Gateway to India's Energy Security - Shale Gas

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Abstract

India has a number of sedimentary basins with proven shale gas reservoirs. Conventional oil resources are depleting. Exploring shale gas, hence, has become our paramount interest. Technical, safety, and environmental standards for hydro-fracturing process including prevention of collateral damage to other geological resources, sourcing water and disposal thereof has to be taken into consideration. The high potential of shale gas as source of natural gas has made it a vital key in today's energy hunger race. This paper projects Krishna-Godavari and Cambay basins as new frontiers for shale gas exploration in India. To commercialise shale gas, we need to overcome the challenges involved and study the economic implications. Various government and private organisations are carrying out in depth research to evaluate prospects for shale gas in India. The conclusions made by the author in this paper are his own but based on data available in the public domain.

1. Introduction

The international energy sector is observing shifts of interest with time and technology. The alarmingly increasing energy demand coupled with the high depletion rates of the conventional sources has shifted focus towards more reliable sources. This focus revolves around unconventional sources and alternative renewable sources of energy.

Four of such unconventional gas resources are tight gas reservoirs, coal bed methane, gas hydrates and shale gas (Figure 1). Gas hydrates, a highly potential unconventional source, is still under examination worldwide. Such resources hold great potential as a source of natural gas and at the moment extensive work is being carried out for the development of these resources across the world. However, the long term potentials, technological advancements, environmental benefits and attractive gas prices bring unconventional gas resources into the forefront of our energy future as compared to oil. The world today is witnessing, with no doubt, the ever expected natural gas revolution. Gas is now targeted as the prime source of energy readily available to us. In future, a significant percentage of the world's energy demands will be satisfied by the natural gas. Gas consumption is constantly rising and this would play a vital role in future economic performance and strategic stability of any nation. Furthermore, some experts believe that the consumption of gas will exceed that of oil by about 2025.

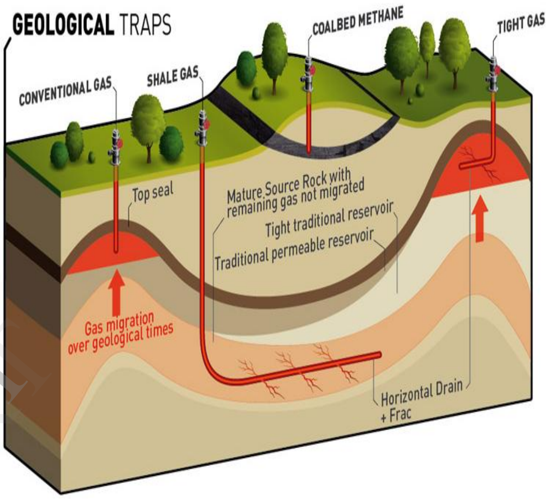

Figure 1: Geological traps for natural gases.

2. Shale Gas

Shale gas refers to natural gas that is trapped within shale formations. Shales are fine-grained sedimentary rocks that can be rich sources of petroleum and natural gas. Shale is composed of flakes of clay minerals and tiny fragments of other minerals, especially quartz and calcite. Shale gas is defined as fine-grained reservoir in which gas is self-sourced, and some of the gas is stored in the sorbed state. Productive shale range from organic rich to fine grained rocks.

3. Extraction of Shale Gas

Shale Gas extraction consists of three stages as discussed below.

3.1. Exploration

A small number of vertical wells (perhaps only two or three) are drilled and fractured to determine if shale gas is present and can be extracted. This exploration stage may include an appraisal phase where more wells (perhaps 10 to 15) are drilled and fractured to characterize the shale; examine how fractures will tend to propagate; and establish if the shale could produce gas economically. Further wells may be drilled (perhaps reaching a total of 30) to ascertain the long-term economic viability of the shale.

3.2. Production

The production stage involves the commercial production of shale gas. Shales with commercial reserves of gas will typically be greater than a hundred meters thick and will persist laterally over hundreds of square kilometres. These shales will normally have shallow dips, meaning they are almost horizontal. Vertical drilling would tend to pass straight through them and access only a small volume of the shale. Horizontal wells are likely to be drilled and fractured. Once a shale formation is reached by vertical drilling, the drill bit can be deviated to run horizontally or at any angle.

3.3. Abandonment

Like any other well, a shale gas well is abandoned once it reaches the end of its producing life when extraction is no longer economic. Sections of the well are filled with cement to prevent gas flowing into water-bearing zones or up to the surface. A cap is welded into place and then buried [1].

4. Hydraulic Fracturing - the Breakthrough

Hydraulic fracturing (commonly called "fracking" or "hydrofracking") is a technique in which water, chemicals, and sand are pumped into the well to unlock the hydrocarbons trapped in shale formations by opening cracks (fractures) in the rock and allowing natural gas to flow from the shale into the well. When used in conjunction with horizontal drilling, hydraulic fracturing enables gas producers to extract shale gas at reasonable cost. Without these techniques, natural gas does not flow to the well rapidly, and commercial quantities cannot be produced from shale.

5. Shale Gas in India

India, the world's fourth largest energy consumer, is need in a continuous rush to attain energy security. In this very race, it has come up to explore its own sedimentary basins for potential shale gas reserves. Ministry of Petroleum and Natural Gas has identified six basins to potentially hold shale gas reserves are Cambay (Gujarat); Assam – Arakan (North East); Gondwana (Central India); Krishna - Godavari (East Coast); Cauvery and Indo - Gangetic plain (Figure 2). Out of these, The Cambay, Krishna Godavari, Cauvery and the Damodar Valley are the most prospective sedimentary basins for carrying out shale gas activities in the country [2].

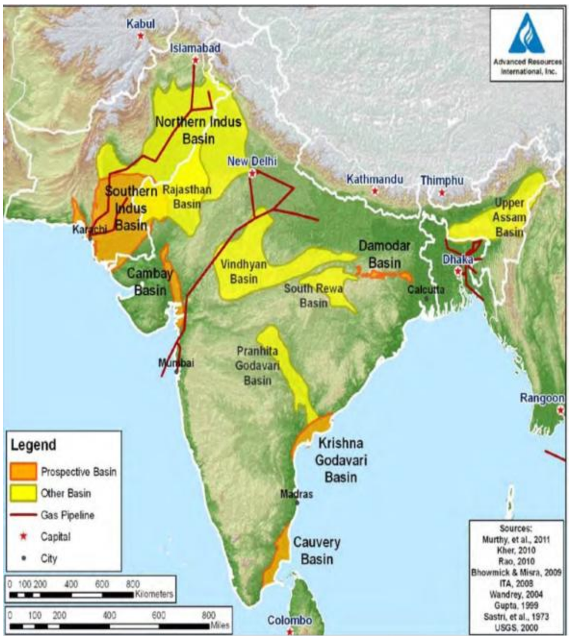

Figure 2: Prospects of Shale Gas in India (Source: Advanced Resources International, Inc.).

6. Shale Gas Revolution

Shale gas revolution is mainly led by (a) change in understanding of reserve size and (b) advancements in extraction technology. The presence of shale gas has been long known. Commercially viable exploitation had proved to be a challenge, since extraction was difficult and the gas deposit was spread over a larger area. Unlike conventional gas, shale gas exploitation requires a much higher number of wells owing to the nature of the deposit and fast depletion rates. Compared to vertical wells that were draining 10-30 acres, the horizontal wells are able to drain larger areas of around 100 acres. Horizontal wells together with intensive fracturing have enabled reduction in costs through: (a) Tapping of a larger land area through horizontal drilling and (b) Improvement in gas yield per well by fracturing, leading to more gas flow paths. The Figure 3 below representing an increase in the oil-to-gas price ratio from 2009 to 2012. The technically recoverable U.S. shale gas resources are estimated at 862 tcf, which is 34% of the domestic natural gas resource base. U.S. drilled over 40,000 wells in different shales. Currently, operators in U.S. deploy over 1500 rigs for shale gas. Also, a close network of pipelines measuring over 600,000 km exists for off-taking of the gas to the market. This unprecedented growth of shale gas in the United States has generated new hopes for energy deficient countries, especially China and India [3].

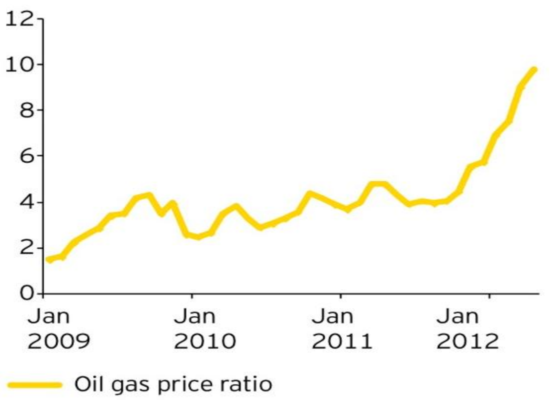

Figure 3: Oil - gas price ratio (Source: U.S. Energy information Administration and Ernst and Young Analysis)

The surging shale gas production in the U.S. and the possibility of replicating this success worldwide holds the potential to revolutionize the global energy market in the future. Figure 4 showing comparison between gas price of U.S. with rest of the world.

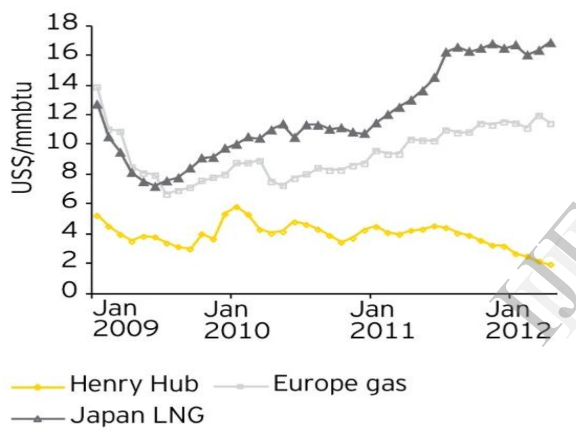

Figure 4: U.S. prices versus rest of the world

Recent technological advancements in hydraulic fracturing and horizontal drilling have made shale gas operations economically viable. The widely dispersed shale gas reserves represent the strong potential of shale gas to emerge as a major alternative source of energy globally [4]. The comparisons between keys factors affecting shale gas exploration are provided in Table 1.

Table 1: Comparison of some key factors affecting shale gas exploration (Source: The Economic Times, May 17, 2013)

Country	U.S.	China	India
Population Density	33.7	139.6	370
Land Usage (%)	18	14.9	48.83
Total renewable water resources (km^3)	3069	2829	1908

The study of shale gas has opened up new frontiers in the energy sector of India. With optimum measures, we can exploit our resources and decrease our energy dependence. Let us now discuss about the potential shale reserves in India. Krishna Godavari and the Cambay are the two basins which could yield up to 47 tcf, amounting to nearly 75% of the total technically recoverable shale.

7. Krishna Godavari Basin

The Krishna Godavari (K-G) Basin extends over a 20,200 km^2 area onshore (plus additional area in the offshore) in eastern India (Figure 5).

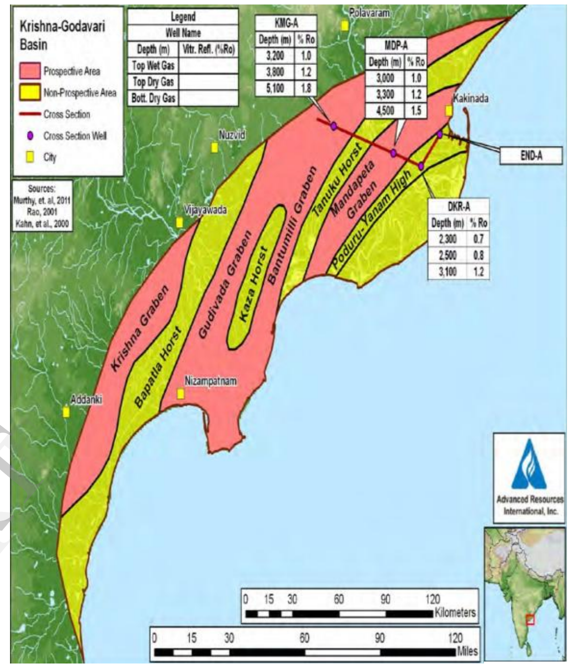

Figure 5: Prospect areas of K-G Basin (Source: Advanced Resources International, Inc.).

The basin consists of a series of horsts and grabens, as shown in Figure 5. The basin contains a series of organically rich shales, including the deeper Permian-age Kommugudem Shale, which is gas prone (Type III organics) and appears to be in the gas window in the basin grabens. The Upper Cretaceous Raghavapuram Shale and the shallower Paleocene and Eocene shales are in the oil window and thus were not assessed by this study.

Kommugudem Formation is the main source rock for this system. It belongs to Artinskian (Upper Early Permian) age. This coal-shale unit is more than 900 m thick in the type well Kommugudem-1.It has a good source rock potential with rich organic matter with Total Organic Carbon (TOC) ranging from 0.5% to 3% and vitrinite reflectance (VRo) in the deeper part of the basin is in the range of 1.0 to 1.3. Generation threshold occurred during Cretaceous.

7.1 Prospects (Kommugudem Shale)

The 11,240 km^2 prospective area of the Kommugudem Shale in the Krishna Godavari Basin is limited to the four grabens (sub-basins) where the thermal maturity is sufficiently high for wet to dry gas generation. Based on an average resource concentration of 60.23 bcf/ km^2 for the four graben areas, we estimate a risked shale gas in-place of 136 tcf, with a risked technically recoverable resource of 27 tcf [5].

8. Cambay Basin

The Cambay Basin is an elongated, intra-cratonic rift basin (graben) of Late Cretaceous to Tertiary located in the State of Gujarat in northwestern India (Figure 6).

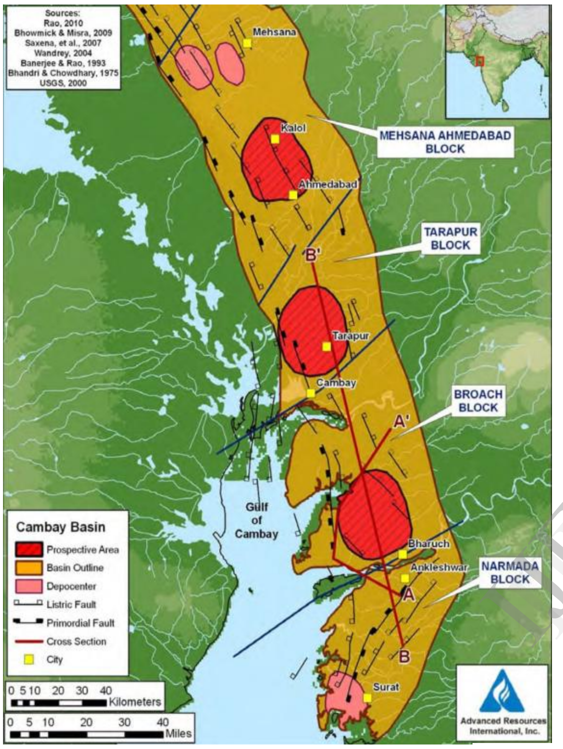

Figure 6: Prospect areas of Cambay Basin (Source: Advanced Resources International, Inc.).

The basin covers an onshore area of about 51,800 km^2. The basin is bounded on its eastern and western sides by basin-margin faults. It extends south into the offshore Gulf of Cambay, limiting its onshore area, and north into Rajasthan. The different fault blocks in this basin include Sanchor Patan (Too Shallow for Shale Gas); Mehsana-Ahmadabad (One Prospective Area); Tarapur (One Prospective Area); Broach (Prospective Area) and Narmada (Insufficient Data).

8.1. Prospects

Using the criteria of vitrinite reflectance (VRo) greater than 1.0% and formation depth between 3 and 5 kilometer, we calculate a prospective area of 5024 km^2 for the "Black Shale" of the Cambay Basin (Figure 6). Based on the estimated prospective area of 5025 km^2 and an average value of 0.15 km for net shale, ARI estimates a risked gas in-place for the Cambay "Black Shale" of 79 tcf, approximately 20 tcf of which may be technically recoverable [6].

9. Challenges

Shale gas exploration incorporates both technical and environment problems. Shale gas plays being different in terms of heterogeneity, constrained reservoir characterization; production methodology demands special skills and experience. Availability of services, infrastructure and resources is very limited in India, which is bound to increase the cost of operations [7].

9.1. Land Usage

Shale gas requires large number of wells to be drilled, which will involve extensive use of land. Against much less than one well per square kilometre for conventional oil & gas, Shale gas typically requires about 2-6 wells per sq. km [8]. However, population density of India is about 370/ sq. km whereas that in USA is 33.7 and even in China it is 139.6. In case of West Bengal, population density is reported at 1035 per sq. km almost three times that of India's average. Moreover, if we look at the land usage part: whereas Arable land in USA and China are 18% and 14.9% respectively, in India it is 48.83%. West Bengal being at a highly fertile plane, 61% of its total land is arable.

9.2. Water Issues

India faces a large gap between current supply of water and projected demand, amounting to a shortfall by 50% (754 bcm) in 2030. This gap is driven by a rapid increase in demand for water for agriculture, coupled with a limited supply infrastructure. Energy production competes with irrigation, drinking water, and industry for the water supply. Fracking of one well requires about 3-4 million gallons of water. Eight out of India's nine major shale basins are in water stressed/scarce regions [9].

9.3. Cost of field development operations

Cost of drilling and completing in Asian countries is 2.5 to 5 times higher than similar operations in USA and Canada. This is certainly due to poor infrastructure and government support in terms of subsidies.

10. Recent Developments

Based on the finalized shale gas exploration policy released by the Ministry of Petroleum and Natural Gas, state owned companies Oil and Natural Gas Corporation (ONGC) would take up 175 blocks and Oil India Ltd (OIL) another 15 blocks, in three assessment phases.

ONGC would get 50 blocks in the first phase, 75 in the second and 50 in the third. OIL would get five blocks each in all three phases. Each assessment phase would be for three years. Companies would get the liberty to select petroleum exploration license or mining lease areas, to be treated as blocks. One pilot well is compulsory in each block during the assessment phase, in every 200 sq. km.

11. Solutions

To overcome these challenges, we need to ensure that we come up with innovative solutions that could trigger the technology utilisation keeping in mind the social, political and environmental issues.

11.1 Optimum land usage

To reduce the usage of land, companies must be encouraged to develop superpads in areas where population density is high. This multi-well pad system enables the drilling of multiple wells from a single location. Although this may push operational costs, it will reduce the geographical footprint of operations and help win public acceptance.

11.2 Water Management

Many companies in the US are implementing new techniques such as advanced well designs and equipment to reduce fracs per well, forward water recycling in fracking, multiple layers of steel casing to prevent water contamination, closed-loop drilling to minimize water usage and discharge of toxic waste.

11.3 Joint Venture

To collapse learning curve, bring in experience, technology and skills, collaborate with the existing players of US through joint ventures. This will also reduce cost and risk.

11.4 Business friendly Regulatory framework

Suitable fiscal incentives by the Indian government such as royalty exemption, tax holidays so that Indian operators are enticed to bring the shale gas into reality. Also, incentives to E&P service providers for growth of service companies, needed for competition, bring cost down and ensure availability.

11.5 Research and development

Universities, research institutes, and related organisations must be encouraged to develop new technologies and improve on the existing technologies and customise it as per as our requirement to optimise the process of shale gas exploration and exploitation.

12. Conclusions

Shale gas, undoubtedly, is one of the promising assets that can turn India's dream into reality by making it energy sufficient. Indian regulators should create conducive environment to nurture this nascent yet highly potential fuel source and prospective operators should position themselves through customised business model to bring shale gas to reality. Universities, research institutes and related organisations must be encouraged to understand the complexities involved in shale gas exploration and come up with economical and environment friendly solutions.

13. Acknowledgement

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