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# India: Inching towards an Unconventional Regime

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***Summary***

*It has been more than a decade since the rolling out of New Exploration Licensing Policy (NELP) in India. NELP was brought in with the twin objective of ushering in the much needed investment in the cost intensive exploration sector as well as to extensively spread out the exploration activities across the sedimentary basins of India. What was at the back of the whole exercise was the much desired energy security of India.*

*Ten years later, today if we analyze the situation, we definitely see some headway been made; in terms of exploration spread, a few significant discoveries and increase in the number of E&P players operating in the country.*

*Incidentally, this was also the decade which witnessed the maximum growth for the Indian economy resulting in soaring consumption. The demand-supply gap went larger.*

*Advent of NELP was expected to yield big results from the unexplored and under-explored onland frontier areas & deep water sectors. Today, with mixed bag success in the deep water and the frontiers remaining frontiers, the country's upstream sector is looking towards the unconventional marvels like shale gas and oil shale deposits of the country; as these resources have been the game changer in countries like USA. The policy makers are in the process of finalizing another milestone regime very shortly in order to bring India in the 'unconventional policy regime' in a big way.*

*This paper attempts to take a stock of the situation and offers a few suggestions.*

***Keywords:*** *NELP Success, Gas Demand, Shale Gas, Policy Regime*

## Introduction

From a real GDP growth rate of 4.4% in year 2000, India posted a GDP growth of 10.4% in year 2010 with promises to remain one of the fastest growing economies of the world. This economic growth demanded more energy consumption and while India's oil consumption grew from 2.26 million barrels per day in 2000 to 3.32 million barrels per day in 2010, its natural gas consumption rose from 26.4 billion cubic meters in 2000 to 61.9 billion cubic meter at the end of year 2010 (source : BP Statistical Review, 2011). Unfortunately, the domestic production scenario could not match the burgeoning demand graph.

During this period, the crude oil production in the country saw a growth from 0.73 million barrels per day to 0.83 million barrels per day. Though the scenario was brighter in the natural gas production; from 26.4 billion cubic meters to 50.9 billion cubic meters, there was still a shortfall with respect to demand.

Let us have a quick reality check of the NELP journey so far. The unexplored area in terms of total sedimentary basinal area has reduced to 12% in 2010 from 41% in 1999 and well explored area has increased from 15% to 22% during the period (source DGH Annual Reports 1999 to 2010). This in itself is quite an achievement. But when we look at the two critical sectors of onland frontier basins and deep / ultra deep water sector, the results do not appear that bright as the estimated resources could not be converted to In-place volume of hydrocarbons to the desired extent.

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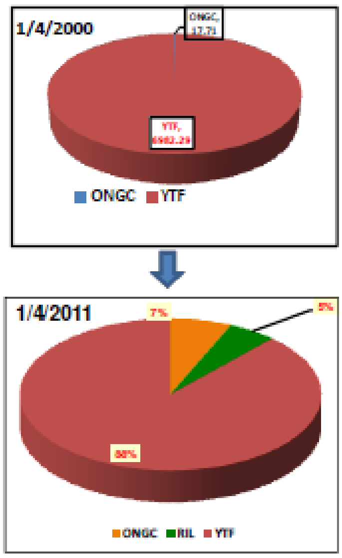


Figure 1: Deepwater Exploration Dynamics in India

The resources estimated in just five onland basins (Kutch, Ganga Valley, Bengal, Himalayan Foreland & Mahanadi) where commercial hydrocarbons have not been discovered was 795 MMt at the launch of NELP in 1999 (source DGH Annual Reports); more than a decade later not even a fraction of this resource could be converted to In place volume of hydrocarbons.

The deep water sector has an estimated resource of 7000 MMt. With a decade of rigorous exploration and more than a hundred wells being drilled by both NOC and private operator, notwithstanding the discoveries, the resource conversion stands at about 11-12% only (Fig-1).

A large chunk of this resource up gradation is again restricted to Krishna-Godavari Basin only with some contribution from Mahanadi-NEC sector.

Looking at the demand scenario, as per the projections made by Oil Ministry for the 12th Five Year Plan (2012-13 to 2016-17), current gas demand of 189 mmscmd is likely to rise to 473 mmscmd. The overall demand would grow from 293 mmscmd (in 2012-13) to 473 mmscmd (in 2016-17) over the 12th plan period and from 494 mmscmd (in 2017-18) to 606 mmscmd (in 2021-22) over the 13th plan period, according to the projections.

This forces the Indian upstream community as well as the policy makers to look for alternate sources of natural gas and what better priority can there be than the shale gas which has revolutionized the energy mix in USA during past one decade.

## Shale Gas Resources of India

According to an independent study initiated by US Energy Information Administration, shales in Indian sedimentary basins have significant resources for shale gas exploration (Fig-2). The study assessed four priority basins: Cambay, Krishna Godavari, Cauvery and the Damodar Valley sub-basins such as Raniganj, Jharia and Bokaro.

Several other basins of India, e.g., Assam Foreland, Vindhyan, Pranhita-Godavari and South Rewa was also studied, but it was observed that the shale in these basins were either thermally too immature for gas or the data used for resource assessment was inadequate. Further, some of these basins are geologically highly complex. Cambay and Cauvery basins 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. While the shale in these basins is thick, some uncertainty does exist as to whether the shale is sufficiently mature for gas generation and if so, then at what intervals.

Recently, ONGC drilled and completed the India’s first shale gas well near Durgapur in West Bengal. The well was drilled to a depth of 2,000 meters and had gas shows at the base of the Permian-age Barren Measure Shale. Two vertical wells (Well D-A and D-B) were previously tested in the Cambay Basin and had modest shale gas production in the shallow intervals of the Cambay “Black Shale”.

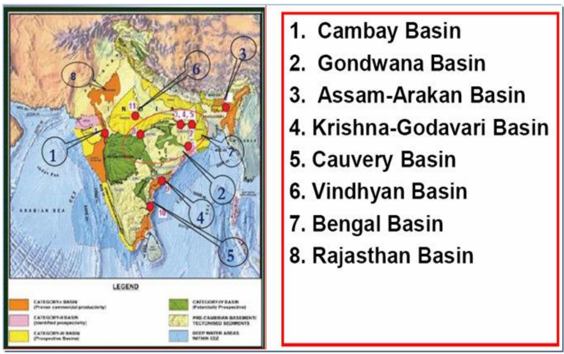


Figure 2: Potential Shale Gas Basins of India

The following table summarizes details of the shale gas reservoir properties of the shale studied in four major basins of India.

| | Basin/Gross Area | | Cambay Basin (20,000 $mi^2$) | Damodar Valley Basin (1,410 $mi^2$) | Krishna-Godavari Basin (7,800 $mi^2$) | Cauvery Basin (9,100 $mi^2$) |
|---|---|---|---|---|---|---|
| Basic Data | Shale Formation | | Cambay Shale | Barren Measure | Kommugudem Shale | Andimadam Formation |
| | Geologic Age | | Upper Cretaceous/Tertiary | Permian-Triassic | Permian | Cretaceous |
| Physical Extent | Prospective Area ($mi^2$) | | 940 | 1,080 | 4,340 | 1,005 |
| | Thickness (ft) | Interval | 1,600 - 4,900 | 0 - 2,100 | 3,100 - 3,500 | 600 - 1,200 |
| | | Organically Rich | 1,500 | 1,050 | 1,000 | 800 |
| | | Net | 500 | 368 | 300 | 400 |
| | Depth (ft) | Interval | 11,500 - 16,400 | 3,280 - 6,560 | 6,200 - 13,900 | 7,000 - 13,000 |
| | | Average | 13,000 | 4,920 | 11,500 | 10,000 |
| Reservoir Properties | Reservoir Pressure | | Moderatly Overpressured | Moderatly Overpressured | Normal | Normal |
| | Average TOC (wt. %) | | 3.0% | 4.5% | 6.0% | 2.0% |
| | Thermal Maturity (%Ro) | | 1.10% | 1.20% | 1.60% | 1.15% |
| | Clay Content | | Medium | HIgh | High | High |
| Resource | GIP Concentration (Bcf/$mi^2$) | | 231 | 123 | 156 | 143 |
| | Risked GIP (Tcf) | | 78 | 33 | 136 | 43 |
| | Risked Recoverable (Tcf) | | 20 | 7 | 27 | 9 |

Figure 3: Shale Gas Reservoir Properties and Resources of India (Source: World Shale Gas Resources: An initial assessment of 14 regions outside USA).

ARI (Advanced Resources International, Inc) study (February, 2011) estimates a total of 290 Tcf of Shale Gas resources in India. Out of this, technically recoverable shale gas resource is estimated at 63 Tcf as on date. However, these estimates are initial estimates and could definitely increase with collection of additional reservoir information and progress of shale gas exploration.

## Shale Gas Exploration - Technical Issues

One aspect which is essential to keep in mind at the very outset is that the term ‘shale’ is used very loosely by the industry and—by intent—does not describe the lithology of the reservoir. Lithological variations in American shale gas reservoirs, which are the pioneers of this global effort, indicate that natural gas is hosted not only in shale but also a wide spectrum of lithology and texture from siltstone to fine-grained sandstone, any of which may be of siliceous or carbonaceous in nature. Much of what is described as shale is often siltstone, or encompasses multiple rock types, such as siltstone or sandstone laminations inter-bedded with shale laminations or beds.

The lack of a strict definition for shale causes an additional degree of difficulty for resource evaluation. The variety of rock types observed in organic-rich ‘shale’ implies the presence of a range of different types of ‘shale gas’ reservoirs. Each reservoir may have distinct geochemical and geological characteristics that may require equally unique methods of drilling, completion, production and resource and reserve evaluation, as indicated by American experience over approximately the last 20 years. This is also true of the shales in Indian sedimentary basins and needs to be incorporated in any shale gas exploration programme.

## What Makes a Shale Gas Play?

A thorough understanding of the fundamental geochemical and geological attributes of ‘shale’ is essential for resource assessment, exploration and development.

Four properties that are important characteristics in each shale gas play are:

1) maturity of the organic matter;
2) type of gas generated and stored in the reservoir (i.e., biogenic or thermogenic);
3) TOC content of the strata; and
4) Permeability of the reservoir

Total organic carbon (TOC) is a fundamental attribute of gas shale and is a measure of present-day organic richness. The TOC content, together with the thickness of organic shale and organic maturity, are key attributes which determines the economic viability of a shale gas play.

However, there is no unique combination or minimum amount to determine economic viability. The factors are highly variable between shale of different ages and can vary, in fact, within a single deposit or stratum of shale over short distances. At the low end of these factors, there is very little gas generated. At higher values, more gas is generated and stored in the shale, provided, it has not been expelled. Such shale can be a target for exploration and production.

Gas from shale is generated in two different ways, thermogenic or biogenic, although a mixture of gas types is also possible:

• Thermogenic gas is generated from cracking of organic matter or the secondary cracking of oil. This gas is associated with mature organic matter which has been subjected to relatively high temperature & pressure in order to generate hydrocarbons. In general, more mature organic matter should generate higher gas-in- place resources than less mature organic matter, all other factors being equal.

• Biogenic gas can be associated with either mature or immature organic matter and can add substantially to shale gas reserves. In the Antrim shale gas field in Michigan, biogenic gas is generated from microbes in areas of fresh water recharge.

Shale, in particular, exhibits permeability lower than Coal Bed (for CBM) or tight gas and, because of this, forms the source and seal of many conventional oil and gas pools. Hence, not all shale is capable of sustaining an economic rate of production. In this respect, permeability of the shale matrix is the most important parameter influencing sustainable shale gas. To sustain yearly production, gas must diffuse from the low-permeability matrix to induced or natural fractures. Generally, higher matrix permeability results in a higher rate of diffusion to fractures and a higher rate of flow to the wellbore.

Furthermore, more fractured shale with sufficient matrix permeability should result in higher production rates, a greater recovery of hydrocarbons and a larger drainage area.

An additional factor to consider is shale thickness. The substantial thickness of shale is one of the primary reasons, coupled with a large surface area of fine-grained sediment and organic matter for adsorption of gas. That is why shale resource evaluations yield such high values. Thus, a general rule is that thicker shale is a better target.

The required thickness to economically develop a shale gas target may decrease as drilling and completion techniques improve, as porosity and permeability detection techniques progress in unconventional targets and, perhaps, as the price of gas increases. Such a situation would add a substantial amount of resources and reserves to the basins.

A quick look at the available data on these crucial parameters with respect to Indian shale reveals that,

1. In Cambay Basin, the average depth of occurrence of the Cambay shale is about 1500 m. The thickness varies from 500 m to 1000m with TOC ranging from 2 to 10% and VR0 from 0.5 to 0.9 % (Fig-4).

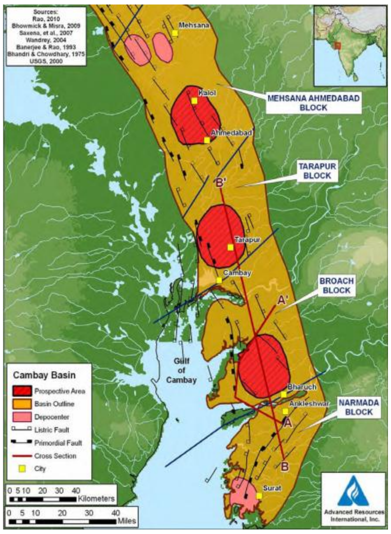


Figure 4: Prospective areas for Shale Gas, Cambay Basin.

2. In the Krishna-Godavari Basin, depth of occurrence of Raghavapuram Shale is between 800m to 2100 m with TOC varying from 1 to 13% and VRO ranging from 0.9 to 1.3%. The thickness ranges from 900 m to 2000m (Fig-5).

3. Satapadi Shale of Cauvery occurs between 1600 to 2300m with maximum thickness reaching 300m. The TOC ranges from 1 to 1.5% and VRO 0.45 to 1.15% (Fig-6).

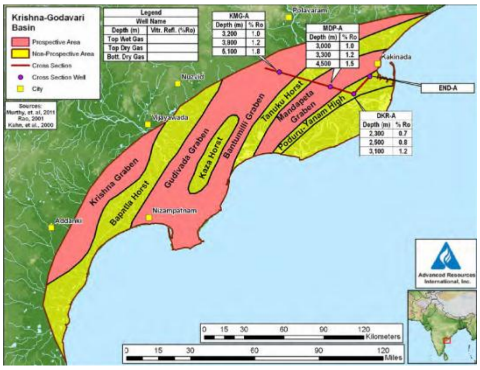


Figure 5: Prospective areas for Shale Gas, Krishna-Godavari Basin

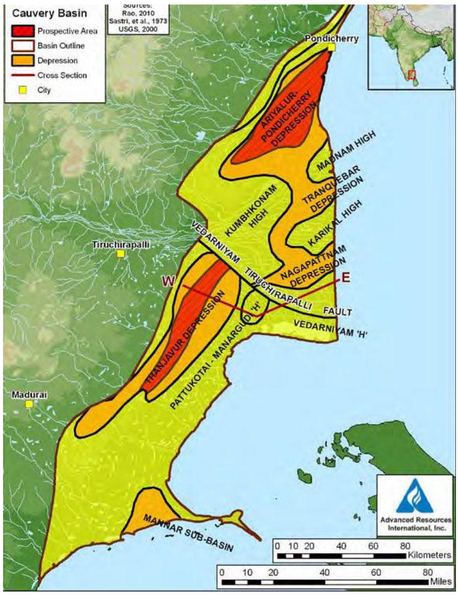


Figure 6: Prospective Areas for Shale Gas, Cauvery Basin

## Regulatory and other issues (with North America as analogy) (ref-2)

In the U.S.A, development and production of shale gas, is regulated under a complex set of federal, state, and local laws that address every aspect of exploration and operation. The US Environmental Protection Agency (EPA) administers most of the federal laws, although development on federally owned land is managed primarily by the Bureau of Land Management (BLM), which is part of the Department of the Interior, and the U.S. Forest Service, which is part of the Department of Agriculture. In addition, each state has one or more regulatory agencies that permit wells, including their design, location, spacing, operation, and abandonment, as well as environmental activities and discharges, including water management and disposal, waste management and disposal, air emissions, underground injection, wildlife impacts, surface disturbance, and worker health and safety. Many of the federal laws are implemented by the states under agreements and plans approved by the appropriate federal agencies.

**1. Land:** In USA, the pathfinder in Shale gas exploration and development, leasing public lands for oil and gas development is based on multiple-use/sustained yield Resource Management Plans (RMPs) prepared by the BLM which offers public land with oil and gas potential for competitive leasing each quarter. The BLM administers oil and gas leasing and development on federally owned minerals both for BLM lands and on behalf of the U.S. Forest Service.

At this point of time, there is no agency like BLM in our country. Thus multiple-use of land for sub-surface resources is an issue of immense debate. In areas like the Gondwana Basin in West Bengal and Jharkhand, coal and CBM production operations from the same land has brought out this issue. With the likelihood of 'shale gas' joining the bandwagon in this basin, the complexity is likely to increase further.

In Cambay, Krishna-Godavari and Cauvery basins, the other likely candidates for shale gas exploration, conventional oil & gas activities are in a mature stage with a number of Petroleum Mining Leases granted by Govt. of India. Issuing exploration licenses for 'shale gas' in these areas in an open auction is another issue which needs to be settled beforehand.

**2. Water use and water disposal**: The drilling and hydraulic fracturing of a horizontal shale gas well may typically require about 10,000 to 20,000 m3of water. Water for drilling and hydraulic fracturing of these wells frequently comes from surface water bodies such as rivers and lakes, but can also come from ground water, municipal water, and re-used produced water. In any basin, one key to the successful development of shale gas is the identification of water supplies capable of meeting the needs for drilling and fracturing water without interfering with community needs.

After a hydraulic fracture treatment, when the pumping pressure is relieved from the well, some of the injected fluids remain trapped underground, but the majority of the injected water— 60% to 80%—returns to the surface as "flowback". It typically contains proppant (sand), chemical residue, and trace amounts of radioactive elements that naturally occur in many geologic formations. The operator must reclaim the temporary storage pits when the drilling and fracturing operations end. In addition, the well operator must separate, treat, and dispose the natural brine co-produced with gas. Underground injection has traditionally been the best option for shale gas produced water. In the event that underground injection is not feasible in the area the company may discharge the flowback to surface waters if the discharge does not violate a stream or lake's water quality standards. Re-use of fracturing fluids is being evaluated by service companies to determine the degree of treatment necessary for re-use

Again, in the USA, there are federal as well as state laws like Safe Drinking Water Act and Clean Water Act to deal with these issues objectively as well as stringently. In absence of any clear legislation, shale gas operations in the Indian sedimentary basins may pose problems both for water availability as well as water disposal.

**3. Air Pollution:** The exploration and production of shale gas may include a variety of potential air emission sources that change depending on the phase of operation. In the early phases of operation, emissions may come from such sources as drilling rigs whose engines may be fueled by either diesel or natural gas and from fracturing operations where multiple diesel- powered pumps are often used to achieve the necessary pressure. Once production has begun, emission sources may include compressors or pumps that may be needed to bring the produced gas up to the surface or up to pipeline pressure. Across the U.S., there is an active enforcement program to control air emissions from all sources, including the shale gas industry.

**4. Populated Areas:** When operations occur in or near populated areas, local governments may enforce rules to protect the general welfare of the citizens. These local rules might require additional permits for issues such as well placement in flood zones, noise level, set backs from residences or other protected sites, site house- keeping, and traffic.

### How other new entrant countries are proceeding?

**Canada:** The most significant interest and progress in the development of shale gas plays in Canada has occurred in the Province of British Columbia. This is reflected by the number of players that are active in the Province and the number of initiatives the Government of British Columbia has developed and implemented to encourage investment in shale gas development in that Province. The Government of Alberta has followed suit and has implemented a couple of initiatives to encourage shale as development. The approach followed in Alberta has been simply to use fundamental shale characteristics, such as TOC, organic maturity, fracturing and sedimentology, in productive areas in order to evaluate and categorize Alberta formations. Similarly, Ontario Geological Survey (OGS) has also initiated a project to assess the shale gas potential of southern Ontario. (ref-4)

**Poland:** Poland's shale gas reserves amount to 5.3 billion cubic metres. The Polish government has put into place very attractive fiscal terms for gas development, although infrastructure and regulatory issues remain as barriers to efficient development. Ministry of the Environment issued about 70 licenses to look for shale gas to companies such as Exxon Mobil, Chevron, Marathon, ConocoPhillips and PGNiG.

**China:** In terms of the shale gas occurring characteristic in China basins, four big provinces could be divided e.g., South China, North China, Northeastern China, and

Northwestern China. It has been estimated that the total technically recoverable Shale Gas resource is 1275 Tcf. China's shale-gas industry is in its infancy; with shale exploration drilling just now being initiated, public information on shale formations in China is quite limited. Innovative approaches to reservoir characterization and development are required to unlock the full potential that lies in such a geologically varied array of prospects. (ref-5)

**Australia:** In Australia, industry estimates are for as much as 400 Tcf of recoverable gas in total. The focus of the local industry over 2011 and 2012 will be to understand whether any of this gas can technically be produced. Cooper and Perth basins are best understood and there is existing production infrastructure and pipelines. Other prospective basins are the Canning, Georgina and Beetaloo, but less is known about rock quality, and production and transport infrastructure is absent. (ref-6)

## What is expected from the policy?

• The first point that comes to mind is whether this policy should be exclusively for 'Shale Gas' only or should include the 'Tight Gas' as well. As discussed under the technical issues, it is very difficult to segregate this type of reservoir on the basis of lithology strictly as a 'shale reservoir'. The only basic difference between 'tight gas reservoirs' and 'shale gas reservoirs' may be that tight gas reservoirs generally contain no organic matter.

• It is felt that at this initial stage itself, it may be prudent to factor in the shale gas and the tight gas reservoirs and their exploration/exploitation as two sub-groups in this policy. For declaring a reservoir as 'tight gas' permeability criteria can be utilized.

• As explained under the 'technical issues', there is a primary need to assess our sedimentary basins both in terms of 'shale gas potential' as well as 'tight gas potential' before the exploration blocks are carved out and offered for exploration.

• The growth in unconventional gas production in North America came from the subsurface knowledge-base and advancements in drilling complexity. Comprehensive knowledge of the geology of these two plays is a pre-requisite before embarking upon the actual exploration. Thus it is absolutely essential to generate the data-base.

• The aspect of multiple surface rights for various natural resources like coal, CBM, shale gas, tight gas etc. needs to be clearly addressed as most of the potential Shale gas plays are occurring in areas where commercial E&P activities of conventional oil & gas as well as CBM are going on.

• A two-pronged approach is suggested; for the basins, where conventional oil & gas exploration has generated enough G&G information over the years, e.g., Cambay Basin, KG onland Basin, Cauvery Basin, etc. This information in terms of 'shale gas and/or tight gas' prospectivity can be integrated into discrete dockets similar to Basin Information Docket / Data Package used for bidding for conventional oil & gas. Availability of such information would boost the investor's confidence.

• For basins where such information is not available in sufficient amount, Government may think initially of opening up of areas for some kind of a time-bound speculative survey by companies experienced in global shale gas ventures for carrying out the geological, geochemical and geophysical/petrophysical studies in order to assess the potential.

• A definitive approach built in the policy aimed towards tackling the issues of land, water, air pollution, operating in populated areas, etc., as mentioned above would be a welcome approach to avoid future litigations.

## References

BP Statistical Review of World Energy 2011

Modern Shale Gas: Development in the United States A Primer, U.S. Department of Energy, April, 2009

World Shale Gas Resources: An initial assessment of 14 regions outside USA, US Energy Information Administration

Alberta's New Royalty Framework, Global Economic Research, October 26, 2007

Geological Features and Exploration for Tight Sand Gas, Shale Gas and Other Unconventional Oil/Gas Resources in China, Cai-Neng Zou, Shi-Zhen Tao, Tang Ping, Xiao-Hui Gao, Zhi Yang, Qiu-Lin Guo, Da- Zhong Dong, and Xin-Jing Li, Search and Discovery Article No. 80135, February 21, 2011

Australia Oil & Gas, Morgan Stanley Research, Asia/Pacific, June 3, 2011

Petroleum Exploration and Production Activities; Annual DGH publications (1999 to 2010)

Various unpublished ONGC reports

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