energy producer, accounting for 2.49% of the worlds total annual energy production. It is the fifth largest energy consumer, accounting for about

3.45 % of total energy consumption in 2004, which has been increasing by an average of 4.8 % percent a year since 1990. The share of commercial energy in total primary energy consumption increased from 59.7 % in 1980-81 to 79.3 % in 2008-09. India's GDP has grown at more than 8-8.5 % during the last few years, and is expected to grow minimum at the rate of 7.5-9 % in the coming few years. The growth has taken place despite the huge deficit in energy infrastructure and infrastructure. Even today, half of the country's population does not have access to electricity or any other form of commercial energy, and still use non- commercial fuels such as firewood, crop residues end during cakes as a primary source of energy for cooking in over two-thirds of households.

Table 1: Major gas projects in India

Project	State	Commissioned Capacity (MW)
RGPPL, Anjanvel	Maharashtra	1480
Dadri	Uttar Pradesh	817
Paguthan	Gujarat	654.73
Auraiya	Uttar Pradesh	652
Jhanor-Gandhar	Gujarat	648
Kawas	Gujarat	645
Faridabad	Haryana	430
Anta	Rajasthan	413
Vemagiri Power Generation Ltd.	Andhra Pradesh	388.5
Rajiv Gandhi CCPP Kayamkulam	Kerala	350

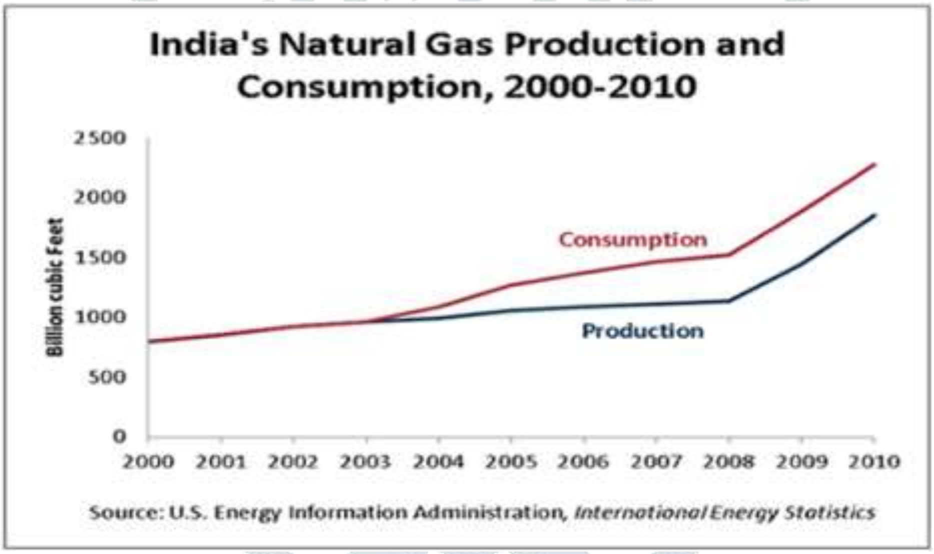

Figure 1: India's natural gas production and consumption

Demand and Forecasts for India

The demand of natural gas has sharply increased in the last two decades at the global level. In India natural gas was first discovered off the west coast in 1970s, and today, it constitutes 10 % of India's total energy consumption. Over the last decade it has gained importance as a source of energy and its share is slated to increase to about 25 % of the total energy basket by 2025-2030. In its Reference Scenario, the IEA expects Indian gas demand to increase to 94 billion cubic meters by 2020 and to 132 billion cubic meters by 2030, driven by the industrial and power generation sectors. This means anannual increase of 5.4 % – one of the highest in the world. In the 450 Scenario, demand by 2020 would be slightly lower (89 billion cubic meters), but by 2030 would almost remain at the same level as in the Reference Scenario –

132 billion cubic meters– as gas would be needed to displace coal. The latest available Indian demand forecasts for the 11th Five-year plan (2007-12) show gas demand increasing by between 37 % and 58 % over that period and the power sector being the main driver for incremental gas demand (see Table below).

Table2: Natural Gas Demand Projection

Sector	2007/08	2008/09	2009/10	2010/11	2011/12	
	I	I	I	I	I	II
Power	29.2	33.2	37.6	41.6	46.4	32.5
Fertiliser	15.0	15.7	19.0	28.8	28.8	28.8
City Gas/Industrial	9.9	10.6	11.3	12.4	13.1	13.1
Sponge Iron	2.2	2.2	2.6	2.6	2.9	2.9
Other (Petrochem/ Refinery/Internal Consumption)	9.1	9.9	10.6	11.3	12.0	12.0
Total (Mcm/d)	179	196	222	265	283	245
Total (bcm)	65	72	81	97	103	89

III. Available option for Natural gas supply In India

Until recently, the exploration and production of natural gas in India was undertaken exclusively by the state owned Oil and Natural Gas Corporation Ltd (ONGC) and Oil India Ltd (OIL). As a result of government initiatives to encourage private sector investment in exploration and production activities and to deregulate the oil and gas sector, several private sector participants are also now engaged in exploration and production (figure 17; PETROTECH Society and PwC 2007; GAIL 2007).

Under the New Exploration Licensing Policy (NELP), operating since 1999, foreign and domestic private sector companies acquire exploration blocks and undertake exploration activities either as joint venture consortiums with state owned companies or independently.

Reliance Industries Ltd (RIL) is the largest oil and gas acreage holder among the private sector companies in the country. It is also India’s first private sector company in the exploration and production sector to have discovered large natural gas reserves in the eastern offshore Krishna–Godavari basin in late 2002. Other private sector participants in exploration and production activities include BG India, Nikko Resources and Cairn Energy.

Domestic Natural Gas in India

According to Oil and Gas Journal, India had approximately 38 trillion cubic feet (Tcf) of proven natural gas reserves as of January 2011. EIA estimates that India produced approximately 1.8 Tcf of natural gas in 2010, a 63 percent increase over 2008 production levels. The bulk of India's natural gas production comes from the western offshore regions, especially the Mumbai High complex, though fields in the Krishna-Godavari (KG) are increasingly important.

In 2010, India consumed roughly 2.3 Tcf of natural gas, more than 750 billion cubic feet (Bcf) more than in 2008, according to EIA estimates. Natural gas demand is expected to grow considerably, largely driven by demand in the power sector. The power and fertilizer sectors account for nearly three-quarters of natural gas consumption in India. Natural gas is expected to be an increasingly important component of energy consumption as the country pursues energy resource diversification and overall energy security. Despite the steady increase in India's natural gas production, demand has outstripped supply and the country has been a net importer of natural gas since 2004. India's net imports reached an estimated 429 billion cubic feet (Bcf) in 2010.

As in the oil sector, India’s state-owned companies account for the bulk of natural gas production. ONGC and Oil India Ltd. (OIL) are the leading companies with respect to production volume, while some foreign companies take part in upstream developments in joint-ventures and production sharing contracts. Reliance Industries, a privately-owned Indian company, will also have a bigger role in the natural gas sector as a result of a large natural gas find in 2002 in the Krishna Godavari basin.

The Gas Authority of India Ltd. (GAIL) holds an effective control on natural gas transmission and allocation activities. In December 2006, the Minister of Petroleum and Natural Gas issued a new policy that allows foreign investors, private domestic companies, and national oil companies to hold up to 100% equity stakes in pipeline projects. While GAIL’s domination in natural gas transmission and allocation is not ensured by statute, it will continue to be the leading player in the sector because of its existing natural gas infrastructure.

Domestic Gas pipe lines network in India

Presently we have a country wide network of 12,000 km of gas pipeline and having capacity to transport 230 mmscmd of gas.

The UPA government under the Union Minister of Petroleum and Natural Gas Minister, Shri S. Jaipal Reddy has dedicated a 2200km long natural gas pipeline to the nation. The gas pipeline inaugurated on 23 March 2012 is built at a massive budget of 13100 crores wherein 505 crore were paid to the landowners whose lands were acquired by GAIL (Gas authority of India Limited) for the purpose. The new pipeline is capable of carrying 66 MMSCMD of natural gas and generating power up to 3500 MW. It will also help to provide the CNG/PNG/ natural gas in the areas from where it will pass. The construction of the pipeline was completed in 45 months and it crosses 25 national highways, 56 state highways, 35 railway crossings, 399 water bodies and 53 other pipelines while passing through the states of Gujarat, Madhya Pradesh, Uttar Pradesh, Rajasthan, Delhi, Haryana, Punjab and Uttrakhand.

Trance-national gas pipe lines

A. Tapi- pipeline: The 1,680-kilometre Turkmenistan-Afghanistan-Pakistan-India (Tapi) pipeline, Ashgabat’s dream project that first appeared in 1995, has been on hold for many years due to the Taliban insurgency in Afghanistan. The presidents of Turkmenistan, Pakistan, and Afghanistan met for the first time to discuss the project, while India was represented by the country’s Energy Minister MurliDeora. They signed an intergovernmental agreement on the Tapi pipeline, with energy ministers signing a separate framework document on the project, but no deal was reached on future sales or the consortium for the future construction tender. Gas Authority of India (GAIL) the state-owned company has signed this natural gas sale and purchase agreement with TurkmenGaz for Turkmen gas shipped via the Turkmenistan-Afghanistan-Pakistan-India (TAPI) pipeline. Turkmenistan would be exporting 90 MSCMD through this pipeline of which 14 MSCMD would be taken by Afghanistan and 38 MSCMD each by India and Pakistan. The pipeline will be built at an estimated investment of $ 7.6 billion approximately. Afghanistan’s President Hamid Karzai called it “a highly important project” and assured that he would “put in efforts to ensure security both during construction and after completing the project". Security of the pipeline inside Afghanistan has been questioned as the route would go through a number of turbulent regions, including the Helmand and Kandahar provinces which have become epicenters of violence. The pipeline would also go through Quetta and end in Fazilka, an Indian city near the India-Pakistan border. "We are witnessing a historic project," said Haruhiko Kuroda, president of the Asian Development Bank which will fund the project. "It is not easy to make it happen. Efforts must be made to ensure its security and the ADB is ready to help realize it." Turkmenistan, which is believed to hold the world's fourth largest reserves of natural gas, has been working to diversify away from its reliance on Soviet pipelines and has had rows with Moscow over the projected trans-Caspian pipeline to Europe, Nabucco. Ashgabat has also opened export routes to China and increased gas supply to Iran in the recent years. Recently Mr. Reddy, the GSPA, signed by national oil companies of the four nations, was witnessed by Turkmenistan Oil Minister, B. Nedirov, Pakistan's Petroleum Minister AsimHussain and Afghanistan's Minister of Mines WahidullahShahrani. "Without a doubt, the economic benefits of the TAPI gas pipeline will be immense for our energy-starved economies. The flow of natural gas will bring in industrial and economic development in our countries," Mr. Reddy said. The Bangladesh government recently expressed its willingness to Afghanistan government and sent a proposal in this regard. The Energy and Mineral Resources Division last month sent a letter to Economic Relations Division (ERD) to move for connecting the country with the multi-billion dollar project through the foreign affairs ministry. Later, the foreign affairs ministry forwarded the government's expression of interest letter to the Afghan energy ministry, the official said.

Figure 2: TAPI- pipeline route

B. Iran-Pakistan-India pipeline: The Iran–Pakistan–India (IPI) pipeline was proposed more than a decade ago to transport gas from the Persian Gulf through southern Iran and Pakistan to link with existing pipeline infrastructure in north western India. Gas would be sourced from the South Pars/North Dome gas field, which straddles the territory of Iran and Qatar in the Persian Gulf. The current proposed pipeline route is around 2800 kilo meters in length.

The Iranian share of the gas field is estimated to contain around 13 trillion cubic meters of gas. The volume of gas supplied by the IPI pipeline could reach 55 billion cubic meters a year. India has sought around 37 billion cubic meters (equivalent to 27 million tonnes of LNG), roughly equal to its current supply from domestic sources, while Pakistan would take around 18 billion cubic meters.

The Indian Government is optimistic that the IPI pipeline could begin delivering gas to India by around 2015. However, since the inception of the project, a number of factors have caused substantial delays in its commencement. These include disagreements related to gas pricing between India and Iran, as well as capital cost increases to around US$7 billion. In addition, geopolitical tensions in India–Pakistan relations, international concernsover trade with Iran, as well as domestic opposition in Iran to gas exports, have also hindered progress. The significant hurdles associated with the project, the potential for further delays, the lengthy construction period and high capital costs heighten the uncertainty surrounding a potential startup date. In this study, it is assumed that the project will not be operational until sometime after 2020. The prospects of IPI ever becoming a reality are also very bleak, despite the fact that Pakistan has repeatedly expressed its resolve to go ahead with the venture. The US is deadly against the IPI and has been applying continuous pressure on Pakistan to abandon this project, going as far as threatening of dire consequences. Secretary of State Hillary Clinton responding to questions in the House Appropriations Sub Committee on State and Foreign Operations on 1, March 2012 warned that Pakistan could face US sanctions if it pressed ahead with its proposed gas pipeline project with Iran. She said that the US administration recognizes Islamabad's essential energy needs. However, she added, construction of a gas pipeline from Iran to Pakistan would mean a violation of US legislation on sanctions against Iran.

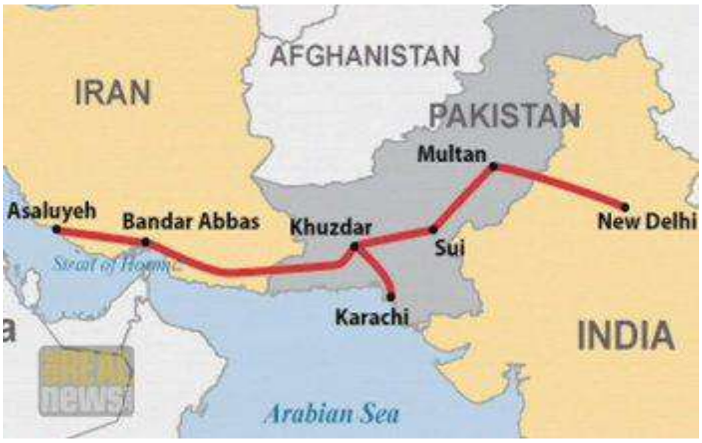

Figure 3: Iran–Pakistan–India pipeline route

C. Myanmar-Bangladesh- India pipeline: The lack of convergence in the energy security policies of India and Bangladesh has impacted the outcome of the Myanmar-Bangladesh-India (MBI) pipeline project. This project, envisaged as an important aspect of the energy security policy of India, has in the past failed to accommodate the needs of Bangladesh; this has resulted in an indefinite delay in project implementation. However, recent changes in the energy scenario of Bangladesh have enabled greater convergence in the energy policies of both countries leading once again to prospects of a revival of the project. Project implementation has also been stalled by the construction of the Myanmar-China pipeline project which consists of dual oil and gas pipelines originate at Kyaukryu port on the west coast of Myanmar and enter China at Yunnan's border city of Ruili. Competition between the two projects stems from uncertainty regarding just how much gas Myanmar actually has for export. The respective national energy security policies of India and Bangladesh constitute the main determinants of the success or failure of this project. The extent to which these policies have been able to accommodate each other and the effect this has had on the Myanmar-Bangladesh-India pipeline project is the crux of the following analysis. Interestingly changes in the importance of natural gas and of natural gas pipelines to both countries are important drivers in the evolution of the energy security policies of both countries.

Figure 4: Myanmar-Bangladesh-India Pipeline Route

To be sure this is not a new project but trails back through current history to an initial lack of convergence in the energy security policies of both countries which led to a breakdown in negotiations in 2005; however changes in Bangladesh's energy policies since then have enabled the establishment of some common ground in the energy security policies of both states leading to prospects of renewed collaboration over the last 24 months. Recently our Prime Minister Mr. Manmohan Singh visits to Myanmar, once again creates hope for revival of this project.

Liquefied Natural Gas (LNG)

India began importing liquefied natural gas (LNG) in 2004. In 2009, India imported 434 Bcf of LNG, nearly 65 percent of it from Qatar, making it the sixth largest importer of LNG in the world. Currently, India has two operational LNG import terminals, Dahej and Hazira. India received its first LNG shipments in January 2004 with the start-up of the Dahej terminal in Gujarat state. Petronet LNG, a consortium of state-owned Indian companies and international investors, owns and operates the Dahej LNG facility with a capacity of 6.5 million tons per year (mtpa) (975 Bcf/y). India's second terminal, Hazira LNG, started operations in April 2005, and is owned by a joint venture of Shell and Total. The facility has a capacity of 3.6 mtpa (488 Bcf/y). New terminals at Kochi and Dabhol are scheduled to come online in 2012. Demand for LNG will only expand to the extent that domestic production plans fall short of stated goals. Further, plentiful and cheap domestic gas that sells at a discount to imported LNG makes the international spot market a marginal option and complicates negotiations for long-term supply contracts. LNG is a clear, colorless, non-toxic liquid that can be transported and stored more easily than natural gas because it occupies up to 600 times less space. When LNG reaches its destination, it is returned to a gas at regasification facilities. It is then piped to homes, businesses and industries.

Regasification Capacity of India

India's LNG re-gasification capacity is expected to increase fourfold in the next five years. Currently, the country has an LNG re-gasification capacity of 13.6 MMTPA, which is expected to gallop to 53.5 MMTPA by 2016-17 as new terminals are commissioned. On a yearly basis, the LNG import terminal capacity is projected to increase from 13.6 MMTPA in 2011-12 to 19.8 MMTPA in 2012-13, to 28.5 MMTPA in 2013-14, to 31 MMTPA in 2014-15, to 46 MMTPA in 2015-16 and further to 53.5 MMTPA in 2016-17. In 2011-12, the LNG re-gasification capacity in the country stood at 13.6 MMTPA, comprising 10 MMTPA at PLL's terminal at Dahej and 3.6 MMTPA at Shell's terminal at Hazira.

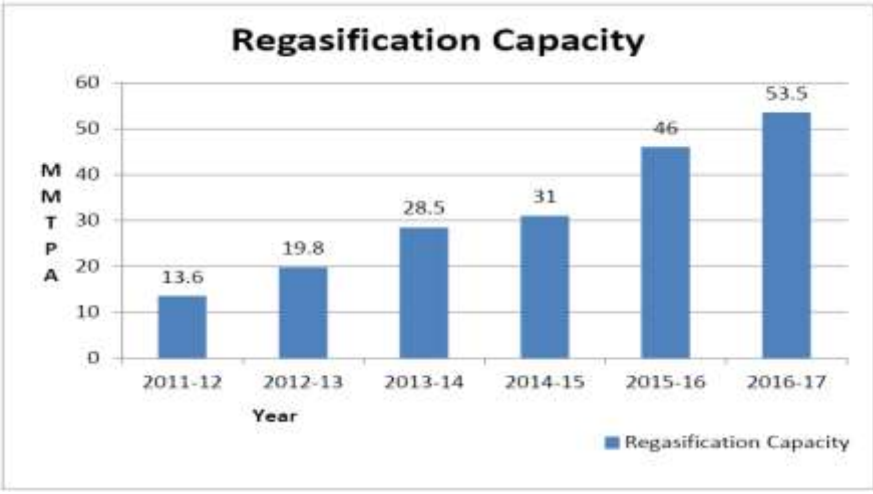

Figure 5: Regasification Capacity

IV. Factors affecting Natural gas pricing

Natural gas pricing in India

Natural gas is a scarce resource in India and Govt. of India plays an important role in its allocation. Historically, gas has been allocated in priority to end-users such as fertilizer producers and power plants. In 2007, the Govt. of India started working on a new Gas utilization Policy. This was mostly a consequence of the dispute between the Ambani brothers and the related issues on gas pricing and utilization, which created a very hot debate in India. In2007, a price was agreed between RIL and the government under the PSC so that RIL was to sell gas at USD 4.20/BTU for first five year of the production. This price level, often reported, reflects the calculation under a formula linking the price of gas to the price of oil:

GP= 2.5 + (OP– 25)^0.15

Where, OP is the annual average Brent crude price for the previous FY, with a cap of USD 60/bbl and a floor of USD 25/bbl. Since 2007, the annual Brent price has always been above USD60.

This and the large gap between demand and available supplies prompted the government to develop a Gas Utilization Policy and to go back to administrative control over prices (Govt. of India introduced a price formula for all discoveries under the first six NELP rounds) and over volumes to be allocated to end-consumers. Therefore, in 2008, the government introduced Natural Gas in India new guidelines called the Gas Utilization Policy, which effectively took away gas producers' rights to sell the gas they discover on the open market. These guidelines would be applicable for the next five years and be reviewed afterwards. The recent ruling of the Supreme Court in May 2010 regarding the dispute between RIL (Reliance Industries Ltd.) and RNRL (Reliance Natural Resources Ltd.), reaffirms the role of the government in the allocation and pricing of gas. Currently, the rules of the General Policy for the gas market imply that gas will be allocated according to industry-wise priorities set up by the government. This does not imply that the gas is "reserved": if one customer is not in a position to take the gas, the next one on the list becomes eligible.

Current Pricing Mechanism in India

The natural gas pricing scenario in India is complex and heterogeneous in nature. There are wide varieties of gas price in the country. At present, there are broadly two pricing regimes for gas in the country-gas priced under APM and non-APM or free market gas. The price of APM gas is set by the Government. As regards non-APM/ free market gas, this could also be broadly divided into two categories, namely, domestically produced gas from JV fields and imported LNG. The pricing of JV gas is governed in terms of the PSC (Production Sharing Contract) provisions. It is expected that substantial gas production would commence from the gas fields awarded by the Government under the New Exploration Licensing Policy (NELP). As regards LNG, while the price of LNG imported under term contracts is governed by the SPA (Special Purchase Agreement) between the LNG seller and the buyer, the spot cargoes are purchased on mutually agreeable commercial terms.

- APM (Administered Pricing Mechanism) Gas Pricing
- Pricing of Gas under Pre-NELP Production Sharing Contracts (PSC)
- Pricing of Gas with reference to NELP Provisions

Imported Gas (LNG) Pricing

A contract was signed with Ras Gas, Qatar for supply of 5 MMTPALNG (equivalent to about

18 MMSCMD) by Petronet LNG Limited (PLL) and supplies commenced from April 2004. This quantity has subsequently increased to 7.5 MMTPA effective from January 2010. The price for LNG has been linked to JCC crude oil under an agreed formula. However, the FOB price for the period up to December 2008 has been agreed at a constant price of

$ 2.53/MMBTU. This price translates to RLNG price of $ 3.63/MMBTU ex-Dahej terminal. The price would vary on monthly basis from January 2009. Further, in July 2007, PLL has signed another contract with Ras Gas, Qatar for supply of 1.25 MMTPA LNG from July 2007 to September 2009 to meet the requirement of Ratnagiri Power Project in Maharashtra.

In order to make the price of spot RLNG affordable, EGoM has decided in the meeting held on January 11th 2007 for pooling of prices of spot cargoes with LNG being imported on term contract basis. This Ministry accordingly issued orders on March 6th 2007 in compliance with the decision of EGoM. In addition to the above term contracts, LNG is also being Sourced from spot market by PLL and Hazira LNG Pvt. Ltd. During 2007-08, an average quantity of about 5.7 MMSCMD was brought into the country as spot cargos.

Pricing Issue

The pricing issue in India has always been quite complex. Firstly, APM gas supplies have been declining while non-APM gas saw a dramatic increase in volume and share. Furthermore, APM gas has been allocated in priority to power producers and fertilizers, two sectors expected to see their demand increasing over the coming decade. While the Ministry of Petroleum and Natural Gas has been pushing for higher prices to limit losses from the PSU, this has met with strong resistance from the Ministry of Power and Ministry of Chemicals and fertilizers. The subsidies to fertilizers have already multiplied by five over the last five years to reach INR 75849 crore (USD 16.6 billion) in 2008/09.

- Supply Side Issue
- Demand Side Issue
- Road Ahead

Framework of New Pool Pricing Mechanism

Need for Pool Pricing: The Indian gas market needs to match customer expectations, gas infrastructure expansion with providing flexibility for new and marginal suppliers to enter the market. Price pooling is a mechanism where the potential for balancing the customer and developer expectation with that of suppliers.

The need and benefits of pooling for the Indian gas markets need to be considered in the context of the market development objectives. These could be summarized as follows:

1. Introducing new gas sources in the market;
2. Ensuring stable price signals for long gestation investments based on gas;
3. Deepening the pipeline network to expand the gas markets geographically;
4. Sending appropriate price signals for efficient use of gas;

The Indian gas markets are relatively small as compared to the size of the economy, but are expanding rapidly. However, as commented earlier, the expansion has not kept pace with the demand. Domestic gas finds, while substantial, are inadequate to meet the burgeoning demand for gas. In particular, the demand from bulk consuming sectors like power and fertilizer is growing at a rapid pace. At the other end, the demand from city gas is also expected to increase rapidly in the coming years. As a result of this expansion of demand, the country is looking seriously at LNG as a potential source of supply expansion.

LNG, as an internationally traded commodity presents two challenges. Firstly, the price of LNG is generally linked to the price of crude oil, especially for long term supplies. The resultant prices of RLNG are typically significantly higher than the prices of domestic gas, including from the NELP fields. Secondly, the prices of such supplies being linked to crude are inherently volatile. The combination of relatively high prices and high volatility make it difficult for user industries like power and fertilizer to plan investments based on LNG.

Price pooling can serve the objectives of introducing substantial quantities of new LNG supplies. The existing base of the pool would serve to reduce the price volatility, and given the impetus for infrastructure development. The graphic below illustrates the impact of 5 MMTPA of new LNG supplies (approximately adequate for 5000 MW of new power projects), on the existing cost pool in India, at various supply price points.

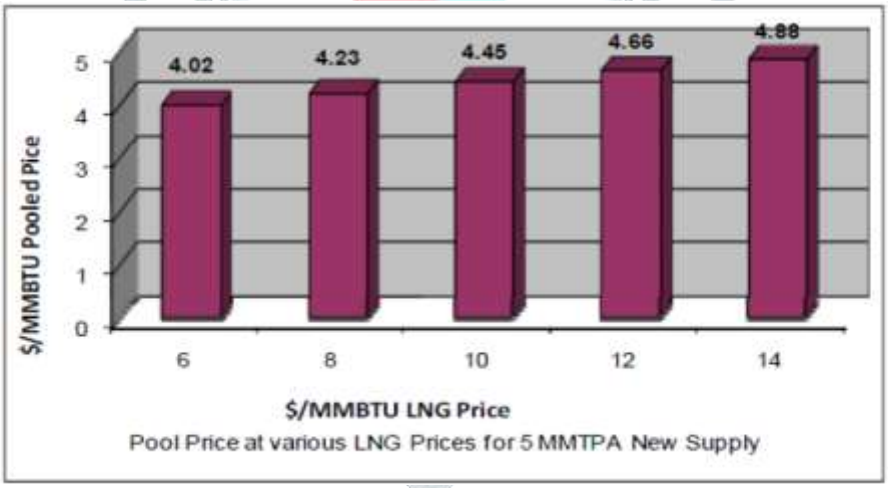

Figure 6: Pool Price at Various LNG Prices for 5 MMTPA New Supply

Proposed Roadmap of Pool Pricing Mechanism

The pooling options have been broadly divided into two major categories viz. Cost Based pool and Bid Based pool. Cost based pool has been further divided into General pool and Sectoral pool. The following section defines the various pools considered for this study.

General Pool-

In this type of pooling arrangement all the gas producers or traders participate in the pool. Gas is supplied to all the customers through the pool administrators. This could feature two basic options as variants.

(i) Mandatory or compulsory pool- In mandatory pool all the gas producers or traders have to participate in the pool and subsequently all the sale of gas will happen through the pool. Similarly, all demand would be required to contract through the pool for supplies.

(ii) Facilitated pool - Facilitated pool does not make it compulsory for the gas producers or gas suppliers to participate in the pool. The gas producers or traders can participate in the pool and exit from the pool as per the defined rules of the pool. The same would apply for buyers from the pool.

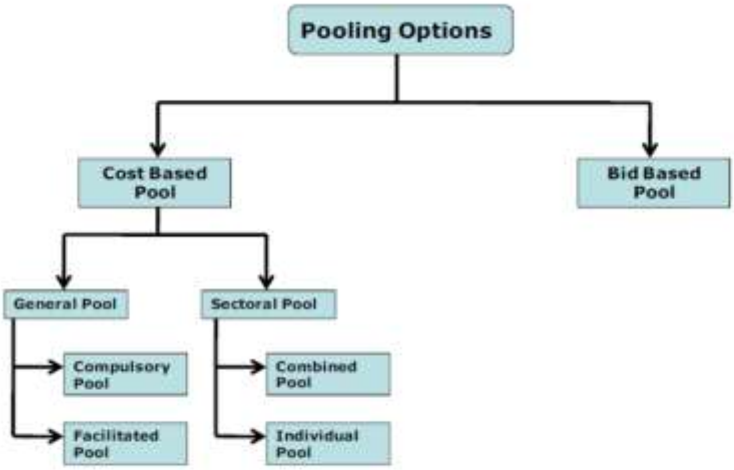

Figure 7: Pooling Options in India

Sectoral Pool

Sectoral pool is specifically for pre-identified sectors. As regards this study, this has been considered for Power and Fertilizer segments, although variants could extend to other sectors as well. Two basic forms of sectoral pools have been considered.

(i) Combined pool- In combined pooling arrangement there is a single pool for Power and Fertilizer. The gas at pooled price is supplied to customers from both the sectors through an identified mechanism.

(ii) Individual pool- In this type of pooling arrangement there will two different pools for Power and Fertilizer separately. The pool operator may or may not be same. The gas at pooled price is supplied to the respective customers through on identified mechanism. The pooled price may or may not be same for both the pools.

The above options have been discussed in the subsequent sections. It needs to be noted that in all options presented herein, the existing cost structures of the gas supply from producers (or importers) remain unchanged, and the revenues to be generated would correspond to these costs, plus the transportation costs, taxes and duties as at present. Hence there is no impact on subsidies as a whole, although the cost of gas to individual consumer costs would be rationalized as a result of the pooling arrangements. In subsequent years, with expansion of supplies in the pool, this would be altered based on the cost and quantum of additional gas supplies. Hence, irrespective of the option selected, specific pool rules would need to be agreed on the cost and quantity limits and implemented by the pool operator accordingly.

Effect of Globalization of Gas market on gas prices

Potential for energy independence as fuel switching to natural gas, efficiency, and domestic production lessen our dependence on oil imports from unstable regions. We are now in the 45 to 50 % range, trending down from above 60.

Potential for economic growth in the petro -chemical sector as production returns to the US, attracted by current feedstock pricing. The Sierra club and other NGO’s are concerned exports will drive more aggressive shale development. Industrial gas consumers and some gas utilities who prefer today’s price.

Balance that with legitimate questions from the free trade lobby:

One would hope we take full advantage of this resource. Canadians are investing in natural gas transportation fuel infrastructure just north of our border; combined heat and power distributed generation enjoys improving economics; and the gas industry and regulators must assure gas generation facilitates rather than discourages development of renewable power.

The price difference between a commodity that is 5% oversupplied (the approximate level of oversupply of NG in North America today) and one that is 5% under supplied is literally unimaginable. Recall that as recently as mid-year 2008, at the onset of the most severe portion of the recession, natural gas sold for $13+ per million BTUs. Some of the fall to today’s approximately $2/MMBTU was due to lost demand, but much of that has been recovered. For example, there was exactly zero fertilizer industry in the U.S. at those NG prices. Most of those plants are now back on line. The real driver was/is on the supply side.

Natural gas is a North American commodity. As such, it is priced by commodity-on-commodity competition. LNG is a global market. It is priced proportional to crude oil, the price of which is dictated primarily by the national oil companies and traders. There isabsolutely no reason to believe that prices will not retrace the 85% price drop seen in the last four years if enough LNG export is allowed. Going the other way, that translates to a 550% increase in price. Say goodbye to the fertilizer industry. And to the displacement of coal-fired power generation.

The current, ultra-low prices will not obtain for even the medium term. While there is an enormous shale gas resource which can be drilled with very high technical probability of success, only the liquids-rich areas like the Marcellus Shale are currently under development in North America. As the price rises, which it inevitably will, that other, lower liquids content shale gas opportunities will become economic. That will provide a governor on the domestic price of natural gas for literally decades.

Unless we export LNG. The current North American oversupply of natural gas is due to excessive enthusiasm on the parts of its developers. Now they wish that we the People to socialize their shortfall via exports, bringing them up to world prices.

There are three distinct regional gas markets, each of which sets natural gas prices differently. The US has gas-on-gas competition, Europe sets prices indexed to certain oil products although nascent gas hubs are starting to change this pricing structure, and Asia indexes its natural gas prices to crude oil, enforce in very long term contracts; this means that Asian prices are around $16 per mmbtu, making LNG exports from the US a very attractive option. There is limited trade between these three regional markets.

MIT modeled the price impacts in 2030 of a continuation of these regional markets compared to a global market in gas where there is substantial trade between regions, like today’s oil markets. The price impacts in the US were substantial, around a 30% drop in prices for US consumers (I am remembering the numbers, not looking at them, they can be seen in the MIT Future of Natural Gas study). Surprisingly, US production didn’t drop in this scenario, it remained steady. This was due to the fact that overall demand for natural gas increased in the US because prices were low. US entry into LNG exports would certainly hasten the development of this global market.

Although I have very high regard for Lew's work and observations, I do not find the story line of a sensational movie to be a compelling reason to oppose either LNG exports or imports. I believe that Sandia National Laboratory did a lot of LNG safety research after 9/11. I will try and find some links to this work but I don't think the conclusions remotely tracked the apparent thrust of this film. I am generally leery of Hollywood efforts to present "facts" on energy and point to the China Syndrome as exhibit A, Gas land as exhibit B. One is entertainment, one is advocacy, and both distort or conflate the real and sometimes serious impacts of the ways we produce energy (none of which is benign, including renewables). These films should not guide our responses to these impacts; analysis, observation and data should.

Brookings just released a study on gas exports from the US (disclaimer: I was a member of the study's advisory group) and concluded that the USG should do nothing to eitherencourage or discourage exports. I tend to agree although I expressed reservations about the political reaction to exports; this is borne out by the listing above of Sierra Club, industry, etc. opposition to exporting gas, all of which is generated by advocacy positions, which should be considered as such.

At the rollout of the Brookings study, I highlighted the investment uncertainty associated with converting current LNG import sites in the US to liquefaction and export facilities (not a small capital investment by any means). I noted that, as an investor, I might be concerned about the development of global shale resources and its overall impacts on LNG demand. China for example has 1275 Tcf of technically recoverable shale resources and only consumes around 3Tcf of gas per year.

The US import market is a prime example of how shale gas can affect LNG import opportunities. In the Bush Administration, the US increased LNG import capacity by an order of magnitude (including Mexico and Canada volumes, destined for US markets), from around 2 bcfd to 22 bcfd. In 2010, we imported just over 1 bcfd, leaving significant stranded assets out there around the country. This is a cautionary tale for potential investment in exports, and to me, suggests that any export volumes of LNG from the US would likely be relatively small and self-limiting.

Finally, the US has a horrible track record on natural gas policy. Example 1 is the LNG import debacle noted above. I also remind people, as example 2, that the Congress outlawed the use of natural gas in power generation in 1978 (based on a completely flawed understanding of what was really going on in US gas markets at the time). This coupled with Three Mile Island (accompanied by the hysteria generated by the movie, The China Syndrome), gave us the ancient, creaky, CO2 emitting coal fleet we have in the US today; this underscores the fact that the energy infrastructure choices we make today will likely be with us for the next 40-50 years.

Finally, I encourage everyone to consider Example 3, namely theoverbuild of NGCC merchant plants when wholesale electricity markets were de-regulated in the mid-90s. We have a fleet of highly efficient gas generation units that are operating at 41% capacity factors, when they are designed to operate at 85-87%. Volatility in gas prices has ensured that old, inefficient coal generation tends to get dispatched first over more efficient, much lower CO2 and other criteria pollutants + non-mercury emitting NGCC plants. Shale gas production has greatly diminished this price volatility, making the NGCC overbuild a good luck/bad luck story — slowly but surely our old coal plants are being retired and we don't require new builds to replace them because we have so much surplus NGCC capacity. It has however, taken 15 years or so to start correcting this market miscue, and perhaps the capital that was stranded over that time period might have been put to better use.

The MIT group's finding that N. American natural gas prices would enjoy a 30% drop given the establishment of a global LNG trading market is very interesting. However, given the already-85% drop in wholesale prices, perhaps some of its assumptions deserverevisiting. Moreover, the excess LNG import capacity provides the U.S. an option on the benefits of such a market. Should MIT's indicated results obtain, imports would once again be competitive. Should the the situation suggest that export of LNG would be an act beneficial to the national economy, such a policy could be pursued at that time. Import/export control has historically been an element of the policy initiatives of most nations. In this case, simply declining to enable LNG exports would be a relatively passive policy imposition.

Secondly, you should be a bit cautious in applying the term "stranded assets" to either the unused LNG import facilities or the oversupply of NG-fired combined cycle plants. The term has previously been applied to electric utility assets that existed because of actions within the framework of a regulatory compact. They became an issue in the context of deregulation of that industry under the assumption that rate-of-return based retail rates were going to be abandoned in the onslaught of deregulation (they weren't). By contrast, both of the over investment situations you cite above result from private decisions regarding the deployment of capital. As such, the possibility of having employed that capital differently is a subject utterly NOT a governmental policy question in a capitalist system. I repeat, there is every reason to avoid socializing those failed investment decisions on the part(s) of private enterprise(s) and every reason – except the desire to benefit a select group of investors – to keep cheap NG prices at home. Salient among them, retiring that "ancient, creaky, CO2 emitting coal fleet we have in the US today". Don't export LNG at this time.

V. SHALE GAS

Shale gas historical back ground and development

Shale gas was first extracted as a resource in Fredonia, NY in 1825, in shallow, low-pressure fractures. Work on industrial-scale shale gas production did not begin until the 1970s, when declining production potential from conventional gas deposits in the United States spurred the federal government to invest in R&D and demonstration projects[18] that ultimately led to directional and horizontal drilling, micro seismic imaging, and massive hydraulic fracturing. Up until the public and private R&D and demonstration projects of the 1970s and 1980s, drilling in shale was not considered to be commercially viable. Early federal government investments in shale gas began with the Eastern Gas Shale Project in 1976 and the annual FERC-approved research budget of the Gas Research Institute. The Department of Energy later partnered with private gas companies to complete the first successful air-drilled multi-fracture horizontal well in shale in 1986. The federal government further incentivized drilling in shale via the Section 29 tax credit for unconventional gas from 1980-2000. Micro seismic imaging, a crucial input to both hydraulic fracturing in shale and offshore oil drilling, originated from coal beds research at Sandia National Laboratories. In 1991 the Department of Energy subsidized Texas gas company Mitchell Energy's first horizontal drill in the Barnett Shale in north Texas. Mitchell Energy utilized all these component technologies and techniques to achieve the first economical shale fracture in 1998 using an innovative process called slick-water fracturing. Since then, natural gas from shale has been the fastest growing contributor to total primary energy (TPE) in the United States, and has led many other countries to pursue shale deposits. According to the IEA, the economical extraction of shale gas more than doubles the projected production potential of natural gas, from 125 years to over 250 years. In 1996, shale gas wells in the United States produced 0.3 trillion cubic feet (8.5 billion) cubic meters), 1.6% of US gas production; by 2006, production had more than tripled to 1.1 trillion cubic feet (31 billion cubic meters) per year, 5.9% of US gas production. By 2005 there were 14,990 shale gas wells in the US. A record 4,185 shale gas wells were completed in the US in 2007. In January 2008, a joint study between Pennsylvania State University and State University of New York at Fredonia professors Terry Engelder and Gary Lash increased estimates as much as 250 times over the previous estimate for the Marcellus shale by the U.S. Geological Survey. The report circulated throughout the industry. In 2008, Engelder and Nash had noted a gas rush was occurring and the New York Times' "There's Gas in Those Hills" was an in-depth look at the development, noting investments by Texas-based Range Resources and increased leasing amongst Anadarko Petroleum, Chesapeake Energy and Cabot Oil & Gas.

Shale Gas Reserve

The development of shale gas plays has become a "game changer" for the U.S. natural gas market. The proliferation of activity into new shale plays has increased shale gas production in the United States from 0.39 trillion cubic feet in 2000 to 4.87 trillion cubic feet in 2010, or 23 percent of U.S. dry gas production. Shale gas reserves have increased to about 60.6 trillion cubic feet by year-end 2009, when they comprised about 21 percent of overall U.S. natural gas reserves, now at the highest level since 1971. [3] The growing importance of U.S. shale gas resources is also reflected in EIA's Annual Energy Outlook 2011 (AEO2011) energy projections, with technically recoverable U.S. shale gas resources now estimated at 862 trillion cubic feet. Given a total natural gas resource base of 2,543 trillion cubic feet in the AEO2011 Reference case, shale gas resources constitute 34 percent of the domestic natural gas resource base represented in the AEO2011 projections and 50 percent of lower 48 onshore resources. As a result, shale gas is the largest contributor to the projected growth in production, and by 2035 shale gas production accounts for 46 percent of U.S. natural gas production.

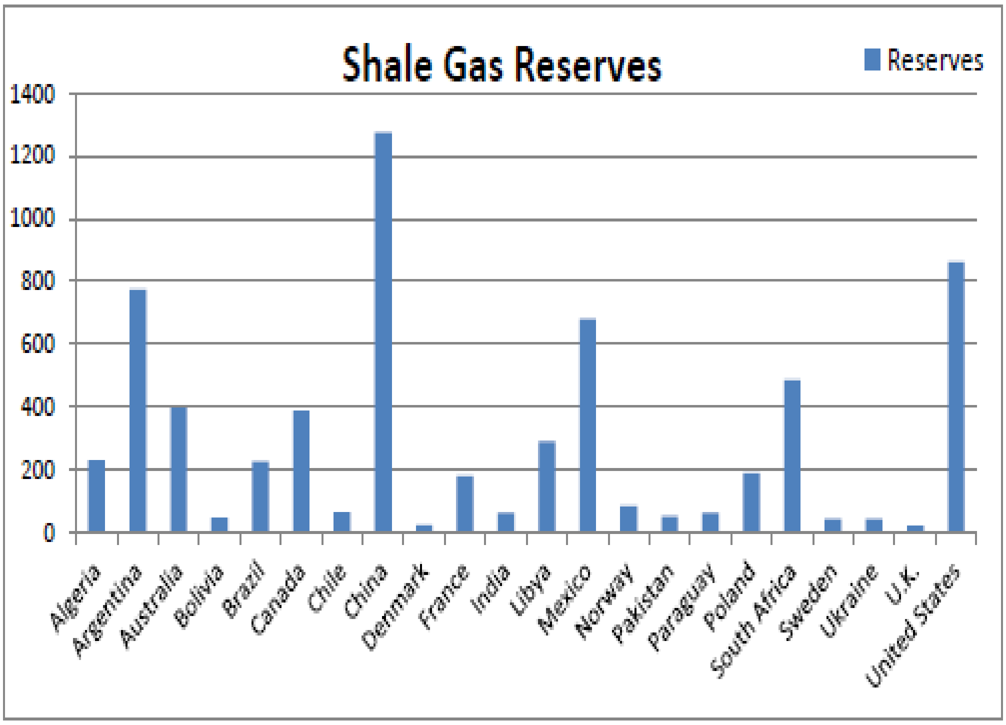

Figure 8: Shale Gas Reserve of various countries

Hydraulic fracking- breakthrough in shale gas

Hydraulic fracturing (fracking) is the method used to make hard shale rock more porous, thus allowing natural gas to flow through the shale to the wellbore. First, producers drill into the earth several thousand feet until they reach the natural gas reservoir. Next, steel casings are inserted to a depth of 1,000 to 3,000 feet, and the space between the casing and the drilled hole is filled with cement to stabilize the well and prevent any leakage. After the cement has set, this process is repeated, using a series of successively smaller casings until the reservoir is reached, usually a distance of 6,000 to 10,000 feet. There are numerous state and federal regulations that govern the casing and cementing process. Once the drilling and casing is complete, typically 3 to 5 million gallons of water, mixed with sand and fractional amounts of chemical additives, are pumped into the wellhead at high pressure, creating cracks in the rock beds. Several videos provide a detailed explanation of the fracking process. The hydraulic fracturing mixture is 95 percent water, 4.5 percent sand and 0.5 percent chemical additives formulated to promote gelling and cleaning according to the Ground Water Protection Council and U.S Over the past 50 years, there have been significant advances in hydraulic fracturing technology. Different types of fracture treatments have been developed ranging from packer and pumping equipment to variations in treatment fluids and prop pants. Each natural gas reservoir is unique due to the variability in geology and geo mechanics.

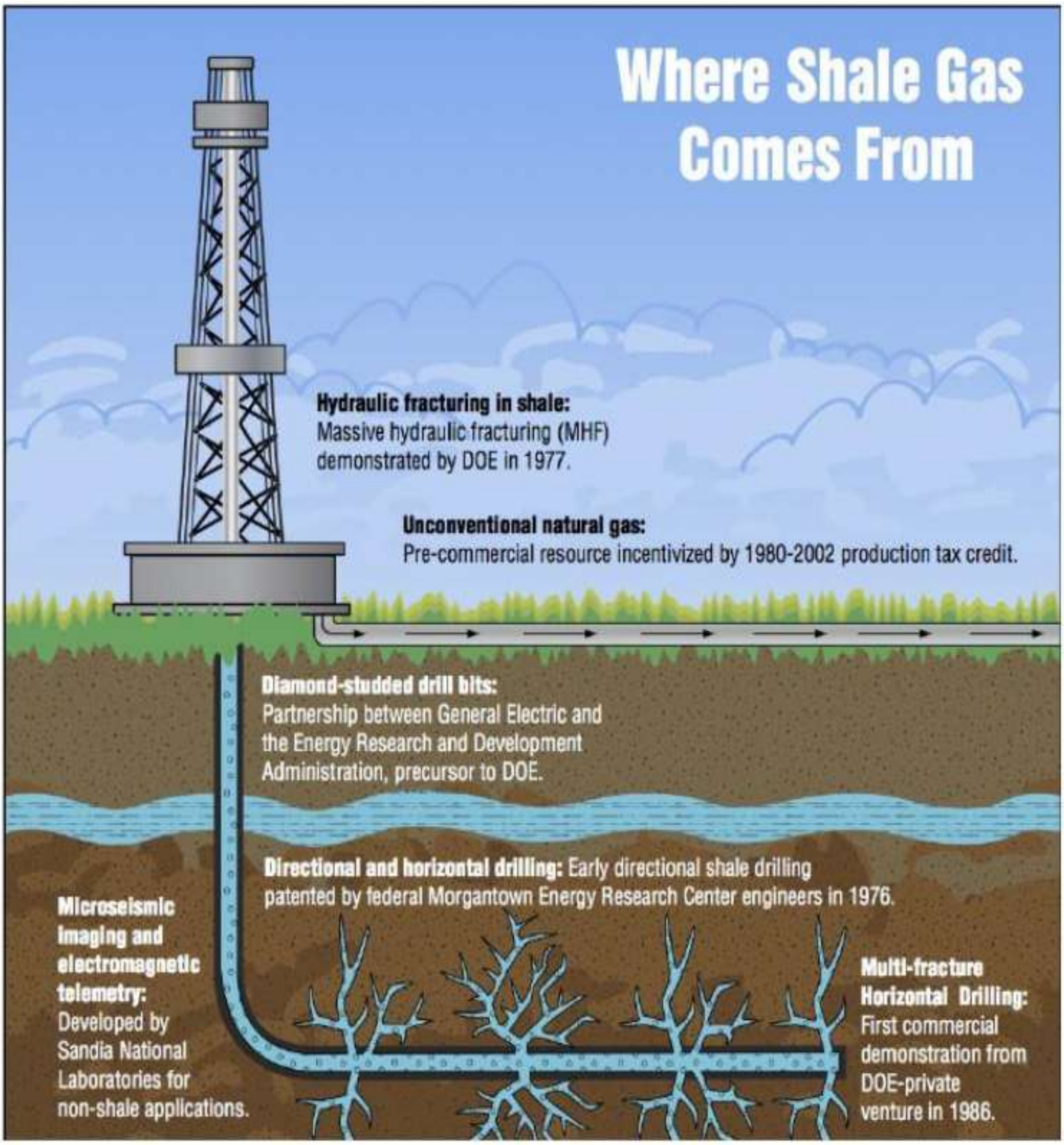

Figure 9: Shale Gas

As a result, there will be different types of hydraulic fracturing treatments used depending on what result is needed in the end and what the parameters of the zone are. Recent developments of fracture technology coupled with horizontal drilling have allowed numerous tight gas reservoirs to yield economic volumes on natural gas. These technological breakthroughs have enabled significant natural gas resources to be added to the country's energy resource base and extending the potential supply by over 100 years.

Issues with Hydraulic fracking

This potentially poisonous method of natural gas drilling is now being used nationwide to release rock bound natural gas formations and has been exempt from U.S. federal oversight by the E.P.A. These natural gas drilling and exploration firms were also allowed to keep secret the list of toxic chemicals they are using to inject into the ground....many of these chemicals have seeped into wells and ground water formations near fracking operations and poisoned people, caused gas explosions and poisoned/killed livestock. Although state governmental agencies are required to regulate "fracking" for natural gas being done by various firms. The drilling method seems to be going largely unregulated with a wink and a nod by regulators.....perhaps because of the enormous profits/income to be reaped by various individuals in the private and public sector. Up until recently these fracking operations were done, largely, in remote, sparsely populated rural areas out west, but now, in the eastern U.S., fracking is being done in close proximity to urban drinking water supplies.

VI. CONCLUSIONS

The concluding points of this paper study are as follows:

- With a burgeoning population, we have to recognize that resources are scarce and plan accordingly.
- End use efficiency, reduction of wastage and accountability has great potential for improvement.
- Solar PV and offshore wind energy resource can to some extent.
- Yet the reality is that we have to rely for the next 20 years on fossil fuel i.e. coal or natural gas.

- Investment in coal base electricity needs critical appraisal because of availability, land requirement, pollution, greenhouse gas emission and ash disposal and increasing cost of environment needs critical appraisal.
- Natural gas based electricity generator are generally not approved because of lack of domestic availability of natural gas besides domestic gas sector has received a thrust with shale gas and Hydraulic fracking technology in US. A relook into fuel import i. e. import of coal vis a vis import of natural gas is a national imperative in view of the need for electricity keeping in view all other collateral concerns.
- Domestic gas production is decreasing and not violable option for new power projects.
- ONGC also have recommended that domestic gas exploration is not viable bellow $7 to $8/MMBTU.
- Piped natural gas is better option for new power projects. Estimated timeline for gas pipeline projects to be operational-
- Due to uncertainty of completion of pipeline gas project, LNG import is better option of fuel supply for power plants.
- Diesel generator can be replaced by natural gas plant- In India electricity generated by DG set- 1200 MW at cost of Rs. 12/kwh and grid power at cost of Rs 3/kwh. This market will grow at the rate of 20% for coming years.
- Natural gas based power plant can be used to supply uninterrupted power to some specified industries such as hospitality and healthcare.
- Natural gas can be used for distributed power generation-Due to heavy distribution and transmission losses (around 30%) distributed generation by natural gas is better option as it can be produced at cost of Rs. 6 to 7 per kwh.

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