ROLEOF UNCONVENTIONAL HYDROCARBON RESOURCES IN SHAPING THE ENERGY FUTURE OF INDIA

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Declaration by the Guide

This is to certify that the Mr. TARUN KUMAR, a student of MBA Oil & Gas management, SAP ID - 500064836 of UPES has successfully completed this dissertation report on "Role of Unconventional Hydrocarbon Resources in Shaping the Energy Future of India" under my supervision.

Further, I certify that the work is based on the investigation made, data collected and analysed by him and it has not been submitted in any other University or Institution for award of any degree. In my opinion it is fully adequate, in scope and utility, as a dissertation towards partial fulfilment for the award of degree of MBA/BBA/B.Sc.

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Executive Summary

Energy plays an important role in growth and shaping of economy of a nation. India will, for the foreseeable future, continue to rely heavily upon oil and natural gas to support our economy, national security, and energy security. As far as the current exploration and production scenario of oil and gas concerned, India produces approximately 25-30% of its total demand. Another major source of energy in India is the huge reserves of Coal. It is estimated that India's reliance on coal will persist even upto 2050 with an envisaged share of 42%-50% in energy mix. India would like to use its abundant coal reserves as it provides a cheap source of energy and ensures energy security as well.

India is endowed with twenty six sedimentary basins covering an area of 3.36 million sq. km spread over Onland, Shallow water (down to 400m isobaths) and Deep water (400m isobaths to EEZ) sectors. The aerial extent of Onland, Shallow water and Deep water are 1.63 million sq. km, 0.41 million sq. km. and 1.32 million sq. km. respectively. A large portion of the basinal area is still to be appraised in terms of knowledge building efforts for evaluating hydrocarbon prospectivity of the basin through Geological studies, Geophysical surveys and exploratory drilling.

The unconventional hydrocarbon reservoirs include shale oil/gas, tight oil/gas, heavy oil, Coal Bed Methane etc. which are capable of providing a cleaner source of energy than other fossil fuels albeit with appropriate safeguards. A number of Indian sedimentary basins possess huge volume of organic rich shale rocks deposited through wide geological time. For the last decade the focus of E&P activities on Unconventional Hydrocarbons has increased many fold resulting into the successful production of Oil & Gas in various countries of the world. Considering the Indian scenario and keeping the objective to draw a road map for Exploration and production of unconventional hydrocarbons in India, a detailed study has been carried out. In the process of the study, Literature survey, suitable research design methodology, detailed interpretation, analysis of data were carried out. In comparison to countries like USA, China, Canada and Russia, India is far behind in exploration and exploitation of hydrocarbons from unconventional resources except CBM from where production of natural gas started in the country about a decade ago. In this research project a detailed study on four major unconventional

hydrocarbon resources viz, Shale Gas, Tight Reservoir, Coal Bed Methane and Gas Hydrate have been carried out. The outcome of the project reveals that the country has a good potential for development of these resource. For the proper development of these reservoirs many elements needs serious attention. The Geo-scientific study, R&D work in the related field, Industry academia interface, joint venture with renowned MNC's & Institutes, induction of state of the art technologies, the environmental concern, various policies introduced by Government of India, Cost analysis, infrastructure, nearby market, global oil & gas price scenario, prevailing geopolitics etc. The progress made so far in the country is good step towards building new data base for further use in the development of these resources. Contribution from Shale gas is still to come, tight reservoirs are being developed and they have started contributing, though at a small scale. Production from CBM has already started from few fields. India has good potential for development of Gas hydrate also. Recently good potential have been established in Krishna-Godavari offshore & Andaman Basins. Overall it is concluded that, India needs to intensify the E&P activities through various measures in appraised and unapprised basins for exploration and exploitation of unconventional hydrocarbons towards shaping the strong energy future of the nation.

Chapter 1:
Introduction

1. Introduction

1.1 Overview

Energy is integral for collective progress of the society and provides the impetus for social and economic development of a nation. It has become a strategic commodity considering the implications it has on sustained growth of economy and human development. India consisting 18% of the world population is one of the fastest developing countries with an estimated economic growth rate of around 6-7%. The hydrocarbons sector plays vital role in the economic growth of the country. As far as the distribution of energy source is concerned, India's energy consumption is about 36% hydrocarbon based and almost 83% is met by import, eating a major chunk of foreign currency and widening the Current Account Deficit (CAD). It is expected that the country will become the world's second largest energy consumer in the next 25-30 years. With the expected economic growth, India will naturally demand enormous amounts of energy to meet its growth objectives in a sustainable manner. Currently India's primary energy mix is dominated by coal (44%) followed by oil (23%), natural gas (5%), Bioenergy (24%), hydropower (2%) and nuclear (1%) and other renewables (1%).

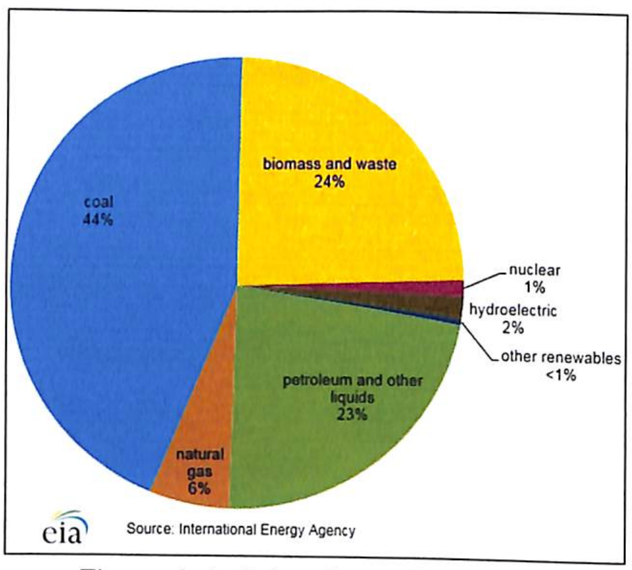

Figure.1: India's primary Energy mix

After independence India adopted a state led Planned Economy Model with 5 year Plans. Between 1947 and 1980, the Indian economy grew at an annual average rate of 3.5%. Given an annual population growth of over 2%, the country's per person income, was at a sub 2% rate of growth. The economic reforms and liberalization initiated in the early nineties ushered in a new era which saw a growth of over 4% in annual per capita income in the last three decades. Under this backdrop, role of energy security for sustainable future has become of paramount importance. Energy security, as per International Energy Agency (IEA) is the uninterrupted availability of energy sources at an affordable price. Unconventional gas is relatively evenly dispersed around the world and many regions will likely witness at least some level of production in the future. In scenarios with favorable unconventional gas development, the USA, China and Other Developing Asia are well placed to become the top producers of unconventional gas. In 2017, India retained its spot as the third-largest energy consumer in the world with oil and gas accounting for 37% of its total energy consumption. Annual oil consumption stood at 4.69 million barrels per day (MBPD) and 54.20 billion cubic meters (bcm) of gas. By 2035, India's energy demand is expected to double to 1,516 Mtoe by 2035 from 753.7Mtoe in 2017. According to the International Energy Agency (IEA), India is expected to account for almost one-third of the global growth in energy demand by 2040. Energy demand of India is anticipated to grow faster than energy demand of all major economies, on the back of continuous robust economic growth. Consequently, India's energy demand as a percentage of global energy demand is expected to rise to 11 per cent in 2040 from 5.58 per cent in 2017. India has proven oil reserves of 600 million metric tonnes (MMT), and gas reserves of 1.2 trillion cubic meters. Production of crude oil reached 0.68 mbpd in 2018-19. Natural gas production during the same period stood at 32.06 bcm.

India has twenty six sedimentary basins covering an area of 3.36 million sq. km spread over Onland, Shallow Water SW, down to 400m isobaths) and Deep Water (DW, 400m isobaths to EEZ) sectors. The aerial extent of Onland, SW and DW are 1.63 million sq. km., 0.41 million sq. km. and 1.32 million sq. km. respectively. A large portion of the basinal area is still to be appraised in terms of knowledge building efforts for evaluating hydrocarbon prospectivity of the basin through geological studies, geophysical surveys and exploratory drilling. India has good potential for exploration and production of oil & gas from various sedimentary basins. Using state of the art technology and proper G&G modelling it is expected that unconventionals will play a vital role towards the goal of reducing the oil import by 10% in near future.

1.2 Background

Over the last two years, the global energy scenario has experienced transforming changes in energy mix of far reaching implications. With an estimated area of 3.36 million sq km and 26 sedimentary basins, India has good potential for exploration and exploitation of unconventional hydrocarbon resources. Unconventional hydrocarbons are geographically extensive accumulations, and difficult to develop and mainly occur as Coal Bed Methane, Shale Gas, Shale Oil, Oil Sands, Heavy Oil, Tight Gas, Gas Hydrates etc.

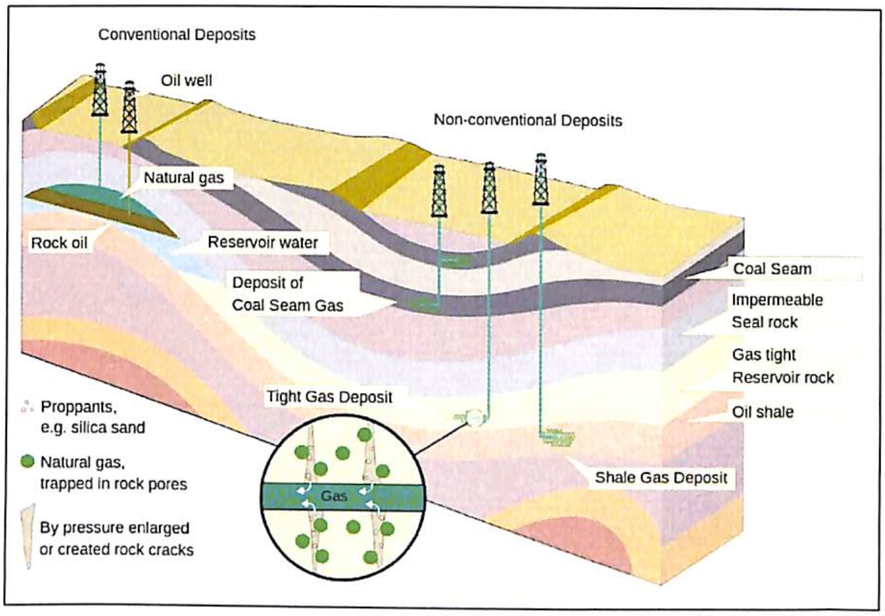

Figure 2: Geology of conventional & unconventional Oil & Gas
(Source: MagentaGreen/Wikimedia)

In this study emphasis have been given for detailed analysis on four major unconventional hydrocarbons resources of the country viz. Shale Oil/Gas, Coal Bed Methane, Tight Gas and Gas Hydrates.

According to the available data and studies undertaken, India has huge shale gas potential. To strengthen its hydrocarbon resource base, India has identified six basins as areas for shale gas exploration: Cambay (Gujarat), Assam-Arakan (North East), Gondwana (Central India), Krishna Godavari onshore (East Coast), Cauvery onshore, and Indo-Gangetic basins.

Coal Bed Methane is an unconventional source of natural gas (Methane) generated during formation of coal and adsorbed in coal. India having fifth largest proven coal reserve, presents a significant opportunity of increasing the gas production keeping in line with the vision of reducing hydrocarbon import & making India gas economic. Despite having challenge of extracting natural gas from CBM reservoir due to low permeability, with the help of technology advancement, new CBM blocks are expected to commence commercial production in 2018-19.

Tight gas is an important unconventional gas resource. It is also a basin centered gas reservoir which is associated with existing oilfields or bypassed zones and characterized by low in situ permeability of less than 0.6 mili Darcy. In the country exploration and production of oil & gas started about a decade ago. Almost all the basins of India has tight reservoirs and have good potential for future oil & gas production.

Gas hydrates are clathrates of natural gases (mainly methane), which are captured in water ice crystals. These clathrated compounds have been discovered in sediments worldwide wherever low temperature, high pressure, salinity, and sediment organic concentrations are conducive to their formation. The gas hydrate research and development world over in the last two decades has established that gas hydrates may be a viable potential resource to significantly bridge the energy gap for ensuring the energy security of India in future. The gas hydrates resources are estimated to be about 742,000 trillion cubic feet (tcf) for the world and 66000 tcf for India.

In India Shale exploration and production of shale oil/gas, CBM & tight gas already started though at a smaller scale but given encouraging results. Gas hydrate reservoirs have been explored in east coast offshore area i.e Krishna-Godawari and Cauvery basin under the GOI noble initiatives through NGHP -01 & 03. The production testing of gas hydrates is planned under NGHP-03.

1.3 Rational for topic selection

In the case of the developing countries, the energy sector assumes a critical importance in view of the ever increasing energy needs requiring huge investments to meet them. The present energy scenario in India is not satisfactory. We are on the cusp of a transition in global energy markets, witnessing revival in crude oil prices, increasing role of natural gas in the energy mix, new players entering both the oil and gas market, loosening up of the inflexible LNG market and the rise of renewables and EVs. In order to meet the exploding energy needs of its vast population, India imports a large proportion of its crude oil and gas requirements. It is in this context and in line to the vision of our Hon'ble Prime Minister to cut down India's import dependence for domestic energy needs by 10% in the near future.

The burgeoning demand of oil and gas, failure to discover big oil fields across the country warrants boost in additional sources of oil and gas. The encouraging results in the recent past in the exploration and production of the unconventional hydrocarbons in the country a necessity was felt to analysis the present status of oil and gas resources in the country. At the same time analysis is to be done for additional upcoming unconventional hydrocarbons resources to add to the reserve kitty of the country for a brighter future. Considering the changing scenario from conventional fuel to more cleaner and environment friendly natural gas based economy, unconventionals hydrocarbons can play a vital role to support the cause as majority of the unconventional hydrocarbon consist of natural gas viz. Shale Gas, CBM, Methane from Gas Hydrate. Natural gas is superior fuel as compared with coal and other liquid fuels, as it is environment friendly, safer and cheaper fuel. Natural gas as a fuel source is much "greener" than alternative fossil fuels. According to the Environmental Protection Agency (EPA), natural gas produces roughly half as much CO_2 as coal and 32% less than oil.

The latest initiatives by Government of India towards boosting the countries oil & gas production, induction of new technologies by national oil companies & MNC's and recent success story across the world along with the burgeoning demand of energy resources in the country, justifies the selection of the topic to carry out this research work.

1.4 The objective of this study

The oil and gas sector is one of the core industries in India and plays a major role in influencing decision making for all the other important sections of the economy. India's economic growth is closely related to energy demand; therefore the need and importance of oil and gas is projected to grow more. The sector in recent years has been characterized by rising consumption of oil products, declining crude production and low reserve accretion. India remains one of the least-explored countries in the world, with a well density among the lowest in the world. This study aims to strengthen the countries oil & gas reserve base through various E&P activities in unconventional hydrocarbon sector. The main objectives are:

- To identify potential locals for exploration and production of Shale Gas, CBM, Tight Gas & Gas Hydrate
- To draw a road map for Exploration and production of unconventional hydrocarbons resources in India
- To develop unconventional hydrocarbon sector as a globally competitive industry through technology up gradation and capacity building
- To develop strategies towards more collaborative approach for a stronger E&P business
- Developing measures for the use of more environment friendly cleaner fuel.

In this research project, a systematic approach with an in depth qualitative data analysis for all the unconventional hydrocarbons resources available in the country will be evaluated for potential assessment. Latest energy statistics of the world and India will be collected and compared for a reasonable outcome. Statistical analysis of the sample points for all the unconventional plays will be interpreted to come out with a possible future road map. The methodology further will comprise determining data propagation across the multiple scales in a hydrocarbon bearing region for unconventional hydrocarbon plays. As India is an oil importing country, the role of hydrocarbon sectors towards the sustainable growth of the Indian economy is very important. The methodologies for this project will also include various economic and financial aspects of the energy security of the country. I would like to analyze the role and impact of available unconventional hydrocarbon resources in the long term perspective in Indian economy. Venues for possible interaction and collaborations with countries across the world producing oil & gas from unconventional reservoirs successfully will also be studied in details for a concrete way forward. In detailed analysis of current status of exploration and exploitation of Unconventional reservoirs in India will be done taking latest data from various oil & gas companies operating in India.

1.5 Schematic overview of the chapters

A brief literature review has been undertaken in Chapter 2 to present the current status of the exploration and production activities in the world with special emphasis on India. In this section, an insight is provided about the history of unconventional hydrocarbon resources in India world. A detailed study of four major unconventional resources viz, Shale gas, Tight reservoirs, Coal Bed Methane & Gas Hydrate, around the world and India has been carried out. Then the history of oil and gas industry is covered in North-east Indian perspective. Also in this section recent publication, books, reports, journals, websites, indexes, databases, etc. are included to have an idea about the recent developments in the industry.

Chapter 3 include research design, methodology and plan for this research project. The activities has been described with as much detail as possible. In this chapter the methodological steps undertaken during my study has been indicated to answer every question or to test every question or hypothesis. This will describe the details of source data, sample size, methods of data collection and tools and techniques of analysis. The framework for the methodology adopted in this research is discussed in details in this chapter.

Chapter 4 presents the core part of the research. In this chapter I have tried to explain the analysis of the data that I have gathered and analyzed through the research tools mentioned in the earlier section. This chapter has described the findings of the literature survey carried out for India and world. The changing scenario of hydrocarbon sector, role of unconventional hydrocarbons in India, the future potential of these resources and the various initiatives taken by the government of India have been discussed. The outcome have been suitable presented through figures and tables.

Chapter 5 is dedicated to the interpretation of results as obtained in light of the analysis contained in the previous section. In this chapter results have been compared with the original set of assumptions, constructs and hypotheses at the start of the research exercise. The interpreted result have been used for getting recommendations.

Chapter 6 will enlist the conclusions based on the elaboration of the major findings, recommendation of an action plan, progressive discussions from previous chapters demonstrating how the research aim and objectives are achieved through the research methodology framework adopted in this study. The Chapter also highlights practical/workable recommendations for a strategic plan with a long term outlook.

1.6 Limitation

Technological innovation and productivity gains have unlocked vast resources of the unconventional oil and gas. Although unconventional oil and gas have made a lot of progresses, many questions are still remained on the realistic significance of unconventional hydrocarbons and its sustainability as a viable fuel supply. Unconventional oil and gas exploration and development become extremely successful in the U.S., but the successful story failed to be replicated by other countries and regions. Unconventional oil and gas has complex geologic reservoir conditions and exploration development environment (Zou et al., 2012b), thus great effort has to be made in the research on unconventional oil and gas geological theories, resource evaluation and other core technologies. As the exploration and development of unconventional oil and gas characterized by huge challenge, rapid production decline and relatively small production per well, recoverability and profitability of resources have to be emphasized in its evaluation. Due to the varieties of unconventional oil and gas resources and their diverse geological characteristics, no single unified method can be directly used for resource evaluation. Unconventional oil and gas has many limitation in its smooth production due to various geological as well as socio-economic factors.

Shale oil/gas has received a great deal of attention recently for the potential negative impacts that its development might have on the environments and communities in which it is explored/developed. Instances of ground water contamination, air pollution and earthquakes have been blamed on gas extraction activities. A thorough understanding of the techniques used to extract gas from shale formations and the safeguards that exist to prevent environmental damage is critical to assess the sources and magnitudes of risk involved in shale gas development.

Coal Bed Methane is generated during coalification process which gets adsorbed on coal at higher pressure. However, it is a mining hazard. Presence of CBM in underground mine not only makes mining works difficult and risky, but also makes it costly. Even, its ventilation to atmosphere adds greenhouse gas causing global warming. India lacks in CBM related services which delayed the scheduled production. Efficient production of CBM is becoming a real challenge to the E & P companies due to lack in detailed reservoir characterization. The main hurdle associated with the production of CBM is the requirement of long dewatering of coal bed before production. Also the problem associated with variation in coal properties related to pressure depletion may be alleviated.

Tight gas reservoirs pose problems during its production due to low porosity and permeability. Special drilling and completion technologies are required to complete the well. It requires identification of potential layers in both carbonate and sandstone reservoirs followed by horizontal drilling, hydraulic fracturing and simulation techniques. The production from tight reservoirs are comparatively low but sustain for a longer duration.

Gas hydrates also pose several problems during its production of methane gas. The major one is sea floor instability due to change in temperature which can release a good amount of methane into the atmosphere. The sea floor instability may also cause origin of local tsunamis. During production of the methane gas formation of hydrates takes place frequently in the pipeline which hampers the production of gas due to plugging and also threat to the high pressure in pipeline which may cause pipeline burst creating hazard to the man and machine as well as the environment. In this process huge volume of Co2 also releases in the atmosphere which may imbalance the ratio of the atmospheric gases.

1.7 Recommendations

Over the last twelve years, there have been significant forward steps in exploring the hydrocarbon potential of the sedimentary basins of India. The unexplored area has come down to 15% which was 50% in 1995-96.

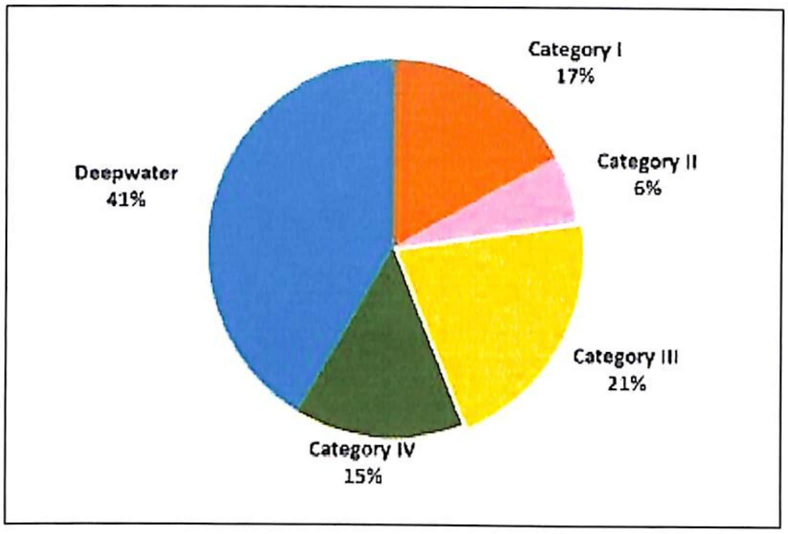

Figure 3: Categories of Sedimentary Basins of India
(Source: Sedimentary Basins of India, MOPNG)

To meet the huge demand of oil & gas in the country a rigorous exploration campaign is required in both appraised and unapprised basins of India. The Union Government has launched National Seismic Programme (NSP) to trace hydrocarbon resources like oil and natural gas in the all 26 sedimentary basins. NSP aims to undertake a fresh appraisal in all sedimentary basins across India in order to have better understanding of the hydrocarbon potential of the country.

Following recommendations are suggested to enhance the role of unconventional hydrocarbon towards the stronger reserve kitty of Oil & Gas of the country.

- Identify suitable exploratory locals in all 26 sedimentary basins of India
- Revisit in all 7 category-I basins with proven hydrocarbon production for fresh G&G modelling of the area.
- Interpretation of newly seismic data being acquired under the National Seismic Programme (NSP)
- Constitution of Multi-Disciplinary Team across the country for detailed analysis of each individual basin.
- Acquisition of latest technology for exploration and production of unconventional hydrocarbons
- Collaboration with world renowned MNC's engaged in unconventional Oil & Gas Exploration and production to enhance the knowledge base.

- Following the new policy guidelines from GOI intensify the E&P activities in all sedimentary basins.

Chapter -2

Literature Review

2 Literature Review

Collection and study of latest information and true data is the basis of any research work. Detailed discussion with the Guide of this project regarding literature survey was carried out to plan for collection of requisite data in a systematic manner. Accordingly, data collection was done in planned manner for this project. Review of various literature in form of journals, papers were carried out for the collection of important data bank for preparation of this research work. Multipronged approach was adopted to fulfill the requirement of this research work. Internet based data/information is the major source for collection of primary data. Various libraries of ONGCL at Dehradun were also explored in this process. Interaction with industry expert were also carried out with prolonged discussions and interactions. Industry-Academia interface was another source of data collections and was carried out very carefully towards specific data fulfilment for this project. Various reports published by government agencies viz. Annual report of MOPNG, DGH, Indian PDU's, published report by various NGO's and MNC's, IEA, EIA , BP Annual Report were referred. Different IIT proceedings were also referred for various new initiatives and research work being carried out in different aspects of unconventional hydrocarbon resources of the country. Data from National Oil major Oil & Natural Gas Corporation Limited was also collected to get the latest information on various activities carried out by the company towards exploration and exploitation of unconventional hydrocarbon resources in the country in the last few decades.

2.1 Brief Description of Unconventionals

"A game changer," "a revolution," and "a paradigm shift"—those are descriptions of the development of unconventional resources (UCRs) seen in the United States news media. The Wall Street Journal called unconventional gas plays "the biggest energy innovation of the decade. Unconventional oil and gas is a term used to describe production reserves that cannot be obtained using historical recovery methods. Oil reserves have become more difficult to extract as a result of location, depth, and formation. Therefore, the need for new technology and methodologies grows with every completion. Shale gas, heavy oil, bitumen, and increasingly deep gas fields are examples of unconventional oil and gas. The economics of retrieving unconventional oil has been a concern in the past, but new technologies and the decrease in conventional oil have created an economic opportunity for UCRs. Kawata and Fujita (2001) quoted Hans-Holger Rogner of the International Atomic Energy Agency, who estimated gas resources of 9,000 Tcf in coalbed methane, 16,000 Tcf in shale, and 7,400 Tcf in tight sands throughout the world. Rogner ranked North America as the top unconventional gas resource holder (25%), followed by the former Soviet Union (16%), and China (15%).

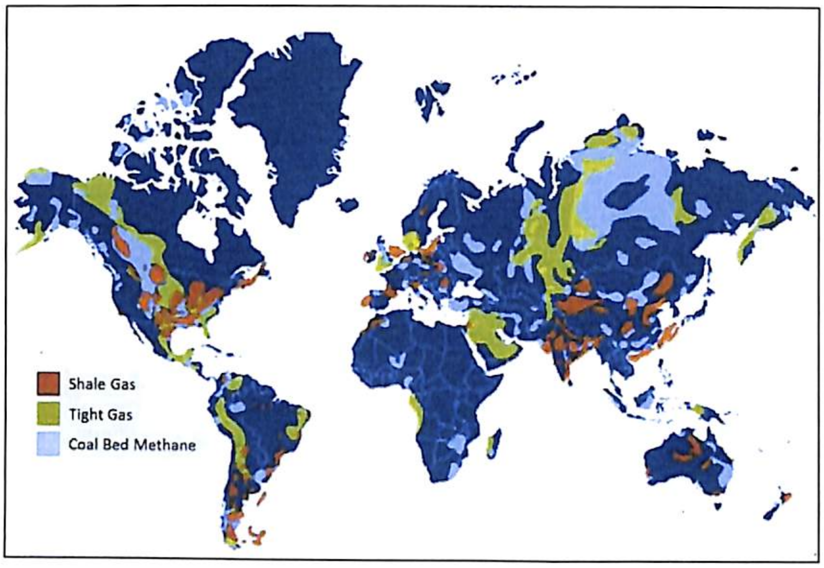

Figure 4: Unconventional Hydrocarbon resource in the world

Because of the availability of conventional reservoirs outside the US, worldwide unconventional plays have largely been overlooked until recently, and in many cases, they had not been studied. Based on the US experience, the need and technical capacity to produce from these reservoirs around the world is likely to emerge in coming decades. In India exploration of shale gas, CBM & tight reservoir already started by NOC's and other MNC's mostly in category-I basin. The new resource assessment indicated a good potential of unconventional hydrocarbon resources across the country. New policy drafted by GOI will definitely boost the E&P activities of these resources in the country.

2.2 Shale Oil/Gas:

Shale oil/gas constitute one of the most important unconventional sources of natural gas generated and stored in organic rich, matured fine grained sedimentary rocks. Apart from the natural gas, part of the oil generated in the shale also is retained which can be exploited by application of appropriate drilling and production technology in favourable geological situations. Shale plays have abundant reserves around the world which may be sufficient to meet the demand of clean energy for many years to come. Shale gas is found in unconventional reservoirs typically trapped in shale rock, having low permeability, originally deposited as clay and silt. Globally shale hydrocarbons have been well established mainly in USA, Canada and to a lesser extent in other places. According to the World Shale Gas Resources study conducted by EIA (2011b), China has the largest shale gas resources of the 32 countries reviewed, at 1,275 Tcf or 19.3% of the estimated world supply. The US has 861 Tcf of shale gas (13%), and Argentina holds 774 Tcf (11.6%), followed by Mexico (10.3%), Australia (6%), and Canada (6%). The study quotes 6,622 Tcf for total shale gas resources, which is almost equal to the world's proved natural gas reserves. The EIA study (2013) suggests that major unconventional shale gas and oil plays in the world are concentrated in six stratigraphic intervals namely Silurian, Late Devonian, Pennsylvanian-Late Permian, Late Jurassic, Middle Cretaceous and Paleogene. All the above mentioned stratigraphic intervals are prolific for prospective shale gas exploration except for Paleogene period based on their maximum organic richness, thermal maturity, prospective area and shallow depth of occurrence (due to Basin inversion).

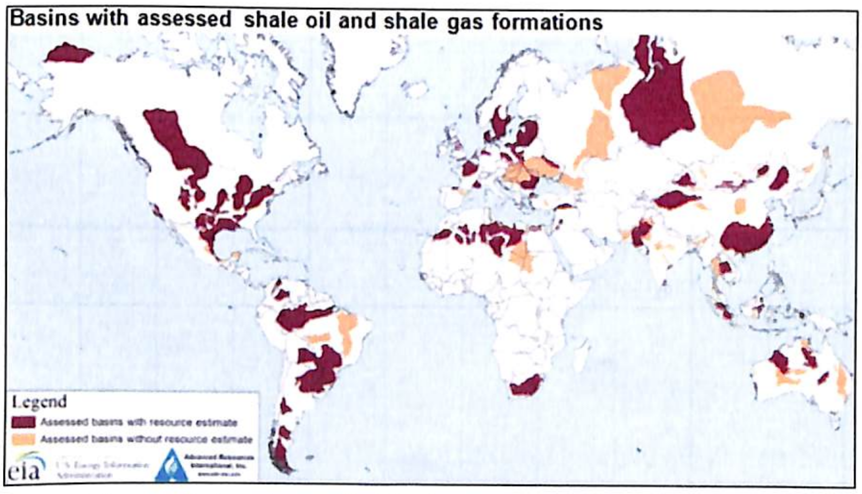

Figure 5: Basins with Shale gas potential in the world

Shale is a fine-grained, fissile, detrital sedimentary rock formed by consolidation of clay (less than 4 micron size). It is composed of fine-grained detrital matrices of silt, clay-sized bits of organic matter, quartz, feldspar, clay minerals, calcite, dolomite and other minerals. Various clay types and their volume influence the quality of the shale reservoir from petrophysical and geomechanical perspective (Atkins et al., 2011). Shale acts as both source and reservoir rock for shale oil/gas.

Shale reservoirs require vertical drilling upto the target horizon followed by a horizontal section exposing the well to more of producing shale. These horizontal sections are then subjected to multistage fracking which involves pumping of great volume of sand with water at a pressure exceeding the fracture pressure of the particular reservoir.

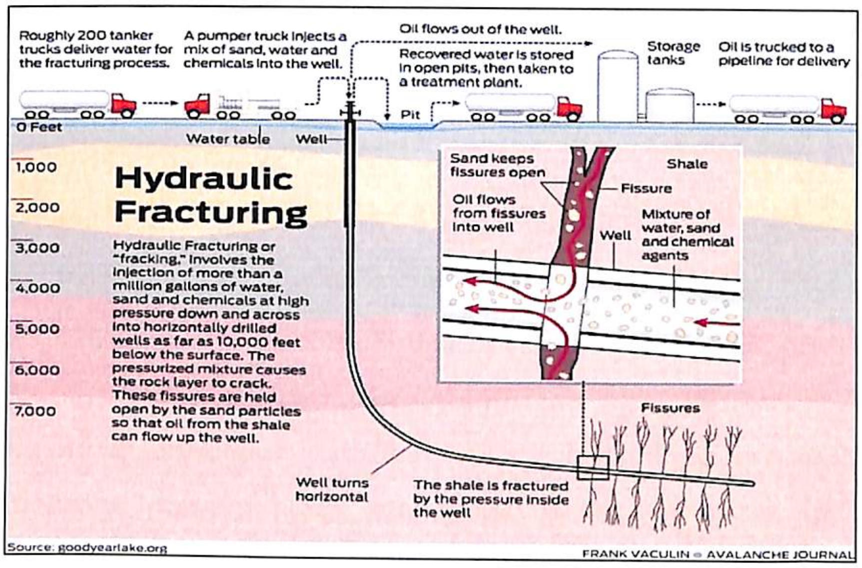

Figure 6: Hydro-fracturing in Shale reservoir

Indian Scenario

A number of Indian sedimentary basins possess huge volume of organic rich shale rocks deposited through wide geological time. Beginning with the oldest, these may be summarized as Proterozoic in Vindhyan Basin, Neo-Proterozoic-Cambrian in Ganga Basin, Permian in Krishna-Godavari (KG), Pranhita-Godavari (PG), Damodar, South Rewa and Satpura basins of Gondwana, Cretaceous in KG, Cauvery basins and Paleogene in Cambay and Assam & Assam-Arakan basins. EIA study (2013) covered four Indian rift basins viz. Cambay, Krishna-Godavari, Cauvery and Damodar Valley for shale assessment.

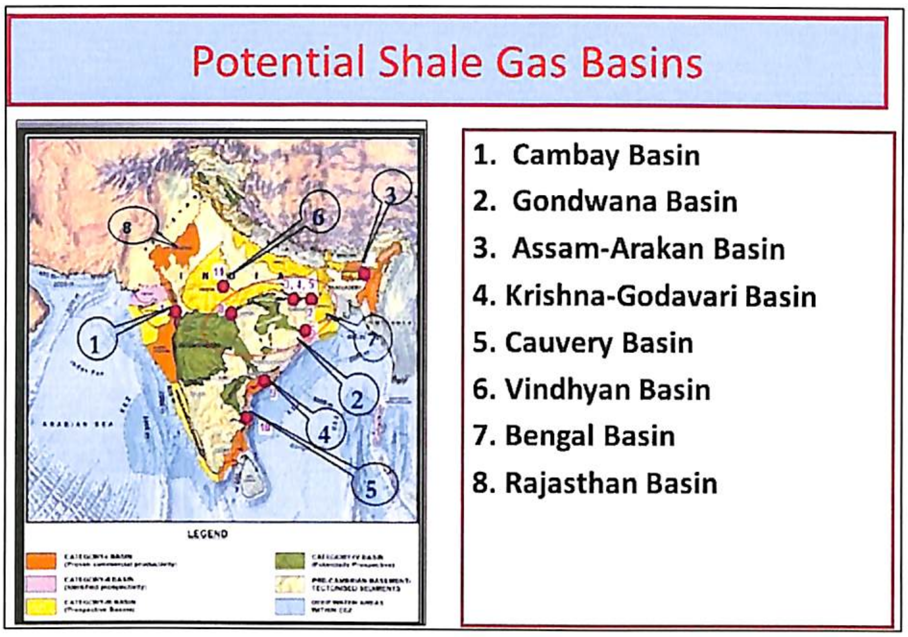

Figure 7: Prospective areas of Shale Oil/Gas Exploration in India, Source: DGH

On comparison of Indian shale vis-à-vis Global shale plays, there are different geological, geochemical, petrophysical and geomechenical parameters like kerogen type, thermal maturity, depth and thickness of shale, gas content, porosity, permeability, hydrocarbon saturation, mineralogical attributes, hydrogen index, TOC, free hydrocarbon (S1) and hydrocarbon generation potential (S2) etc. which are used to provide a first order overview of the geologic characteristics of the major shale gas and shale oil reservoirs.

On the basis of the data generated so far, it has been observed that:

Indian shales are rich in clay content (>50%), shale is characterized by low matrix permeability (Nanno darcy), depositional environment is shallow marine to non-marine, the reservoir pressure is mostly normal to slightly over-pressured (locally), shale sequences are generally organic rich with average TOC content ranging between 1.0 and 3.5%, organic matter is mostly in early to late oil generation maturity window VRo: 0.6-1.2%), kerogen is primarily Type-III with minor contribution of Type-II OM, the average depth of shale sequence is high (2500-5000m), Low resource concentration and low oil saturation.

Various agencies have estimated the shale gas resource potential in selected sedimentary basins/ sub-basins as indicated below:

- Schlumberger: 300 to 2100 TCF of shale gas resource for the country (as available in public domain)
- Energy Information Administration (EIA), USA in 2011: 290 TCF of shale gas in 4 basins (Cambay Onland, Damodar, Krishna Godavari Onland & Cauvery Onland)
- Energy Information Administration (EIA), USA in 2013: 584 TCF of shale gas and 87 billion Barrels of shale oil in 4 basins (Cambay Onland, Damodar, Krishna Godavari Onland & Cauvery Onland)
- ONGC: 187.5 TCF of shale gas in 5 basins (Cambay Onland, Ganga Valley, Assam & Assam-Arakan , Krishna Godavari Onland & Cauvery Onland)
- Central Mine Planning and Design Institute (CMPDI): 45 TCF of shale gas in six sub basins (Jharia, Bokaro, North Karanpura, South Karanpura, Raniganj & Sohagpur)
- USGS under MoU between DoS & MoPNG in Jan'11 estimated Technical Recoverable Shale Gas of 6.1 TCF for three basins, namely, Cambay, KG & Cauvery. Further, USGS in April 2014 estimated Technical Recoverable volume of 62 million barrels of shale oil for Cambay Basin and more than 3.7 TCF of technical recoverable gas for Tight Sandstone reservoirs for Cambay & KG basins. Further, USGS has indicated that these basins have also potential for shale oil.

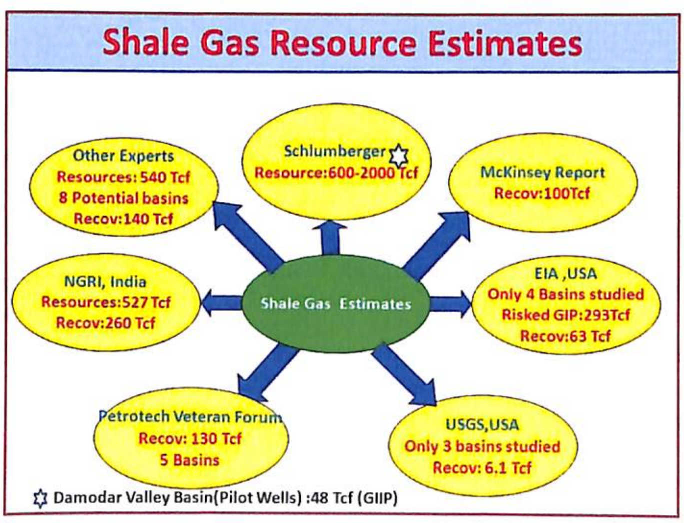

Figure 8: Shale Gas Resource estimate for India by different Agencies
(Source: Dr.V.K.Rao, IUGF2013)

There are also negative impact on environment and societies.

The environmental hazards in shale exploration may be summarized below:

I. Excessive use of water for hydro-fracturing from few thousands to 20 thousand cubic metres per well causing depletion of aquifers in a water stressed country like India

II. Inappropriate disposal of drilling and fracking fluid leading to contamination of ground water and surface water resources

III. Requirement of vast land cover in comparison to conventional oil and gas exploration in an ever shrinking land area due to urbanization.

IV. Environmental pollution due to excessive movement of hydro-fracturing equipment and machinery.

2.3 Coal Bed Methane

Coal bed methane (CBM), coal bed gas, coal seam gas (CSG), or coal-mine methane (CMM) is a form of natural gas extracted from coal beds. In recent decades it has become an important source of energy in United States, Canada, Australia, and other countries. The term refers to methane adsorbed into the solid matrix of the coal. It is called 'sweet gas' because of its lack of hydrogen sulfide. The presence of this gas is well known from its occurrence in underground coal mining, where it presents a serious safety risk. Coalbed methane is distinct from a typical sandstone or other conventional gas reservoir, as the methane is stored within the coal by a process called adsorption. The methane is in a near-liquid state, lining the inside of pores within the coal (called the matrix). The open fractures in the coal (called the cleats) can also contain free gas or can be saturated with water.

Unlike much natural gas from conventional reservoirs, coal bed methane contains very little heavier hydrocarbons such as propane or butane, and no natural-gas condensate. It often contains up to a few percent carbon dioxide.

The major parameters that determine the suitability of the coal basin for commercial CBM operation are depth, thickness of the seam, coal rank, gas content and permeability. CBM wells are shallow depth wells. Most of the CBM wells drilled are vertical wells. The horizontal wells are also used in some CBM basins to enhance gas production.

Indian Scenario

The prognosticated CBM resources in the country are about 92 TCF (2600 BCM) in 12 states of India. The Gondwana sediments of eastern India host the bulk of India's coal reserves and all the current CBM producing blocks. The vast majority of the best prospective areas for CBM development are in eastern India, situated in Damodar Koel valley and Son valley. CBM projects exist in Raniganj South, Raniganj East and Raniganj North areas in the Raniganj coalfield, the Parbatpur block in Jharia coalfield and the East and west Bokaro coalfields. Son valley includes the Sonhat North and Sohagpur East and West blocks. Currently, commercial production has commenced from Raniganj South CBM block operated by M/s. GEECL since July 2007. India having 17 coal fields with a total coal reserve of 200 billion tons, only three basins are viable reserves for CBM, namely Raniganj (West Bengal), Jharia (Jharkhand), and Singrauli (Madhya Pradesh). The reserves of these mines are good candidates for CBM production.

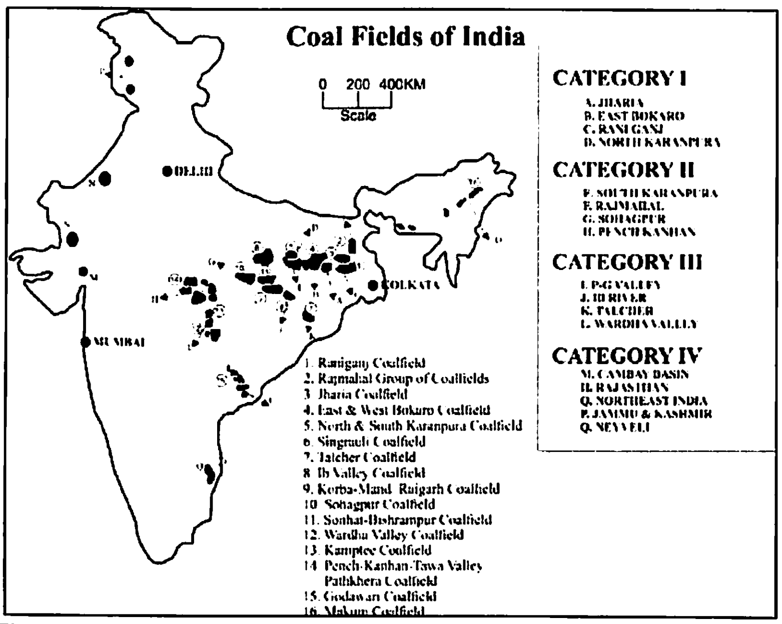

Figure 9: Prospective areas of CBM Exploration in India
(Source: Research Gate, Peters et al)

Indian coals are largely sub-Bituminuous 'B' to Bituminous 'C' as per ASTM Classification. Indian coals being heterogeneous show tremendous variations in Reservoir Parameters. High rank coals occur in Damodar Valley grabens with Gas content between 6 – 15 m^3/t. Methane constitutes >90% of total Gas content.

The prognosticated CBM resources in the country are about 92 TCF (2600 BCM) in 12 states of India. In order to harness CBM potential in the country, the Government of India formulated CBM policy in 1997 wherein CBM being Natural Gas is explored and exploited under the provisions of OIL Fields (Regulation & Development) Act 1948 (ORD Act 1948) and Petroleum & Natural Gas Rules 1959 (P&NG Rules 1959) administered by Ministry of Petroleum & Natural Gas (MOP&NG).

Sl. No.	STATE	Prognosticated CBM Resources (IN BCM)	Prognosticated CBM Resources (IN TCF)
1	Jharkhand	722.08	25.5
2	Rajasthan	359.62	12.7
3	Gujarat	351.13	12.4
4	Odisha	243.52	8.6
5	Chattissgarh	240.69	8.5
6	Madhya Pradesh	218.04	7.7
7	West Bengal	218.04	7.7
8	Tamil Nadu	104.77	3.7
9,10	Telangana/AP	99.11	3.5
11	Maharashtra	33.98	1.2
12	NORTH EAST	8.50	0.3
Total CBM Resource		**2599.48**	**91.8**

Table 1: CBM Resources in India (State wise), Source: DGH

Current CBM production (March 2015) was around 0.77 MMSCMD from 5 CBM blocks which includes test gas production from 4 CBM blocks and commercial production from 1 CBM block. Seven more CBM blocks are expected to start commercial production in near future. In March 2017, the government approved pricing and marketing freedom to CBM gas producers and also allowed them to sell the fuel to affiliates in case they cannot identify buyers. Oil and gas companies are boosting production of coal bed methane (CBM) gas that they are free to sell at market prices. Among companies ramping up CBM output are Reliance Industries Ltd (RIL), Essar Oil Ltd, and Great Eastern Energy Corp. Ltd (GEECL). State-run Oil and Natural Gas Corp. Ltd (ONGC) has already begun test production from its CBM blocks.

2.4 Tight Gas

Tight gas reservoirs characterized with low porosity and permeability, small drainage radius and low productivity, require significant well stimulation – hydraulic fracture treatment – or the use of horizontal or multi-lateral wells to produce at economic rates. Tight gas refers to natural gas reservoirs locked in extraordinarily impermeable, hard rock, making the underground formation extremely 'tight'. The tight reservoirs are characterized by low permeability, large pressure gradient across reservoir, often layered and complex, high transient decline rate and comingled production. Typical lithology of tight reservoirs are sandstone/siltstone and rarely carbonate with permeability as low as (<0.1md). Tight gas reservoirs are generally gas-saturated with little or no free water. Special recovery processes and technologies like hydro-fracturing, steam injection etc are used to produce hydrocarbons from theses reservoirs.

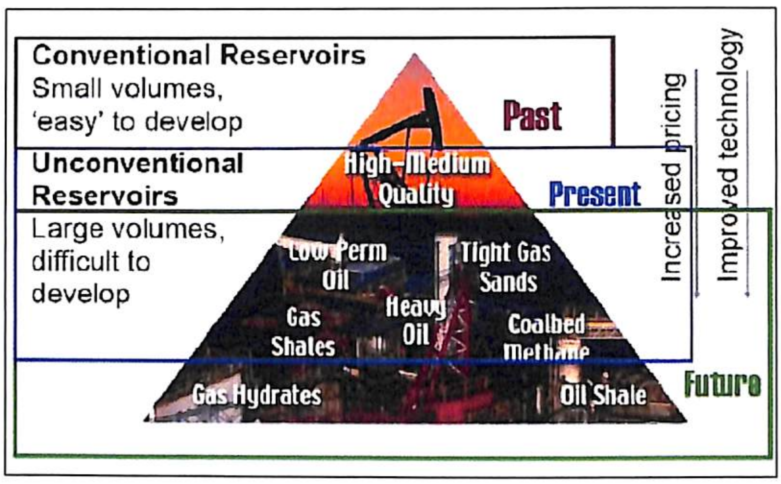

Figure 10: The Resource Triangle, (Source: Holditch, 2006)

The above figure is a Resource Triangle which demonstrate the distribution and economics of conventional hydrocarbons is very different from the unconventional or resource play hydrocarbons.

Few countries like USA, China, Australia, Canada are the pioneer in the development of tight reservoir. At present 50% of daily US gas production recovered from tight reservoir Alberta basin, Michigan basin, Andarko basin, Spraberry field of Western Texas containing billions of barrel of oil in place. Tight gas fields are also being developed around the world e.g. Yucal Pacer field in Venezuela, Aguada Pichana in Argentina, Timimoun in Lgeria and Aloumbe in Gabon, Sui area in Balochistan of Pakistan, Warro field in western Australia. Recoverable tight gas reservoirs is Canada-20.4 TCM, CIS (commonwealth of independent states)- 5.4 TCM, Middle East-3.4.

Developing the tight gas sands is a huge challenge to geoscientists faced with understanding the depositional setting, stratigraphy, structure, geochemistry, geomechanics, seismic character, and petrophysical properties controlling production.

Important issues for such formations relate to the identification of "sweet spots" as well as the well placement and completion design for specific reservoir zones. The challenges of planning and execution of Horizontal / multilateral wells, infill wells requires to be addressed in the beginning of field development planning. A tight gas reservoir is a low-porosity, low-permeability formation that must be fracture treated to flow at economic gas rates and to recover economic volumes of gas. Without a fracture treatment, gas from tight gas reservoirs will produce at low flow rates under radial flow conditions. After a successful fracture treatment, the gas flow mechanism in the reservoir will change from radial flow to linear flow, as shown in Figure 11.

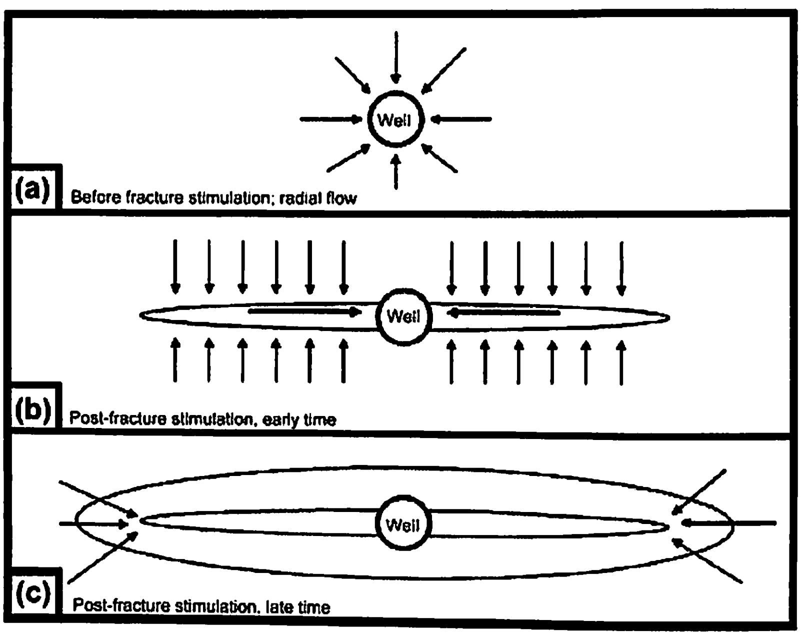

Figure 11: Gas flow mechanism before and after fracturing (from Holditch 2005)

To induce the tight reservoir for taking production, processes other than hydraulic fracturing, steam injection and acidization are also used worldwide. Tight Gas Sands (TGS) represent approximately 70% of the unconventional production and significant reserves are yet to be developed. New technologies and enhanced applications of existing techniques are making it possible to extract these tight gas resources safely, responsibly and economically. TCM & Others-1.4 TCM.

Tight Gas depends on the used methods and technologies that address the following challenges:

- Geomechanical, petrophysical and geological characteristics

- Formation evaluation

- Reservoir engineering studies (field/well modeling & simulation)

- Massive hydraulic-fracturing treatments.

- Advanced drilling: Horizontal, multilateral and UBD

- Special completion methods.

Usually gas production from TGS reservoirs requires some form of artificial stimulation, such as hydraulic fracturing. Wells completed in tight reservoir rocks have to be stimulated by one or several hydraulic fracs in order to achieve an economically adequate production rate. Compared with conventional reservoirs, TGS often show a much weaker response to the frac treatments, resulting in low production rates and a high economic risk. It is known that natural rock fractures are an important factor in the economic recovery of gas from tight reservoirs.

Indian Scenario

Tight reservoirs occur in almost all the producing basins of India and in frontier basins viz. Bengal & Vindhyan basin. Exploration of tight reservoir has already started in KG-PG, Cauvery and Cambay basins. Tight reservoirs in Indian sedimentary basins hold a huge potential of hydrocarbon reserves. Exploration of deeper and synrift sequences in the last decade in KG and Cauvery basins resulted into many discoveries. Field like Mandapetta in KG and Bhuvanagiri and Parivarmangalam-Vijyapuram show presence of tight reservoirs and pose difficulty in exploration & exploitation of hydrocarbons. After hydro fracture job few wells in KG and Cauvery basins are producing oil & gas with considerably low rate. Field in Cambay basin viz Limbodra, Gamiz, Vasna, North Sobhasan, Nawgaon, Sadra etc have also been identified as new field for the exploration of tight reservoirs. Recently ONGC has discovered a new gas field in Vindhayn basin which showed tight nature of the reservoir. The same is being developed with induction of latest hydraulic fracture technology.

2.5 Gas Hydrate

Gas hydrate is a solid ice-like form of water that contains gas molecules in its molecular cavities1. In nature, this gas is mostly methane. Methane gas hydrate is stable at the seafloor at water depths beneath about 500 m. The gas hydrate stability zone extends into the seafloor sediments down to a depth where temperature exceeds gas hydrate stability, usually some 10s to 100s of meters beneath the seafloor. At this depth, thin methane gas layers are often present causing strong reflections in seismic records. The reflections approximately follow a line of constant temperature. Temperature in the subsurface is a function of heat flow and depth, so the reflections usually mimic the shape of the seafloor. Hence, they are named bottom simulating reflections (BSRs). Large quantities of gas hydrates exist on the world's continental margins. Methane from gas hydrates may constitute a future source of natural gas. This energy potential is probably the main motivation for many national gas hydrate programmes overseas, e.g., in Japan and the U.S. Natural gas hydrates occur on continental margins and shelves worldwide from Polar Regions to the tropics.

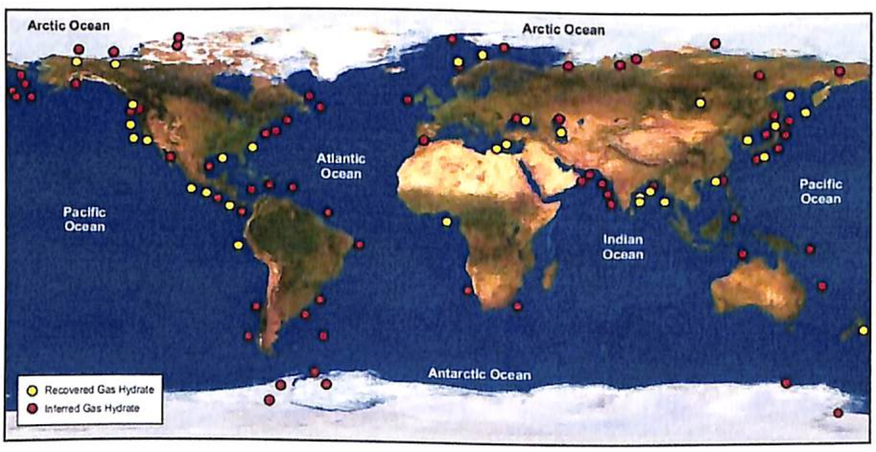

Figure 12: Distribution of methane hydrate in world
(courtesy, Council of Canadian Academies (2008), based on data from Kvenvolden and Rogers (2005)).

Indian Scenario

The shallow sediments along the Indian continental margin are good hosts for gas hydrates, and the methane within gas hydrates has been prognosticated as more than 1500 times of India's present natural gas reserve. The total organic carbon content (TOC), sediment thickness and rate of sedimentation indicate that the Cauvery and Kerala–Laccadive basins are also prospective for gas hydrates. India has the second largest gas hydrate reserves after America. The Krishna-Godavari (KG), Cauvery and Kerala basins alone have 100-130 trillion cubic feet of estimated reserves.

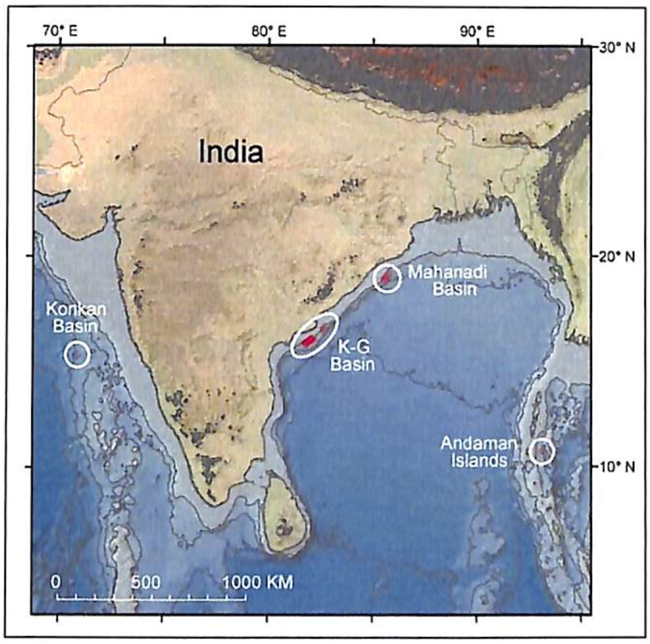

Figure 13: Prospective areas for Gas Hydrate in India, (Source: Maritime, 2016)

Each molecule of Gas hydrate contains upto 164 m3 of Methane (CH4). Initial work in India on Gas Hydrates as energy resource, was done by GAIL and NIO. In 1995 an expert committee realized the potential of gas hydrates in India. Gas hydrate exploratory activities/ research in India is being steered by the Ministry of Petroleum & Natural Gas under National Gas Hydrate Program (NGHP) which was initiated in 1997 with participation from Directorate General of Hydrocarbons (DGH), National E&P companies (Oil and Natural Gas corporation Ltd, GAIL India Ltd, Indian Oil Corporation & Oil India Ltd) and National Research Institution (National Institute of Oceanography, National Geophysical Research Institute and National Institute of Ocean Technology). Steering Committee was headed by Secretary, P&NG with Joint Secretary (E) as convener. The

Technical Committee was chaired by DG, DGH and has participation from all National Oil Companies (NOC) like OIL, ONGC, GAIL, IOCL, and National Institutes like the NGRI, NIO & NIOT. The NGHP was restructured in the year 2000.

The gas hydrates resources are estimated to be about 742,000 trillion cubic feet (tcf) for the world and 66000 tcf for India. These estimates include gas hydrate occurrences in all geologic and reservoir conditions. The gas hydrate research and field tests suggest that sand hosted hydrates are technically feasible for production. Therefore, gas hydrate resources in sand dominated lithologies have been estimated and these are 43000 tcf worldwide and 933 tcf for India. The recently completed second expedition known as NGHP-02 has discovered two world class potentially producible gas hydrate reservoirs in KG area. Based on the data obtained from second expedition, 134 tcf of gas initially in place in gas hydrates is estimated in KG deep offshore area. The estimated sand hosted gas hydrate resources in Indian Offshore areas of about 933 tcf is equivalent to 23510 Mtoe which is about 15 times of the energy demand – supply gap. This makes gas hydrates as potential new frontier for energy security of India.

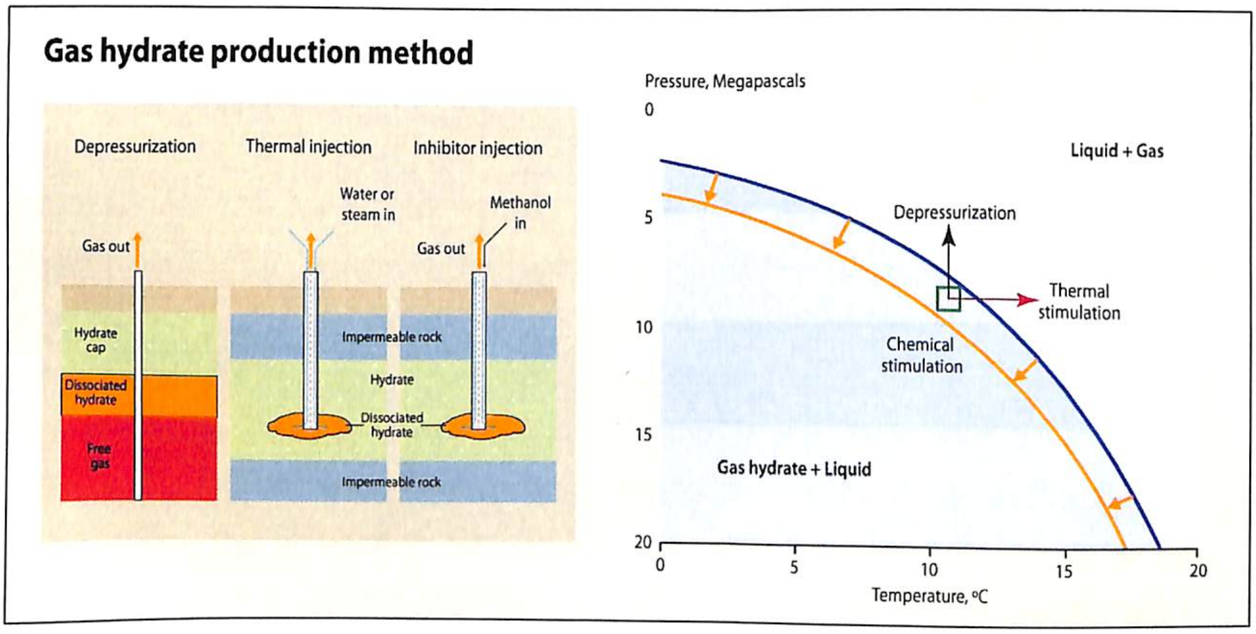

Figure 14: Gas Hydrate Production Method

Gas Hydrate Production Method

The natural gas from gas hydrate can be produced via depressurization, chemical inhibitor injection and thermal stimulation (Figure 14).

For each of the three proposed gas hydrate production methods (left frame), conditions within initially stable hydrate-bearing sediment are shifted such that hydrate at that location is no longer stable, and will begin dissociating.

Right frame: ***Depressurization:*** achieved by reducing the formation pressure below equilibrium limits. ***Thermal stimulation:*** achieved by increasing the formation pressure beyond equilibrium conditions. ***Chemical stimulation:*** changes in gas hydrate equilibrium conditions are induced by inhibitor injection.

There are two main technologies that have been successfully trialed to free gas from similar deposits. These are depressurizing or injecting CO2 to replace the gas in the icicles. However, the technology is still in pilot stage. Japan has stated plans to start commercial gas production from its offshore hydrates from 2020 after commercial testing expected to be completed by 2018.

Hazards

Although methane hydrates are not recent discoveries, it is only now that their extraction and production are becoming commercially feasible as a major new energy source. They are present offshore in almost every coastal state, and their economic potential for endowing those states with abundant natural gas is vast. Gas hydrates are also a risk, representing a hazard to oil and gas drilling and production. If gas hydrates dissociate suddenly and release expanded gas during offshore drilling, they could disrupt marine sediments and compromise pipelines and production equipment. Water can be a hazard in process plants. When water is mixed with some materials, typically gases but also liquids, it can form a crystalline, ice-like solid. This solid is called a hydrate. When a hydrate forms, it can plug piping, instrument connections, valves, and other equipment, which causes process upsets that may be hazardous. Offshore drilling operations that disturb gas hydrate-bearing sediments could fracture or disrupt the bottom sediments and compromise the wellbore, pipelines, rig supports, and other equipment involved in oil and gas production from the seafloor. The greatest unique environmental problem is the uncontrolled release of methane hydrates.

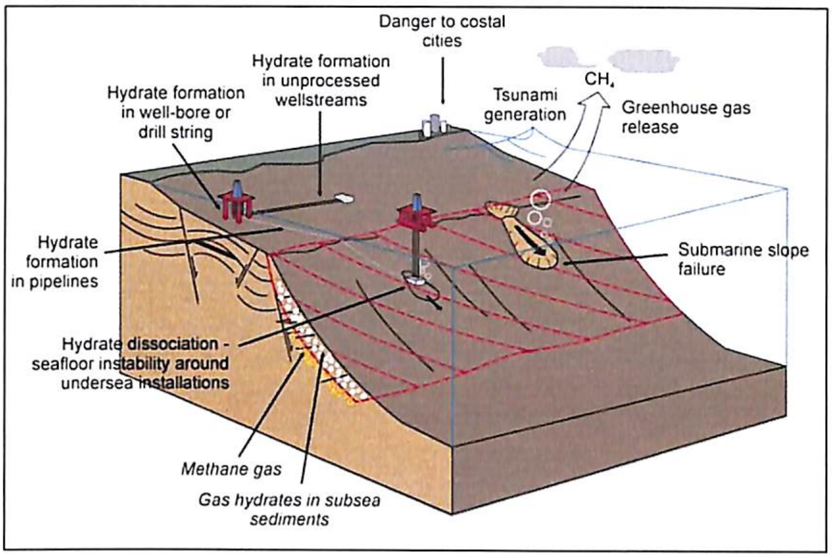

Figure 15: Major issues of Gas Hydrate
(Source: School of Energy, Heriot-Watt University, Edinburgh)

Above figure represents various types of hazards which can occur during the drilling and production of methane from gas hydrate reservoirs. Methane hydrates lay under essentially plastic mud and sedimentary layers, so as the hydrates are moved and the structural support for the overlaying materials are removed, the seabed is likely to deform and sag. Subsidence can impact the subsea structural systems related to the methane extraction and it can impact the local eco-system. Perhaps the greatest concern on subsidence is that it can become a precursor for landslides, which in turn could result in massive amounts of uncontrolled methane eruptions.

Chapter - 3

Research Design, Methodology and Plan

Chapter 3: Research Design, Methodology and Plan

3.1 Introduction

In this Chapter the description of the research process has been presented. It provides information concerning the method that was used in undertaking this research as well as a justification for the use of this method. The Chapter also describes the various stages of the research, which includes the selection of participants, the data collection process and the process of data analysis. The Chapter also discusses the role of the researcher in qualitative research in relation to reflexivity. The Chapter ends with a discussion of validity and reliability in qualitative research and discusses the way in which these two requirements were met in the current study.

3.2 Research Design and Methodology

A research design is the set of methods and procedures used in collecting and analyzing measures of the variables specified in the problem research. The design of a study defines the study type (descriptive, correlation, semi-experimental, experimental, review, meta-analytic) and sub-type (e.g., descriptive-longitudinal case study), research problem, hypotheses, independent and dependent variables, experimental design, and, if applicable, data collection methods and a statistical analysis plan. A research design is a framework that has been created to find answers to research questions.

Different Steps in Research

1. Problem identification
2. Review of available literature
3. Problem formulation
4. Writing a research proposal
5. Deciding the methodology
6. Sample selection and preparation of tools of data collection
7. Collecting the data
8. Analysing and interpreting the data
9. Writing the research report

Figure 16: Different Steps in Research, (Source: Pathshala, MHRD, GOI)

A research method is a systematic plan for conducting research (Figure 14). Sociologists draw on a variety of both qualitative and quantitative research methods, including experiments, survey research, participant observation, and secondary data. Quantitative methods aim to classify features, count them, and create statistical models to test hypotheses and explain observations. Qualitative methods aim for a complete, detailed description of observations, including the context of events and circumstances.

3.3 Research Process

Scientific research involves a systematic process that focuses on being objective and gathering a multitude of information for analysis so that the researcher can come to a conclusion. The research process involves identifying, locating, assessing, and analyzing the information you need to support your research question, and then developing and expressing your ideas. These are the same skills you need any time you write a report, proposal, or put together a presentation.

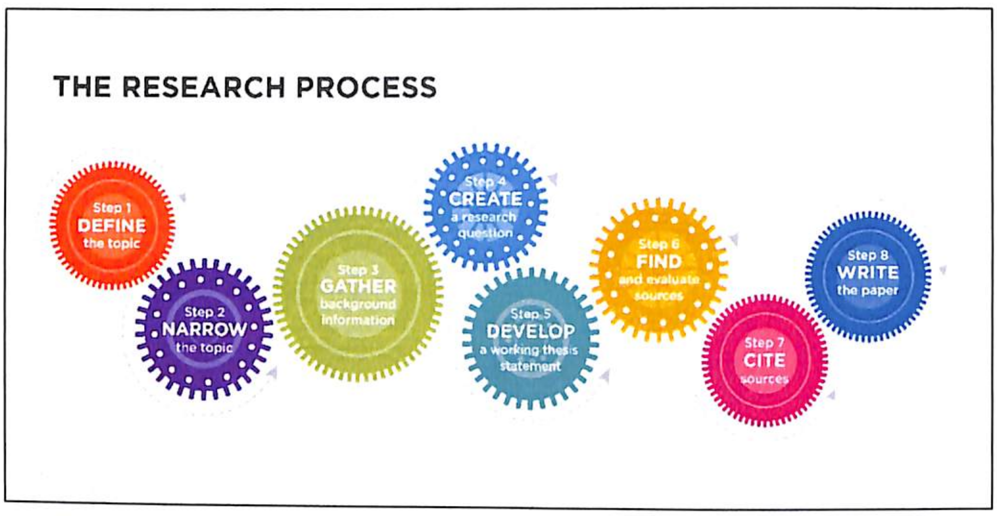

Figure 17: Different Steps in Research Process, (Source: Lumen learning)

Research process contains a series of closely related activities which has to carry out by a researcher (Figure 17). Research process requires patients. There is no measure that shows your research is the best. It is an art rather than a science. The research process is not a linear process in which you must complete step one before moving on to step two or three.

3.4 Mixed Methods Research Methodology

A mixed methods research design is a procedure for collecting, analyzing, and "mixing" both quantitative and qualitative research and methods in a single study to understand a research problem.

The following section discusses in detail, the qualitative and quantitative research methods that were used in this study and, later the phases in the data collection and analysis are tabulated.

Quantitative Research

This is a type of educational research in which the research decides what to study; asks specific, narrow questions, collects quantifiable data from participants (a large number of participants); analyzes these numbers using statistics; and conducts the inquiry in an unbiased, objective manner. It generally attempts to quantify variables of interest and questions must be measureable. It involves collecting numerical data that can be subjected to statistical analysis. The data is generally referred to as "hard" data. Examples of data collection methodologies are Performance Tests, Personality Measures, Questionnaires (with closed-ended questions or open-ended but transferred to quan data) and Content Analysis.

Qualitative Research

A type of educational research in which the researcher relies on the views of participants; asks broad, general questions; collects data consisting largely of words (or text) from participants; describes and analyzes these words for themes; and conducts the inquiry in a subjective, biased manner. This method of research generally involves listening to the participants' voice and subjecting the data to analytic induction (e.g., finding common themes) and are more Exploratory in nature. Examples of data collection methods are Interviews, Open-ended questionnaires, Observations, Content analysis and Focus Groups.

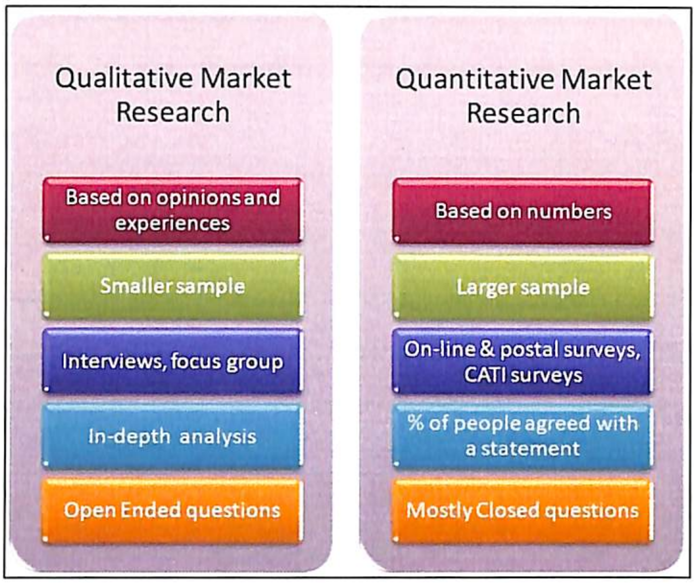

Figure 18: Difference between Qualitative & Quantitative Research
(Source: Arema Connect & Market Research, Ireland)

3.5 Ensuring Validity and Reliability

Validity encompasses the entire experimental concept and establishes whether the results obtained meet all of the requirements of the scientific research method.

Internal validity is a crucial measure in quantitative studies, where it ensures that a researcher's experiment design closely follows the principle of cause and effect.

External validity is the process of examining the results and questioning whether there are any other possible causal relationships.

The idea behind **reliability** is that any significant results must be more than a one-off finding and be inherently repeatable.

As this study entails the use of both qualitative and quantitative research data, the concepts used to express validity and reliability are broader than those traditionally associated with quantitative research. When working with qualitative data, the concepts of trustworthiness, dependability, transferability, and credibility are also used.

The reliability and validity of data used in this research work were done with in depth analysis with the help of opinion and experiences of senior executives of ONGC having detailed and correct knowledge of the subject. Questionnaires were prepared on the relevant points of the subject and the same was validated by domain experts of the

Industry. The following processes for ensuring validity and reliability, legitimizing the data, and finally lending credibility to the research report were used for this study.

Triangulation

Triangulation means using more than one method to collect data on the same topic. This is a way of assuring the validity of research through the use of a variety of methods to collect data on the same topic, which involves different types of samples as well as methods of data collection. However, the purpose of triangulation is not necessarily to cross-validate data but rather to capture different dimensions of the same phenomenon.

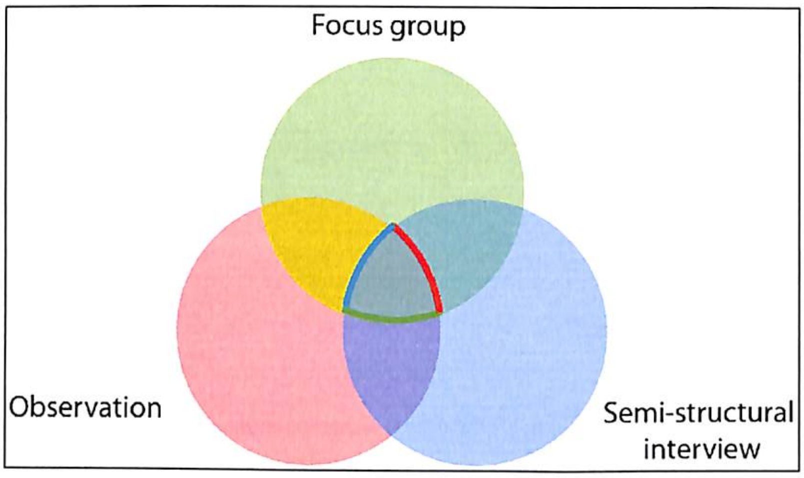

Figure 19: Representation of the triangulation of data sources

The above diagramme represents the three data sources used by the researcher. The concept of focus group of done to ensure the validity of data collected from different sources. The other two observations and semi-structural methods were used for data collection and proving its reliability and validity. Triangulation offered the following benefits for this study: it provided additional sources of valuable insight that could not be obtained from the literature review alone; it minimized the inadequacies of single-source research by engaging three data sources which complemented and verified each other, and it also provided richer and more comprehensive information in the sense that the researcher was able to draw information from various sources including the face-to-face interviews which provided first hand, lived experiences of the principals.

Thick Description

Thick description is described by Lincoln and Guba (1985) as a way of achieving a type of external validity. By describing a phenomenon in sufficient detail one can begin to evaluate the extent to which the conclusions drawn are transferable to other times, settings, situations, and people. The purpose of reporting the findings using thick description is to provide as much detail as possible for the readers. It also enables the readers to make decisions about the applicability of the findings to other settings or similar contexts.

Peer Review

The third and last procedure for ensuring validity and reliability in this study is peer review. The peer review process is integral to any scholarly research. It is a process of subjecting research methods and findings to the scrutiny of others who are experts in the same field. It functions as a form of self-regulation by qualified members of a profession within the relevant field. This procedure was used during both phases of my data collection and interpretation. The peer reviewer was and experienced holding position of senior manager in national Oil Company, ONGCL based at Dehradun. He has enough experience and knowledge of the relevant field to validate my work. Peer carried out in depth analysis of the work done for this project. During this period peer discussed on various relevant points. He provided valuable advice and feedback on the work done for this research work.

3.6 Summary and Conclusions

This chapter started with introduction to the various methods planned to be employed in the project work. Various kind of data collection method were explained and the type of data used for the research were also explained. The collected data were validated and also the reliability was assessed by reviewer. The suggested modifications were incorporated and work improved after getting feedback.

Chapter - 4

Finding and Analysis

Chapter 4: Finding and Analysis

4.1 Changing Scenario in Energy Sector

India is the 3rd largest global consumer of oil and its energy requirement is expected to grow at a CAGR of 4.6% through 2030, making it the fastest growing energy consumer in the world. Over the past two decades, the Indian oil and gas industry has had a major transformation triggered by liberalization and increasing demand for oil and gas products. While India has become a regional leader in the downstream refining sector, the upstream and gas midstream sectors have lagged behind, resulting in India importing approximately 80% of its crude oil requirement; and 49% of its natural gas requirement and gas accounting for only 7% of the energy mix.

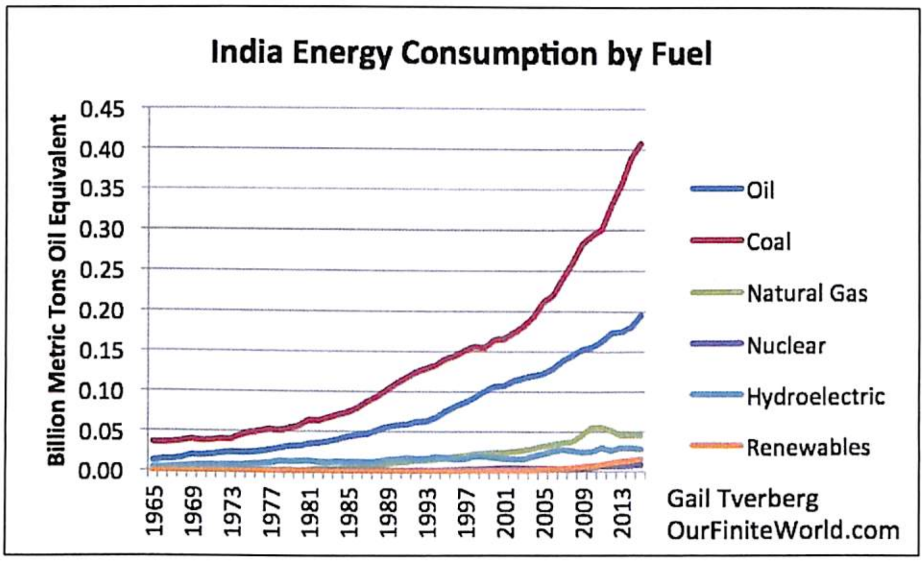

Figure 20: India Energy consumption by Fuel, *(based on BP 2016 SRWE)*

With a targeted GDP growth rate of 8.5 to 9.5 percent, the energy requirements of India are expected to grow at 5.6- 6.4 percent per annum over the next few years. This implies a four-fold increase in India's energy requirement over the next 25 years. This poses a significant gap in supply and demand of energy to meet industrial and domestic requirements. Analysis of energy demand and supply suggests that the energy demand is expected to be about 1900 Mtoe by 2040. The current domestic energy production is around 320 Mtoe and is not likely to increase in future.

In the present changing scenario in various facets of E&P Industry throughout the world, it is necessary to study, observe and chalk out the new business strategies for the sustainability and its growth in future. The era of transition and transformation in the energy mix of the globe has begun about two decades back, but the necessity has been realized in recent years. In the present scenario E&P industry in India is undergoing transformation and disruption phase with increasing share in renewable energy sources. India is poised to transit into a low carbon clean energy system. The conventional hydrocarbon resources with the help of suitable technological interventions, favorable policies by the Government of India can go a long way for augmenting the oil & Gas production in the country which is still at a very nascent stage. There is a strong need for potential reassessment of the prospective unconventional hydrocarbons locals in all 26 sedimentary basins of India as has been done recently for conventional hydrocarbons resources of the country. It is pertinent here to mention that simultaneous exploration and exploitation of both conventional and unconventional hydrocarbons resources from a single acreage can lead to substantial increase in oil & Gas production.

4.2 Role of Unconventional HC in India

Unconventional resources have been identified throughout the world and contain enormous in-place volumes but tight and unfamiliar reservoirs challenge the transformation of these resources to supplies. The key issue is whether industry can grow production from unconventional reservoirs at a rate that will offset declines from older conventional reservoirs. E&P companies are attracted to such resources because they have low exploration risk, material production volumes, long-lasting production and exist near mature, stable markets. On the basis of present G&G studies carries out by various NOC's and MNC's it is estimated that India poses a huge potential for exploration and exploitation of unconventional oil & gas. Contribution from CBM and Tight reservoirs has already started though at a small scale in total oil & gas production of the country. G&G work is in progress for shale gas and gas hydrate and it is expected that contribution from these two resources will commence in near future. The new policies announced by GOI will definitely boost the development in unconventional oil & gas sector.

4.3 Focus on Geo-scientific Studies

To assess, explore and produce the unconventional hydrocarbon reservoirs requires an exhaustive study. Fresh Geological modelling will be required with the help of newly acquired seismic data throughout the sedimentary basins of India. Several wells have been drilled by NOC's mainly in Category-I basins, the same need to be extended to rest of the basins viz Category, II, III & IV. Wherever required parametric wells to be drilled to acquire subsurface information. Basin modelling with the help of remote sensing, field geology and 2D & 3D seismic data to be carried out to identify the suitable drillable prospects in the basin. One of the most critical issue is formation evaluation and reservoir characterization. This issue can be resolved using state of the art and latest technology available in the world for the well logging. The latest interpretation tool and available interpretation software can help for the better imaging and reservoir characterization which would help in furtherance towards exploitation of the unconventional oil & gas. Entire east and west coast of India upto required quick evaluation in light of the development process of Gas Hydrate.

4.4 Future Potential and planning

As far as the future potential is concerned India has good potential of unconventional hydrocarbons in the country. In case of shale gas various agencies have estimated the shale gas potential from 60 TCF to 2100 TCF. To date, most CBM exploration and production activities in India is pursued by domestic Indian companies. Total prognosticated CBM resource for awarded 33 CBM blocks, is about 62.4 TCF (1767 BCM), of which, so far, 9.9 TCF (280.34 BCM) has been established as Gas in Place (GIP). The recently completed second expedition known as NGHP-02 has discovered two world class potentially producible gas hydrate reservoirs in KG area. Based on the data obtained from second expedition, 134 tcf of gas initially in place in gas hydrates is estimated in KG deep offshore area. The estimated sand hosted gas hydrate resources in Indian Offshore areas of about 933 tcf is equivalent to 23510 Mtoe which is about 15 times of the energy demand – supply gap.

The economic viability of developing unconventional resources depends upon many factors. These include:

- Geology (nature of resource, nature of source rock, resource depth, size of resource, etc.);
- Geography (e.g., size of markets, proximity of resource to markets);
- Topography (ability to construct well pads, water sources, sand sources, etc.);
- Governance (e.g., nature and stability of laws and regulations, over-arching fiscal regime, mineral ownership, lease/resource access, royalties/taxes, liability exposure, rights of way policies);
- Supporting infrastructure (e.g., roads, railways, waterways, power sources, pipelines, disposal options, worker housing/social services);
- Supporting labor force (availability of trained personnel);
- Materials and equipment availability (drilling, fracturing and environmental management equipment, cement, gravel, sand, chemical additives, trucks, piping, etc.); and
- Pricing (the price being offered for the given oil or gas commodity at the time of investment decisions).

The costs and anticipated development pace associated with each of these factors can encourage or discourage investments in one location relative to other regions or countries. Considering the unconventional nature the exploration and development of unconventional required meticulous planning. The G&G Study, Basin Modeling, Petroleum System Modeling, Identification of suitable prospects, reservoir characterization, identification of suitable drillable locations, nearby facilities, environmental concerns, the state regulatory, economics, companies overall view, future potential of the prospect, acreage scenario, government regulations etc.

4.5 Government Initiatives

Government has taken a series of policy decisions to promote exploration and production of oil and gas. They include; Reassessment of hydrocarbon resources, Survey of un-appraised areas of sedimentary basins, Setting up of National Data Repository, Hydrocarbon Exploration Licensing Policy, Discovered Small Field Policy, Policy for early monetization of coal bed methane, Policy for exploration and exploitation of unconventional hydrocarbons, Policy to promote and incentivise enhanced oil discovery methods, Reforms in gas pricing, marketing and pricing freedom etc.

The recent policy initiatives are a part of Government's "Ease of Doing Business" initiative to make Indian oil & gas sector fair, transparent and investor friendly through appropriate regulatory, fiscal and policy interventions. The World Bank declared that India has moved up 30 places (to 100 h rank) in the Global Ease of Doing Business rankings. Government has also identified oil and gas sector as one of the 25 priority areas for promotion of manufacturing under the "Make in India" campaign.

The Union government has approved a policy framework for exploration and exploitation of unconventional hydrocarbons, a change that would allow private companies to exploit unconventional hydrocarbons including shale gas and Coal Bed Methane (CBM) from their existing blocks. Prior to the new policy, field operators were not allowed to explore and exploit CBM, shale gas and other unconventional hydrocarbons from allotted licensed area. Similarly, contractors with CBM fields were not allowed to exploit any other hydrocarbons except CBM. This policy will enable the realization of prospective hydrocarbon reserves in the existing Contract Areas which otherwise would remain unexplored and unexploited. Exploration and exploitation of additional hydrocarbon resources is expected to spur new investment, impetus to economic activities, additional employment generation and thus benefiting various sections of society.

An additional 10 per cent profit petroleum will be levied for new CBM discoveries and National Oil Companies (NOCs) will be allowed to explore and exploit unconventional hydrocarbons under the existing fiscal and contractual terms of exploration or lease license. There will be complete shift from 'One hydrocarbon Resource Type' to 'Uniform Licensing Policy' which is presently applicable in Hydrocarbon Exploration & Licensing Policy (HELP) and Discovered Small Field (DSF) Policy,"

GOI has also announced policy framework to promote and incentivize for enhanced oil & gas recovery to provide fiscal incentives to adopt Enhanced Recovery (ER), Improved Recovery (IR) and Unconventional Hydrocarbon (UHC) production method.

In the policy, Unconventional hydrocarbon production methods include following:

- ✓ Shale oil / shale gas production
- ✓ Tight oil production (less than 1md) / tight gas production (less than 0.1 md), The permeability will be average of payzone.
- ✓ Production from Oil shale
- ✓ Production from gas hydrates
- ✓ Production from Heavy Oil, Oil which is less that 20 API at standard conditions or with viscosity greater than 100 CP (centipoise) at in-situ condition.

Chapter - 5

Interpretation of Results

5.1 Interpretation of Results

In this research work literature survey was carried out in length along with study using different suitable research methodology. The data gathered and studied were validated and its reliability was ascertained with the help of peers from renowned oil industry. The present status of unconventional hydrocarbon exploration in the country was analyzed in detailed with respect to the world producing basins. The data collected reveals that a healthy amount of work has been done towards the exploration and exploitation of unconventional hydrocarbon in the country. At the same time it is also brought out that country needs a long way to go to establish the true potential of unconventional hydrocarbon. Compared to the countries viz USA, Canada, China etc India too have good potential for future exploration and production of unconventional hydrocarbon.

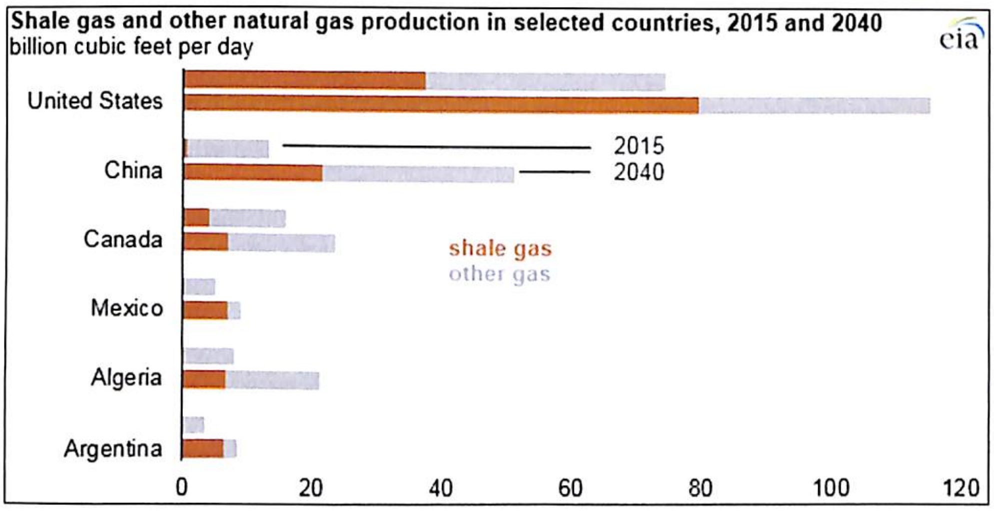

Figure 21: Country wise Shale Gas and other natural gas production

The above figure represents the share of shale gas in total gas production of natural gas in different countries projected till the year 2040. This itself indicates a handsome share of unconventional gas in the total production in different countries.

The new policy initiative taken by Government of India to boost the exploration and production of Oil & Gas in country will definitely help the oil & gas companies to enhance E&P activities across the different sedimentary basins, operating in the country.

5.2 Comparison of Results

Unconventional versus Conventional

The oil and gas industry has used the terms "conventional" and "unconventional" resources for decades, though no standard definitions exist. At its most basic level, a "conventional" resource will flow on its own to the wellbore, while an "unconventional" resource will not. Unconventional resources require the application of external stimulation to enable hydrocarbons to flow. Hydraulic fracturing, which cracks underground source rock to release gas or oil embedded within it, is one such form of external stimulation. 5 While other definitional contrasts exist, for the purposes of this report the need to provide external stimulation – e.g., through hydraulic fracturing – is the critical factor for labeling a resource as unconventional. Most community and stakeholder interest surrounding unconventional resources development today is focused on hydraulic fracturing, including the inputs and operations surrounding the practice.

During the project work a comparative study of producing basins with indian basins were carried out, The same has been elaborated as below:

Shale Gas

US has been driven largely due to the discovery of giant 'fields': the Eagleford, Haynesville, Horn River and Marcellus shales. Although these were all discovered since 2007, deep shale gas production had actually become a commercial reality in the 1980s and 90s, with the discovery of the Barnett Shale in North Central Texas. Statistically speaking, shale gas provided only 1% of US natural gas production in 2000, however, by the end of 2010, it took a driving seat and contributed more than 20% of the total US gas production. As predicted by the Energy Information Administration of US Government, 46% of the United States' natural gas supply will come from shale gas by 2035.

Canada is the first country outside the United States to see large-scale development of shale resources, which already account for 8 percent of total Canadian oil output. China is estimated to have the world's largest shale gas reserves. In 2013, the EIA updated it estimation of China's shale gas reserves, reporting that China had 1115 trillion cubic feet (31 trillion cubic meters) of recoverable shale gas.

Looking at the reserves of shale gas, the EIA has listed eleven countries where technically recoverable shale gas reserves are available namely Argentina, Algeria, Australia, Brazil, Canada, China, India, Mexica, Russia, South Africa and US.

The studies carried out by various agencies suggested that globally total Risked Gas-inplace (GIP) is approximately 21048 Tcf and the total Risked recoverable shale gas is approximately 4450 Tcf. The contribution of India in total Risked GIP is approximately 584 Tcf (2.8% of total Risked GIP of global shale gas, Fig. 19).

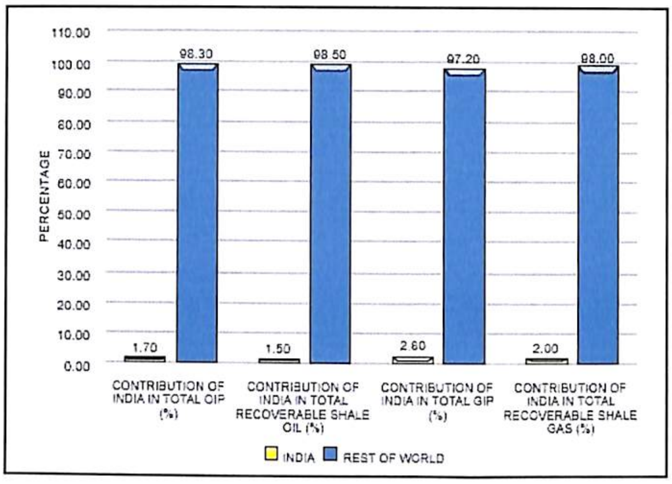

Figure 22: Contribution of India vis-à-vis World in Shale Gas and Oil (%)

Comparison of Indian shale vis-à-vis Global shale plays with different Parameters

There are different geological, geochemical, petrophysical and geomechenical parameters like kerogen type, thermal maturity, depth and thickness of shale, gas content, porosity, permeability, hydrocarbon saturation, mineralogical attributes, hydrogen index, TOC, free hydrocarbon (S1) and hydrocarbon generation potential (S2) etc. which are used to provide a first order overview of the geologic characteristics of the major shale gas and shale oil reservoirs. These help in selecting shale gas and shale oil basins and potential shale sequences for more intensive assessment. On the basis of the data generated so far, it has been observed that:

Indian shales are rich in clay content (>50%), characterized by low matrix permeability (Nanno darcy), the depositional environment is shallow marine to non-marine. The reservoir pressure is mostly normal to slightly over-pressured (locally), shale sequences are generally organic rich with average TOC content ranging between 1.0 and 3.5%. The organic matter is mostly in early to late oil generation maturity window VRo: 0.6-1.2%). The kerogen is primarily Type-III with minor contribution of Type-II OM. The average depth of shale sequence is high (2500-5000m). Low resource concentration and low oil saturation.

Coal Bed Methane

CBM reserves are discovered in USA, Russia, China, Australia, Canada, Indonesia, India, Ukraine, UK and Kazakhstan (Table-1). About 90% CBM reserves are found in five countries namely USA, Russia, China, Australia and Canada.

Sl No.	Country	Reserves (TCF)
1	USA	1,748
2	Russia	1,730
3	China	1,307
4	Australia	1,037
5	Canada	699
6	Indonesia	453
7	UK	102
8	India	71
9	Ukraine	42
10	Kazakhstan	23

Table 2: CBM Reserves of top 10 countries, (Source: DGH, India)

To understand CBM basin characteristics, Indian CBM blocks are compared with commercially successful CBM basins in USA, Canada, Australia and China. All the CBM blocks in India are at depth ranging from 300–1500 m, with average depth 907.5m. This indicates that Indian CBM blocks are at shallow depth compared to other basins of the world. The coal seam thickness of commercially successful CBM basins is in the range of 4–100m. The coal seam thickness of Indian CBM blocks is in the range of 1–120m which is almost similar to CBM basins of USA. The gas content range of commercially successful CBM basins is 0.8–25.5 m3/ton. Indian CBM blocks are having gas content in the range of 2–17m3/ton. This shows gas content in Indian CBM blocks is within range of productive basins. Compared to the maximum value, gas content in Indian CBM blocks is low.

The major technical challenge is geological complexity of coal basin in India. Gondwana basin consists of multiple coal seams. The assessment of the CBM potential is challenging due to scarcity of CBM related data. Indian coal is inferior grade resulting in low gas content and gas saturation. Low porosity and permeability of the CBM basins may yield low production rates. Under the CBM policy, till date, four rounds of CBM bidding rounds have been implemented by MOP&NG, resulting in award of 33 CBM blocks which covers 16,613 sq.km out of the total available coal bearing areas for CBM exploration of 26,000 sq.km.

Tight Gas

Tight gas is predominantly a cost-effective issue. Production is relative to technology development, well cost, stimulation cost and existing gas price. The development of many tight gas sand fields that are productive today began in the Western United States San Juan Basin By 1970s. Tight sands produce about 6 Tcf of gas per year in the United States which is 27-30% of the total gas produced. Tight gas developments are currently underway in Germany, offshore Holland and the UK. Energy Information Administration (EIA) estimates that 310 Tcf of technically recoverable tight gas exists within the U.S, representing over 17% of the total recoverable gas. Worldwide, more than 7,400 TCF of natural gas is estimated to be contained within tight sands (Rogner, 2006) with some estimates as large as 30,000 TCF. India holds significant in-place of oil and gas volume in tight reservoirs with very low recovery. Exploiting locked up potential of such reservoirs is an opportunity as well as a challenge. Every well completed in the tight or low permeability reservoir requires hydro-fracturing job for the commercial production. The integration of geological understanding, petro-physical evaluation, geo-mechanical modelling, effective hydro-fracturing design and reservoir engineering studies are key to success of the development planning of any tight reservoir.

Gas Hydrate

The gas hydrate programme by India began in 1997 and with the help of a consortium (including Overseas Drilling, Fugro, McClelland Marine Geosciences, Geo-TeK, Lamont, Doherthy and Earth Observatory), it first conducted studies in 2006.

The United States, Canada, Japan, and India all have vigorous research programs working to discover viable technologies for producing gas hydrates. Methane hydrate will likely play an important role in our future energy mix. For more than two decades, deepwater gas hydrate has been the focus of ocean drilling expeditions led by scientific consortia, governments, and private companies. Among the best studied locations are the northern Gulf of Mexico and areas offshore of Oregon; Vancouver, Canada; India; Japan; South Korea; and China. Japan and Canada are two countries that have been working on the technology for a long time, and claim it would be possible to produce commercial gas from gas hydrates in the next 4-5 years.

The gas hydrates resources are estimated to be about 742,000 trillion cubic feet (tcf) for the world and 66000 tcf for India. These estimates include gas hydrate occurrences in all geologic and reservoir conditions. The gas hydrate research and field tests suggest that sand hosted hydrates are technically feasible for production. Therefore, gas hydrate resources in sand dominated lithologies have been estimated and these are 43000 tcf worldwide and 933 tcf for India. The recently completed second expedition known as NGHP-02 has discovered two world class potentially producible gas hydrate reservoirs in KG area. Based on the data obtained from second expedition, 134 tcf of gas initially in place in gas hydrates is estimated in KG deep offshore area. The estimated sand hosted gas hydrate resources in Indian Offshore areas of about 933 tcf is equivalent to 23510 Mtoe which is about 15 times of the energy demand – supply gap. This makes gas hydrates as potential new frontier for energy security of India.

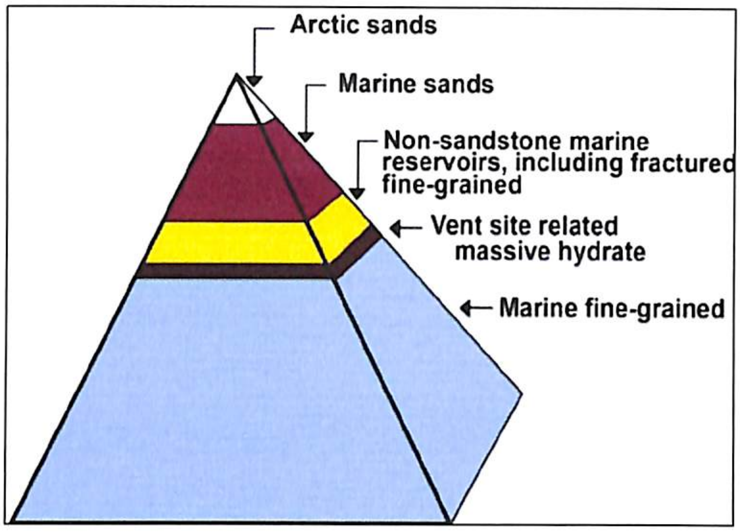

Figure 23: Gas Hydrate Resource Pyramid (from Schoderbek and Boswell)

The above figure shows the occurrence of gas hydrate in various zones in the nature. According to the latest estimates of the US Geological Survey, we have the second largest gas hydrate reserves after America. The Krishna-Godavari (KG), Cauvery and Kerala basins alone contributing 100-130 trillion cubic feet of estimated reserves. To prove the reserves of Gas Hydrates in India, pilot production testing is planned in the KG Deepwater area under the ambitious programme NGHP-3. A study is being conducted by a team of officials led by ONGC, along with the US Geological Survey and the Japanese Drilling Company. So far, the Oil Industry Development Board (OIDB) has sanctioned grants to the tune of around Rs 200 crore for the programme. Based on the arrangement, costs for these R&D activities are shared between OIDB, ONGC, GAIL India, Oil India and Indian Oil Corporation. For further study in detail, Oil and Natural Gas Corporation Limited (ONGC) has set up at a dedicated Gas Hydrate Research & Technology Centre (GHRTC) at Panvel (Navi Mumbai). This centre gives impetus to the Gas Hydrate research & technology development and contributes to GOI's plan to commercialize Gas Hydrates as energy resource at the earliest. Apart from the US and Japan, India has entered into an agreement with Canada to develop technology in this regard.

5.3 Benefits of developing unconventional hydrocarbons

The revolution in energy production brought about by the rapid growth of unconventional gas and oil development in the United States has generated widespread economic benefits. The result has been increased economic prosperity, a revitalized manufacturing sector, improvement of millions of lives through direct and indirect employment and lower energy costs, new sources of government revenues, and strengthened energy security for the nation.

The development of unconventional resources also can bring substantial reductions in operational surface footprint. Industry's ability to drill multiple wells from a single well pad (more than two dozen wells in some cases) and the technique of drilling long horizontal wells to access the shale or tight sand resource, combine to enable unconventional resources development with fewer surface impacts compared to conventional drilling.

Natural gas development through hydraulic fracturing has brought about significant greenhouse gas reductions in the United States. Natural gas is the cleanest burning fossil fuel, and less carbon intensive than other fossil fuels. When used for power generation, natural gas emits considerably less carbon dioxide than coal. Emissions of mercury, sulfur, and nitrogen oxide are also significantly reduced. Studies by the U.S. Department of Energy, Energy Information Administration and Environmental Protection Agency and academics have shown greenhouse gas emissions of unconventional natural gas to be about 50 percent less than those for coal on a full lifecycle basis.

In the country like India development of unconventional hydrocarbon will play a vital role in various sectors.

- With appropriate safeguards, they can provide a cleaner source of energy than other fossil fuels.
- Creates jobs and provides economic benefits to the entire domestic production supply chain, as well as to chemical and other manufacturers, who benefit from lower feedstock and energy costs.
- Increase domestic production - aspiration of 10% reduction in imports by 2022
- Build infrastructure – Greenfield and brownfield refineries, petrochemical plants, pipelines, LNG terminals.
- It will attract FDI & technical expertise.

Chapter - 6

Conclusions and Scope for Future Work

Chapter 6: Conclusions and Scope for Future Work

The global energy landscape is changing rapidly. The main driver of these changes is the shale revolution which has taken place in a small number of countries, yet still has global consequences. The future of the global energy market, in the short run, remains the same but, in the long run, new participants will emerge and fight their way to the top of the hydrocarbon-exporting countries. Hydrocarbon Exploration is becoming increasingly challenging as easy to find resources are mostly explored/exploited and the search for YTF hydrocarbons is expanding to ever more complex geological settings. Unconventional hydrocarbons resources are potentially enormous, approaching 3.6 trillion barrels of oil equivalent (boe) globally. There are substantial challenges to transform these huge resources into supplies. Exploiting unconventional hydrocarbons requires additional technology, energy, and capital compared to the industry standard. To unlock their potential, many technical, commercial, fiscal and environmental issues must be overcome. Indian government has initiated several policy and regulatory measures to ensure development of unconventional energy resources in the country. To secure adequate supply of energy resources it is important to develop bilateral and regional strategic energy partnerships that promote, diversification of hydrocarbon supply sources, acquisition of foreign hydrocarbon assets, enhancement of the national knowledge-base and acquisition of latest technologies. It is a known fact that in future unconventional hydrocarbons will play vital role in transforming the energy scenario of not only India but whole world and the geopolitics as well. With the development of drilling and production technology, especially the application of horizontal drilling and hydraulic fracturing technology, the production of unconventional oil and gas resources has increased consecutively with increasing proportions of oil and gas production. The proportion of unconventional oil and gas production occupies close to 10% of the total oil and gas production, becoming an important component of global oil and gas output. Such proportion will become even larger in the future oil and gas supply. Variations in gas production of the United States during 1949-2009 are the most direct reflection of this trend of oil and gas resource production structure.

India will be the biggest contributor to energy growth demand globally in the years to come and hydrocarbons is an important component of India's energy basket in future. By

2035, India is likely to be among the fastest growing oil and gas markets, with oil demand almost doubling to ~10 million barrels per day and gas demand tripling over the same period. This research work discussed about the four mail unconventional hydrocarbon resources. The comparative studies has concluded that country has good potential for development of unconventionals. A good progress have been made since last one decade mainly through NOC's especially ONGC with the support of GOI in the development of unconventional in the country. To secure adequate supply of energy resources it is important to develop bilateral and regional strategic energy partnerships that promote diversification of hydrocarbon supply sources, acquisition of foreign hydrocarbon assets, enhancement of the national knowledge-base and acquisition of latest technologies.

Regarding development of Shale Gas, a number of wells has been drilled in many basins of the country and encouraging results have also been obtained. Many agencies have estimated the potential of shale gas in India in a varying scale. On the basis of present geo-scientific studies it is prudent to mention here that the quality of shale in India is of not at par with the producing sales in USA. Presently focus for exploration of shale gas is in Cambay & Krishna –Godavari Basins. In case of Coal Bed Methane, countries progress is satisfactory with contribution of natural gas from different fields. Many NOC's and private operators are involved in developing the CBM in India. There is huge scope to develop 91 Tcf of CBM resource and start production in significant amount. As is known that tight reservoirs exists in almost all basins because of its unique character and geological settings. The new approach for exploration of tight gas has already started in the country and with the support of new technologies it has stated giving fruitful results. Gas hydrate has enormous potential in Indian offshore areas as established under the noble programme initiated by Government of India i.e NGHP-01 & 02. Fresh reserves in KG Basin is estimated to be around 134 trillion cubic feet (tcf), about one-third of the gas reserves of the United States, which is the largest producer of natural gas in the world. Such a huge quantity of gas from Gas hydrate can turn India's fortunes in the future, by making the country self-sufficient in the energy sector, which currently imports 80% of its consumption requirements. Further production testing to know the production potential in

Eastern offshore area is planned under the further programme of NGHP-03 with joint collaboration with Japan.

As long as the unconventional share in the world portfolio of hydrocarbon resources continues to grow, industry professionals will have to ask whether we are ready for this "revolution." Undoubtedly, "revolutionary thinking" is required and several paradigm shifts will occur during the journey, with the clear need to challenge the basics of petroleum engineering. UCR development presents the challenge and opportunity of the unknown. Experience is key, but fresh, new ideas will drive the future.

Scope for Future Work

Development of Unconventional hydrocarbons are no doubt a challenging task for any country and in the present scenario the country able to develop these reservoirs will lead the list of the energy efficient economies of the world. Though many initiatives have been taken in the country still India needs several studies and steps to develop Unconventional hydrocarbons in its fullest potential. The suggestive future work are

Geo-scientific studies

The first and foremost work is to understand the geological settings across all 26 sedimentary basins of India. It requires to prepare geological models with the help of all available G&G data along with data from NDR (National Data Repository) of DGH. Detailed reservoir characterization with the help of formation evaluation, core data and other available Geo-scientific data from drilled wells will help to establish the exact potential of the unconventional reservoir.

Drilling & Completion Technology

For successful completion of the unconventional hydrocarbon resource project the best technology available in the world would be required for the successful drilling and completion. The Shale Gas, Coal bed Methane, Tight reservoir and gas Hydrates all have unique set up of their occurrences in nature. The required horizontal drilling, multi-lateral drilling, PAD drilling etc. The completion of these reservoir are also complex and need a careful execution of extraction methods with the help of latest technologies. Various simulation techniques required for these unconventional gas reservoirs for production from these reservoirs for a longer duration.

Collaboration with MNC's

There are many MNC's across the world successfully producing hydrocarbons from unconventional reservoirs. Along with USA, China and Russia are in the line to become another largest producer of unconventional oil & gas in near future. European countries are also developing the expertise for production of hydrocarbons from unconventional reservoirs. India needs more and more collaborative approach with institutes of eminence as well as Industry experts. These will included production enhancement and enabling investments into E&P, to encourage collaboration among the industry, academia, investors, service providers and consultants to bring-in new technology, reduced cost and operational efficiency.

Policy Initiatives

The Government of India has notified "Policy Framework for exploration and exploitation of Unconventional Hydrocarbons under existing production sharing contracts, CBM and nomination fields in 2018". Such policies will not only attract investments in the country but also spur the national oil companies the NOC's to extract hydrocarbons both conventional and unconventional reservoirs from the same acreage. It is suggested that government may bring out policies related to natural gas pricing conducive to E&D operators in te country specially for locked up gas reserves which are on the threshold og economic limit.

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