Shale Gas Scenario in India and Comparison with USA

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Abstract: ***Natural gas extracted from organic rich Shale rock Formations has become the fastest-growing source of Gas in USA and could become a significant new global energy alternative unconventional source. Although the energy industry has long known about huge gas resources trapped in organic rich shales, it is over the past decade that energy companies have combined two established technologies- hydraulic fracturing and horizontal drilling- to successfully unlock the tight and shale oil/gas resource. A recent study by EIA (Energy Information Administration) assessed 95 shale gas basins in 41 countries. India is one of the countries covered in this study along with China, Canada, Mexico, Australia etc. With current available data, the initial estimates of technically recoverable shale gas resource in these countries is 7299 TCF. At present, the shale gas is not exploited in India. Encouraged by the USA results and preliminary USGS assessment, Govt of India is seriously contemplating to carry out detailed exploration, followed by phased extraction. The Cambay, Krishna-Godavari, Cauvery and Damodar valley are the four major basins of shale gas reservoirs as indicated by considerable thickness of shales; sufficient TOC (2 to 6 wt%) content; and good thermal maturity with vitrinite reflectance of more than 1.0. The Vindhyan, Upper Assam, Pranhita-Godavari and Rajasthan basins are other prospective basins that need to be probed by geo-scientific methods. The gas in these shale reservoirs can occur within the natural fractures or pore spaces or as adsorbed gas on the organic matter. The unlocking of domestic shale gas reserves could help India meet its growing energy demand, besides reducing its dependence on expensive energy imports. This is considered as the next generation major energy resource after gas hydrates and coal bed methane. In addition, the development of the domestic shale gas industry could boost the Indian economy.***

Keywords: Shale gas scenario in India , Shale gas reserves in USA , comparison between India and USA, Reason behind less production in India , Recent development

1. Introduction

Natural gas plays the key role in increasing energy demand. But the gap between natural gas demand and supply has been increasing day by day. To bridge the gap between energy demand and supply , it is necessity to found other energy resources. Unconventional sources of energy are one of the best alternative to natural gas in the international energy sector. Shale gas Coal Bed Methane, Gas hydrates, tight gas etc. are best unconventional energy sources. These resources has great potential as a source of natural gas .nowadays detailed work is being done for the development of these resources.At moment the world is witnessing an increasing demand of gas. Thus unconventional gas resources development has the focus of increased attention. India is the fourth largest energy consumer in the world after USA, China and Japan. About 52% of her energy requirement is met by coal, 32% by oil and 6% by natural gas (Sen, 2013) Shale gas is the future energy basket worldwide. USA and Canada are leading commercial shale gas production which is 20% of total gas production. India have Good prospects of shale gas in different sedimentary basins i.e. Cambay, Assam Arakan, Krishna – Godavary, Gondwana.

The shale gas is defined as the gas present as adsorbed form on the organic matters within pores, cracks and fracture of shale rock. Shale occurs over a broad geological age from Proterozoic to Cenozoic. Shale is a fine-grained, clastic sedimentary rock composed of mud that is a mix of flakes of clay minerals especially quartz and calcite. Shale can accumulate a large amount of organic materials compared to other rocks, and are deposited under fluvial, marine and lacustrine environments. The gas is mostly thermogenic in origin. Shale gas is defined as self-sourced reservoir. Shale gas is not just "shale". Shale has low matrix permeability, so commercially viable gas production requires fractures to provide permeability. Shale gas has been produced for years from natural fractures; the shale gas production in recent years has been due to modern technology in hydraulic fracturing to create effective artificial fractures around well bores. Horizontal drilling is also used with shale gas wells. The geological parameters for shale gas evaluation are thickness and areal extent thermal maturity, faults and fracture, type of organic matter and its richness, mineralogy, gas content /gas storage, adjacent water bearing formations etc.

2. Indian Shale Gas Scenario

India has large shale deposits across the Gangetic plain, Assam, Gujarat, Rajasthan, and many coastal areas. Shale gas has been found in large scale across the world, but due to shale,,s low permeability- gas does not flow easily through this rock, its extraction has been viewed as uneconomic.

Overall, estimatation a total of 584 Tcf of risked shale gas in-place for India.The risked, technically recoverable shale gas resource is estimated at 96 Tcf in India. India is the world"s 4^{th} largest consumer of energy, could be require as much as 96 trillion cubic feet (tcf) of recoverable shale gas reserves.

India contains a number of basins with organic-rich shales, mainly the Cambay, Krishna Godavari, Cauvery, and Damodar Valley basins. As per available data, six basins - Cambay (in Gujarat), Assam-Arakan (in the North-East), Gondawana (in central India), KG onshore (in Andhra Pradesh), Cauvery onshore and Indo-Gangetic basins,hold shale gas potential. There are some other potential reserves such as the Upper Assam, Vindhyan, Parinhita- Godavari, and South Rewa. But production of shale remains a long way from this basins because it was found that either the shales were thermally too immature for gas or the data with which to conduct a resource assessment were not available.

Huge potential of shale gas within the Upper Paleocene to Middle Eocene Cambay Shale in Cambay Basin; Upper Jurassic to Cretaceous Raghavapuram Shale and its stratigraphic equivalents in Krishna Godavari Basin; Lower to Upper Cretaceous Andimadam and Sattapadi Shales in Cauvery Basin and Barren Measures Shale in Damodar Basin.

Shale basins in India are geologically complex. Cambay basin have horst and graben structures and are extensively faulted. The prospective area for shale gas in cambay and cauvery basins is restricted to a series of isolated basin depressions (sub-basins).

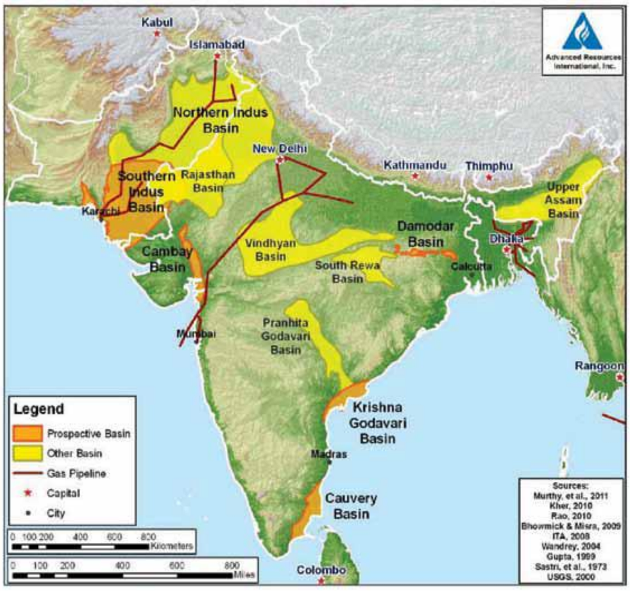


Figure 1: Distribution of Identified shale gas Basins in India(EIA-2011)

A. Cambay Basin

Cambay basin contains Area of 56,000 sq. km between 21° - 25°N and 71°30' -79°30'E.Cambay basin is an Intracratonic basin in the form of N – S (NNW – SSE) trending graben flanked in the East by Aravalli and Deccan Plateau and in the West by Saurashtra plateau. Age of cambay basin ranging from Eocene to Recent deposits, Tertiary with mainly clastic sediments.The Cambay Basin is an elongated, intra-cratonic rift basin ,located in the State of Gujarat in northwest India. The basin contains main four assessed faultblocks: Mehsana-Ahmedabad, Tarapur, Broach and Narmada.

Cambay basin contains Precambrian basement (igneous and metamorphic rocks) the Deccan Trap, composed of horizontal lava flows, forms the basement of the Cambay Basin. Above the Deccan Trap, there is the Olpad Formation, the Late Paleocene and Early Eocene Cambay Black Shale. The Cambay Black Shale represents the marine transgressive episode in the basin. thermal maturity of cambay shale ranging from about 0.7% to 2%.

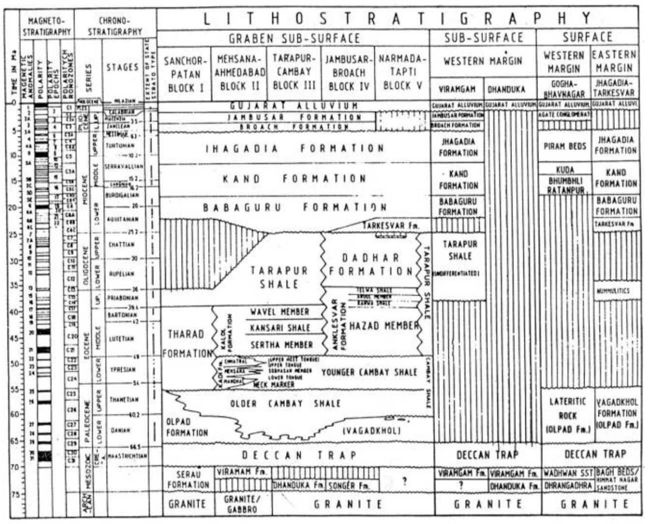


Figure 2: General stratigraphic column of the Cambay Basin (after Sivan et al., 2008).

- **Prospective of Cambay basin**

The depth of the Cambay Black Shale ranges from about 6,000 ft in the north to 16,400 ft in the lows of the southern fault blocks. Thermal gradients are high, estimated at 3oF per 100 feet,providing high thermal maturity to the organics. The Cambay Black Shale interval ranges from 1,500 to more than 5,000 ft .The Kadi Formation forms an intervening 1,000-ft thick non-marine clastic wedge within the Cambay Black Shale interval. Cambay shale contains kerogen type primarily of Type II and Type III (terrestrial) with a TOC that ranges from 2% to 4%, averaging 2.6%. The shale formation is moderately over-pressured and contain medium clay content. Within the overall 1,940-mi2 Cambay Black Shale prospective area in the Cambay Basin, approximate a 580-mi2 area contain prospect for dry gas.

- **Resource**

The Cambay Black Shale contains 228 Bcf/mi2 of shale gas in its 580-mi2 dry gas prospective area; 170 Bcf/mi2 of wet gas and 19 million barrels/mi2 of condensate in the 300-mi2 wet gas/condensate prospective area; and 80 million barrels/mi2 of shale oil (plus associated gas) in the 1,060-mi2 oil prospective area. Cambay Black Shale contains risked resource in-place of 146 Tcf for shale gas and has 30 Tcf of risked, technically recoverable shale gas.

B. Krishna-Godavari Basin

Krishna Godavari basin is a pericratonic basin on the east coast between 15° and 17° north latitudes. The Krishna-Godavari Basin covers a 7,800 mi2 area on land and the offshore area also. The 4,340 mi2 prospective area of the Kommugudem Shale is limited to four grabens where the thermal maturity is sufficiently high for wet to dry gas generation. KG basin has resource concentration of 156 BCF/mi2, total shale gas was estimated at 136 TCF with technically recoverable amount of 27 TCF.

The KG basin has a series of organic-rich shales, including the Triassic-age Mandapeta Shale and Permian-age Kommugudem Shale. These shale contains Type III. Kerogen , which is gas prone.These shale contains thermal maturities ranging from 0.7% to 2% Ro.

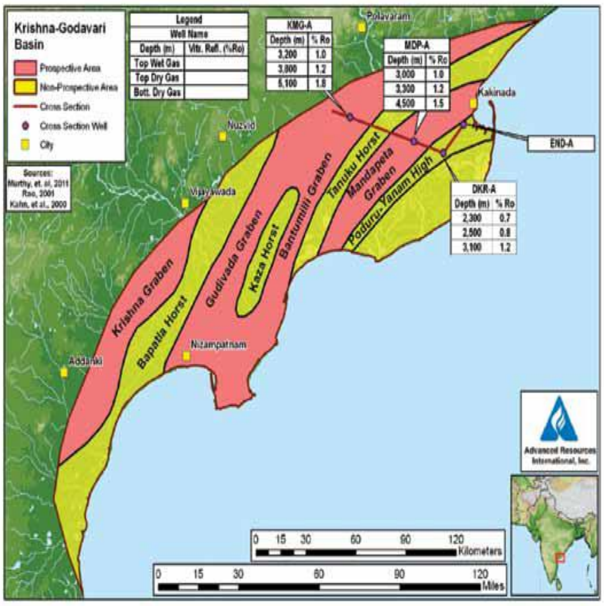


Figure 3: Prospect for shale gas in Krishna-Godavari Basin (Source: US EIA 2011)

As describe above KG basin has shale of two different age:-

- **Permian-Triassic Shale**

The Kommugudem Shale is a thick Permian-age rock containing alternate sequences of carbonaceous shale, claystone, sand and coal. It is the lower unit of the Permian-Triassic Shale. The Mandapeta Graben is the most explored area of the Krishna-Godavari Basin.

The deposition of the Kommugudem Shale was in fluvial, lower deltaic, and acustrine environments. Analysis of the shale gives low S2 values from pyrolysis which indicates high levels of primary inertinite and hydrogen-deficient organic matter. Vitrinite reflectance of the Permian-Triassic Shale ranges from 0.7% to 2% Ro. Permian-Triassic Shale has normal pressure gradient. The reservoir contains moderate to high clay content based on its lacustrine deposition. The interval thickness of shale ranges from 945 to 1,065 m in thickness. The TOC content of the Kommugudem Shale varies from 3% to 9%.

- **Raghavapuram Shale**

The Cretaceous-age Raghavapuram Shale provides an additional potential shale resource in the Krishna-Godavari Basin. The Upper Cretaceous Raghavapuram Shale and the shallower Paleocene- and Eocene-age shales are in the oil window. The TOC of this shale unit ranges from 0.8% to 6.4%. The shale becomes thermally mature around 440 to 475o C. Krishna-Godavari Basin has risked shale gas in-place of 381 Tcf, with 57 Tcf as the risked, technically recoverable shale gas resource.

C. Cauvery Basin

The Cauvery basin covers an onshore of 25,000 km2 on the onshore and 30,000km2 in the offshore. It Occupies most of the coastal plains of Tamil Nadu and Pondicherry and extends offshore into the Bay of Bengal (8°30' – 12°12' N; 78°30' – 80°30' E). The cauvery basin contains large numbers of horsts and grabens.It also contain thick organicrich source rocks in the Lower Cretaceous Andimadam Formation and Sattapadi Shale.

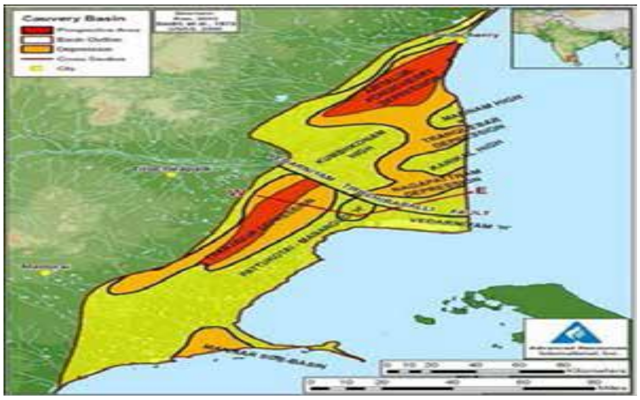


Figure 4: Location map of Cauvery Basin(source :EIA-2011)

The shale resource prospective area of the Cauvery Basin is limited to four depressions.

1) Nagapattnam
2) Tranquebar
3) Ariyalur-Pondicherry and Thanjavur
4) Mannar Sub-basin.

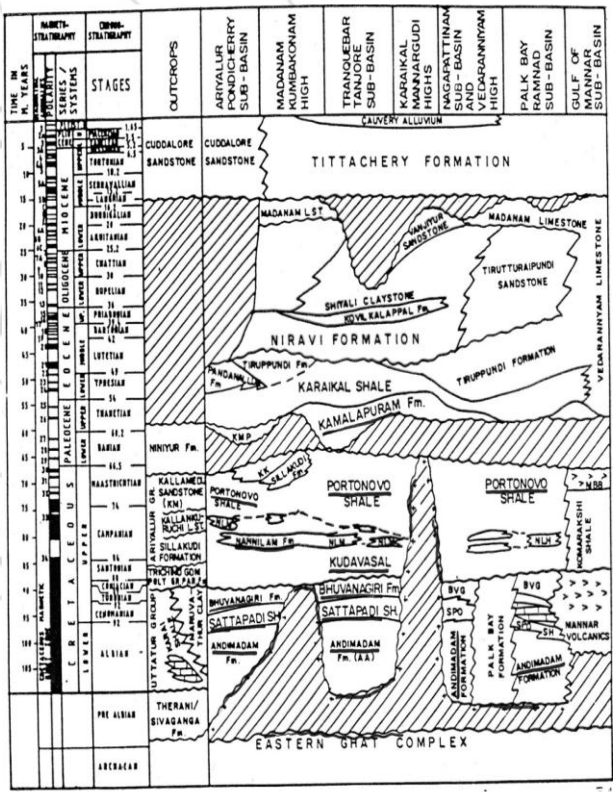


Figure 5: Stratigraphic succession of Cauvery Basin

The source rock is generally Type III along with Type II. The oldest rocks are the shallow marine, Late Jurassic sediments and Early Cretaceous deposits. The thickness of the Lower Cretaceous interval is 3,000 to 5,000 feet. The TOC of Cauvery Shale is estimated at 2% to 2.5%, averaging 2.3%.

As we discussed about four depressions of Cauvery basin , Two of these sub-basins are Ariyalur-Pondicherry and Thanjavur contains thermally mature shales. Organic-rich gross pay thickness is 1,000 ft in Ariyalur-Pondicherry sub-basin with net pay of about 500 ft. The thermal maturity of Ariyalur-Pondicherry is 1.0% to 1.3% Ro. The organic-rich average net pay thickness of Thanjavur sub-basin is 500 ft.The TOC and thermal maturity for the shale in this sub-basin(Thanjavur) is the same as in the Ariyalur-Pondicherry Sub-basin.

The inplace shale gas in Cauvery basin is calculated as 43 TCF, of which 9 TCF is considered as technically recoverable.

D. Damodar Valley Basin:

After the Cambay basin, the Damodar Valley basin has highest prospect for the exploration and production of shale gas. The Damodar Valley Basin is part of a group of basins collectively named the "Gondwanas",This basin has Permo-Carboniferious through Triassic deposition. The Damodar Basin is a Permian basin that has huge thickness of organic rich shale in Barakar and Barren formation. The Barren formations have good hydrocarbon potential with low hydrogen index. It contains gas-prone type-III organic matter. The formation thickness varies up to 1200 m in the deepest part.Damodar valley basin has average TOC content varying from 4.2 to 6.6%. Thermal maturity of Barren Measure Shale ranging from 1.1% to 1.3% Ro. It contains shale within the wet gas/condensate window The shale in Barakar formation has higher TOC values ranging from 4.40 - 8.29 %. The basin contains a resource concentration of 123 BCF/m2 with approximately 7 TCF of technically recoverable shale gas.

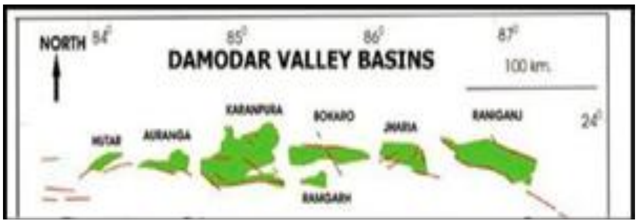


Figure 6: Distribution of Damodar Valley Basin sub basins

The Damodar Valley Basin has a series of sub-basins - - the Hutar, Daltonganj, Auranga, Karanpura, Ramgarh, Bokaro, Jharia and Raniganj. Though these sub-basins share a similar geologic history, tectonic events and erosion since the early Triassic have caused extensive variability in the depth and thickness of the Barren Measure Shale in these basins.

Table 1: Different shale properties in different shale gas prospective and resource potential of India. (Source: ARI and US EIA 2011)

			Cambay			Krishna-Godavari			Cauvery	Damodar Valley
Basic Data	Basin/Gross Area		Cambay ($7,900\ mi^2$)			Krishna-Godavari ($7,800\ mi^2$)			Cauvery ($9,100\ mi^2$)	Damodar Valley ($2,270\ mi^2$)
	Shale Formation		Cambay Shale			Permian-Triassic			Sattapadi-Andimadam	Barren Measure
	Geologic Age		U. Cretaceous-Tertiary			Permian-Triassic			Cretaceous	Permian-Triassic
	Depositional Environment		Marine			Marine			Marine	Marine
Physical Extent	Prospective Area (mi^2)		1,060	300	580	1,100	3,900	3,000	1,010	1,080
	Thickness (ft)	Organically Rich	1,500	1,500	1,500	330	500	1,300	1,000	1,000
		Net	500	500	500	100	150	390	500	250
	Depth (ft)	Interval	6,000 - 10,000	10,000 - 13,000	13,000 - 16,400	4,000 - 6,000	6,000 - 10,000	10,000 - 16,400	7,000 - 13,000	3,300 - 6,600
		Average	8,000	11,500	14,500	5,000	8,000	13,000	10,000	5,000
Reservoir Properties	Reservoir Pressure		Mod. Overpress.	Mod. Overpress.	Mod. Overpress.	Normal	Normal	Normal	Normal	Slightly Overpress.
	Average TOC (wt. %)		2.6%	2.6%	2.6%	6.0%	6.0%	6.0%	2.3%	3.5%
	Thermal Maturity (% Ro)		0.85%	1.15%	1.80%	0.85%	1.15%	1.50%	1.15%	1.20%
	Clay Content		Low/Medium	Low/Medium	Low/Medium	High	High	High	High	High
Resource	Gas Phase		Assoc. Gas	Wet Gas	Dry Gas	Assoc. Gas	Wet Gas	Dry Gas	Wet Gas	Wet Gas
	GIP Concentration (Bcf/mi^2)		55.9	170.5	228.0	6.9	57.8	204.7	119.6	62.9
	Risked GIP (Tcf)		35.5	30.7	79.4	3.4	101.4	276.4	30.2	27.2
	Risked Recoverable (Tcf)		3.6	6.1	19.8	0.2	15.2	41.5	4.5	5.4

3. Other Basin

A. Upper Assam Basin

The Upper Assam basin is a very important petroleum province in the northeast India, The TOC content in the lower source rocks varies from 1 to 2%, and reaches up to 10% in the Barail Group.The vitrinite reflectance range from 0.5 to 0.7% for the Kopili formations and from 0.45% to 0.7% for the Barail Group

B. Vindhyan Basin

The Vindhyan basin in the north of central India contains a series of Proterozoic-age shales. Pulkovar shales appear to have some organicrich matter. Toc for this formation range from 0.5 to 3.8%. Sandstone, shale and limestone are deposited in marine environment. Presence of algal origin fungi, acritarch remains and stromatolites in this basin suggests the organic matter as Type-I and Type-II.

C. Rajasthan Basin

The Rajasthan basin covers a large part of the northwest India. The basin is structurally complex and characterized by numerous small fault blocks. The Permian-age Karampur Formation is the primary source rock, which is a Type III and classified as mature.

4. Shale Gas Prospect in USA

Figure 7: Prospective Shale Basins of Northern South America (source ARI 2013)

Three main basins are present in northern South America that contain prospective marine-deposited shales.

A. Middle Magdalena Valley Basin (Colombia)

The focus of shale exploration leasing and drilling activity in the region thus far, the MMVB near Bogota also is Colombia‟s main conventional onshore production area. It contains thick deposits of the organic-rich. Cretaceous La Luna Formation, mostly in the oil to wet gas windows.

B. Llanos Basin (Colombia):

This large basin in eastern Colombia has prospective Gacheta Formation source rock shales of Cretaceous age that are equivalent to the La Luna Fm. TOC and Ro generally appear low, but the western foothills region may be richer and more thermally mature.

C. Maracaibo/Catatumbo Basin (Venezuela and Colombia)

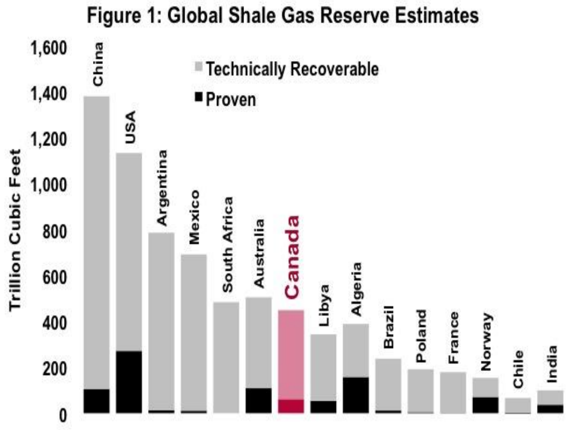
One of South America‟s richest petroleum basins, the Maracaibo (Venezuela) and Catatumbo (Colombia) basins have extensive oil and gas potential in thick, widespread Cretaceous La Luna Shale.

A fourth basin, the **Putamayo Basin** in southern Colombia, also may contain shale potential but was not assessed due to lack of data.

5. Comparison of Shale Gas Reserves of India and USA

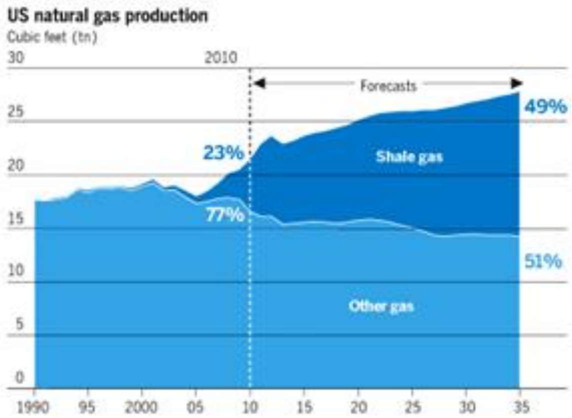
According to the data published in 2011, global shale gas reserves from an assessment of 48 shale gas basins in 32 countries made by the US Energy Information Agency. The EIA estimates that over 6,600 Tcf of shale gas resources are estimated to be technically recoverable.

According to the data published by the scientist of National Geophysical Research Institute the total amount of shale gas in 28 sedimentary basins of India is around 527 tcf out of which only 63 tcf of the reserves is found to be recoverable which gives an indication of future energy resource of around 20 years at current consumption rate.



Source: urbanomics blogs

It can be concluded from graph that many of the shale reservoirs are already explored in U.S. till now. Whereas in India experts supposed that it‟s needed to accurately explore shale gas because mainly shale gas reserves have found in eastern and western part of the country but it is predicted to have some isolated shale gas reserves in central India.

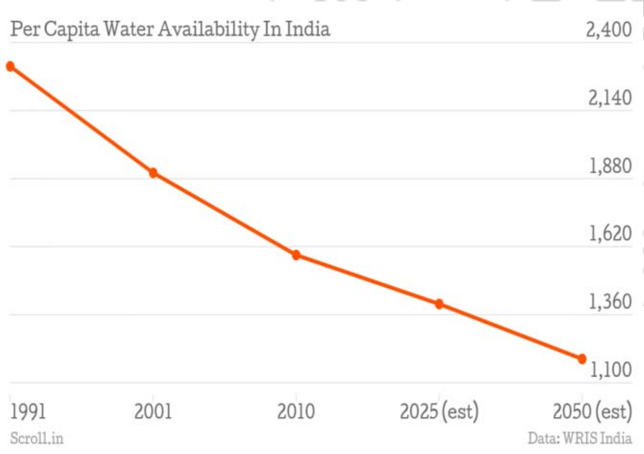


With the advance of extraction technology, shale gas production has led to a new abundance of natural gas supply in the United States over the past decade, and is expected to continue to do so for the foreseeable future. It is estimated that the shale as production will raise from 23% in 2010 to 49% in 2035 and parallely production of other gas would decreases to a considerable amount. Whereas India is still on the way to start shale gas exploration and some exploratory wells have been drilled.

6. Reason for Less Shale Gas Production in India

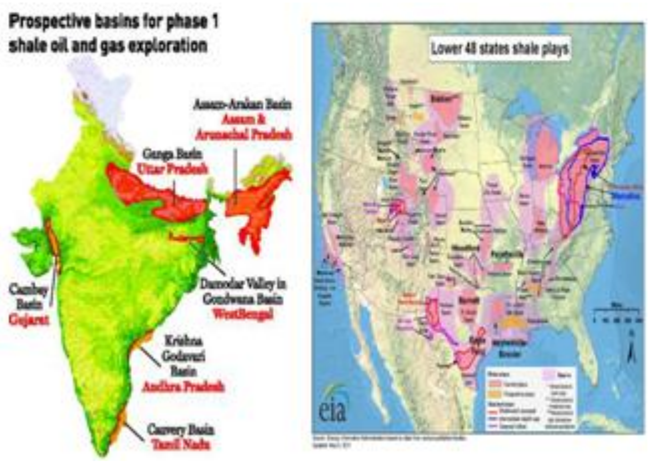
- Cost of field development operation**:-**The cost of drilling and completing in India is around 2.5-5 times higher than what in US may be due to less infrastructure and government support in terms of subsidities. Ex:- Cairn Energy would develop the Barmer oil fields with an investment of about Rs.22.5 billion. It is expected that Rs.27.5 million worth oil per day would be produced from the oil field.
- Lack of fiscal incentives and infrastructure :- Unlike the USA and Canada, most countries have so far not offered significant fiscal incentives.

- Inabilities to experiments with wellbore **:-** Reservoir study in US is built around the need to experiment with the wellbore – a process of trial and error. But Asian based companies think differently and they applies much of the engineering prospective based on the actual performance of the wellbore.
- Lack of political will **:-** There are considerable political differences among many of the countries in this region - so much so that some of the countries have actually been to war with each other in the recent memory. Apart from this corruption, bureaucracy, political instability, and prohibitive customs regulations all mean that operations are often significantly delayed or cancelled altogether.
- Competition from alternative sources :- Companies need to face a huge market competition from existing products and also due to the monopoly of gas rich countries.
- Water crisis**:** - In the process of hydrofracturing high amount of chemically-treated water is being used to create the fractures in the shale deposits which are brought back to the surface at the time of production which can not be used even for further hydrofracturing. India suffers from physical and economic water scarcity. The energy and resource institute (TERI) demonstrates that India is already a water-stressed country and is fast approaching the scarcity benchmark of 1,000 m3 per capita with unabated growth in the irrigation sector. It is estimated that in the next 12-15 years, while the consumption of water will increase by over 50 per cent, the supply will increase by only 5 to 10 per cent, leading to a water scarcity situation. Whereas the U.S. do not have the same water worries. Thus water crisis is also a point of consideration while dealing with the hydrofracturing and develop the processes for the reuse of the chemically-treated water.



A complication to shale gas in India is that the government-issued leases for conventional petroleum exploration do not include unconventional sources such as shale gas. However, this policy now has been changed under the Hydrocarbon exploration and licensing policy, which provides a uniform license for exploration of conventional and unconventional oil and gas resources and includes private participation.

- **Geology related problems:-**



Sources: National Petroleum Council

Totally 8 basins have been found in India. Shale gas basins in India are geologically highly complex and India does not have such a developed technology that the highly complex shale gas is easily produced. As we discusses above any of the basins, such as the Cambay and the Cauvery, have horst and graben structures and are extensively faulted. The prospective area for shale gas in these basins is restricted to a series of isolated basin depressions (sub-basins). While the shales in these basins are thick, considerable uncertainty exists as to whether (and what interval) of the shale is sufficiently mature for gas generation. ONGC in collaboration with schlumberger had drilled four pilot wells in Damodar basin which produced shale gas from Barren Measure formation of Permian age in the last week of September 2010 which is estimated to have a shale gas potential of 7 TCF (trillion cubic feet). The main target Barren measure shale gas was encountered from 985 to 1843 meters. Gas flowed from an interval at a depth of around 1700m in narren measure shale after hydrofracturing.

Four basins namely, Cambey , Krishna Godavari, Cauvery and Damodar are currently in focus for shale gas exploration. Other Indian sedimentary basins such as Assam, Bengal, Pranhita Godavari, South Rewa, and Satpura basins are merit attention for shale gas exploration.

Totally 48 shale gas plays have been found in USA. Among the top seven plays, four had already peaked to their maximum production. USA is technically well developed and the geology of the shale basins are also not such complex. Here we can see from the map that most of the basin boundaries are more or less connected to each others many of them are on-shore basins. Most of the basins have such a high amount of shale gas comparable to the shale gas basins in India.

7. Recent Shale Gas Developments in India

Government of India along with the Indian companies, is undertaking undertaking various initiatives for development of shale gas reverses. As a part of this initiative, the government has set up multi-organizational team (MOT) comprising directorate general of hydrocarbon (DGH), ONGC , OIL , GAIL for analyzing the existing data set and suggesting a methodology for shale gas development in India.

ONGC had drilled the first well in Jambusar in October 2013 to explore the natural gas trapped within the shale formations located in Cambay basin. 16 wells that have been drilled at the Mandapeta Graben (K.G. basin) into the Permian-Triassic Shale in search for hydrocarbons. In late September 2010, Indian National Oil and Gas Company (ONGC) spudded the country‟s first shale gas well, RNSG-1, in the Raniganj sub-basin of the Damodar Valley. The Shale gas exploration activities are being carried out along with ConocoPhilips, a US-based oil company.

8. Conclusion

Shale gas is definitely an opportunity and if explored and exploited effectively, it could fulfil the major energy requirement of the country. The unlocking of domestic shale gas can help India meet its growing energy demand, besides reducing its dependence on expensive energy imports and the energy import bill. Taking a note from the impact of shale gas development in the USA, the development of the sector can help increase economic activity in the country, thereby boosting government revenues and creating new jobs.

The shale gas resources in India were untapped due to lack of technological knowledge, expensive tools and technology, socio-political conditions of the country, lack of R&D facilities and its funding etc. However, with the advent of new technologies and the growing energy needs coupled with appropriate market prices and policies make this time right to explore & exploit this resource on equal priority.

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