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Shale Gas: An Indian Market Perspective

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ABSTRACT

Energy demand has been increasing day by day with the advancement in industrialization and urbanization all across the world. Most of the demand is fulfilled with the help of primary conventional energy sources viz. coal and oil. One such source of energy is the shale from which oil and gas are extracted to be used as fuel. Shale gas resource has been visible on the global energy scenario map since the 1950s but was not being significantly focussed upon until 1990s when it gained economic and technical accessibility. The fast-technological breakthrough in the US resulted in fall in the breakeven cost of shale gas which had brought about a revolution in the US energy market in the 2000s. This revolution helped the US to turn itself from an importer of gas to an exporter of gas. Thus, it is important to discuss the current shale gas scenario, its prospects as well as its scope for growth in the future Indian energy market. Thus, the country needs to focus on the development of shale oil and shale gas resources as they have the potential to significantly contribute to the gas supply at a relatively low cost.

Keywords: Shale Gas, Indian Shale, American Shale Revolution, Hydraulic Fracturing, Horizontal Drilling, Shale Gas Policy
JEL Classifications: O3, O4

1. INTRODUCTION

Shale is a sedimentary rock which forms under high-pressure compaction of fine-grained silt and clay. The shale rock is characterised by the high content of clay (chamosite and kaolinite) of 55% along with 29% presence of quartz. The organic shale can be categorised into three types viz. type-1 kerogen, type-2 kerogen and type-3 kerogen. (U.S Department of Energy, 2015). This organic-rich sedimentary rock which is found deep inside the ground converts organic matter into oil and gas due to high pressure at a suitable temperature. The major chunk of this oil and gas gets expelled and on migration, gets trapped in ideal places from where it can be extracted with greater ease, thus, constituting the conventional oil and gas. The remaining minor chunk of oil and gas is retained inside the original rock-forming shale oil and gas which is unconventional to extract. These shale oil and shale gas are in the form of free hydrocarbons that are trapped inside pores, cracks, natural fractures, etc. Some of the gas also gets stored as

an adsorbed gas on the organic texture of the rock. As a result of this, there is very less free movement of the oil and gas inside the sedimentary rock. Hence, the shale has low matrix permeability (Alexander and Bartik, 2019).

Shale oil and gas is an unconventional form of oil and gas, is characterised by a large area of distribution and variation in abundance of availability. The source rocks i.e. the shale rocks act as reservoirs for the shale oil and gas and they are spread widely throughout the area. They act as continuous reservoirs with no or very fewer traps which in turn results in the distribution of shale oil and gas extensively with no distinct boundaries. This increases the likelihood of the formation of large oil and gas provinces. Presence of water is also a significant factor that needs to be considered while studying and evaluating a reservoir for the extraction of oil and gas. Shale rocks do not have gas-water contacts. Hence, the flow of gas is not affected by the flow of adjacent water. Also, shale rocks are continuously distributed throughout the area of the basin. This continuous and spread-out accumulation of shale oil

and gas primarily depends on three factors viz. extensive reservoir rocks, good source rocks and coexisting reservoir-source intervals (Negi et al., 2017).

Any reserve of oil and gas, be it conventional or unconventional, needs to be studied properly so that it is easier to determine the processes to be carried out on the reservoir, the technologies that need to be employed, etc. For this, the first step is to classify the reserve into different groups. Broadly, reserves or resources can be classified into four major types: (Kumar et al., 2017).
1. Remaining oil and gas in place
2. Technically recoverable resources
3. Economically recoverable resources
4. Proved reserves.

Daniel and Jarvie defines a "shale gas system" to be a system that considers the nature of shale found in the basin, as well as the extraction process, incorporated followed by storage and distribution. The study classifies such systems into two main types: biogenic and thermogenic. Biogenic gas plays (a play is where the oil and gas are found in a basin) contain dry gas adsorbed to organic matter whereas thermogenic systems include high thermal-maturity shale rocks, low thermal-maturity shale rocks, a mixed-lithology intraformational system that contains shale, silt and sand, "informational" system where gas is generated in a mature shale and gets stored in less mature shale rock and a combination of plays that have production of both conventional and unconventional resources (Chen et al., 2012). Whereas describes a shale gas system saying that the system boundaries are divided into five phases viz. preproduction, production, processing, transmission and distribution. He thus focuses on the upstream shale gas industry (Jarvie et al., 2007).

2. SHALE OIL AND GAS EXTRACTION

Conventional hydrocarbon is usually found in the positive elements like craton large uplift, passive continental margin and macrotectonic zone in the down faulted basin and secondary structural units look over the hydrocarbon distribution. On the other hand, an unconventional hydrocarbon is primarily distributed within the negative elements such as depression slopes in foreland basin, central depression basin and craton syncline. The unconventional hydrocarbon occupies the centre of the basin and the slope and is distributed continuously in a large space (Dwivedi, 2016).

Since the unconventional oil and gas are distributed irregularly all over the reservoir, traditional vertical drilling is less useful. Hence, to effectively extract shale oil and gas, other technologies need to be focussed on. Among these, two main technologies that are usually used in the extraction of shale oil and shale gas are hydraulic fracturing (fracking) and horizontal drilling. A brief process of extraction of shale oil is as follows and is represented by Figures 1 and 2.

The preliminary process of extraction is the exploration of the reservoir and various studies being conducted on the identified reservoir. The contract company like ONGC starts drilling only

after verifying the presence of economically recoverable resources. The type of drilling that is initially employed is the vertical drilling that is useful in breaking through the solid rock layers of the Earth's crust. The vertical drilling is employed only until the drill reaches the production layer where the oil and gas are present. After reaching this layer, horizontal drilling is employed where horizontal is not a perfect 90° angle with the vertical but an 85° angle with the vertical so that the pressurised oil and gas in the ground is concentrated towards the mouth of the well for efficient

Figure 1: Horizontal fracturing versus vertical fracturing
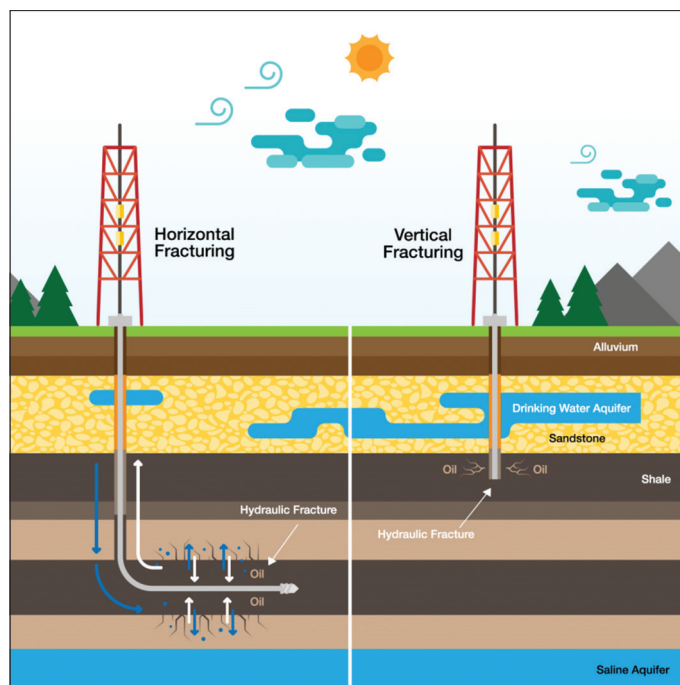
Source: Authors, Adapted from: "Hydraulic Fracturing: How It Works and Recent State Oversight Actions" (Legislative Analyst's Office, 1 December 2016), <https://lao.ca.gov/Publications/Report/3513>

Figure 2: Hydraulic fracturing and directional drilling
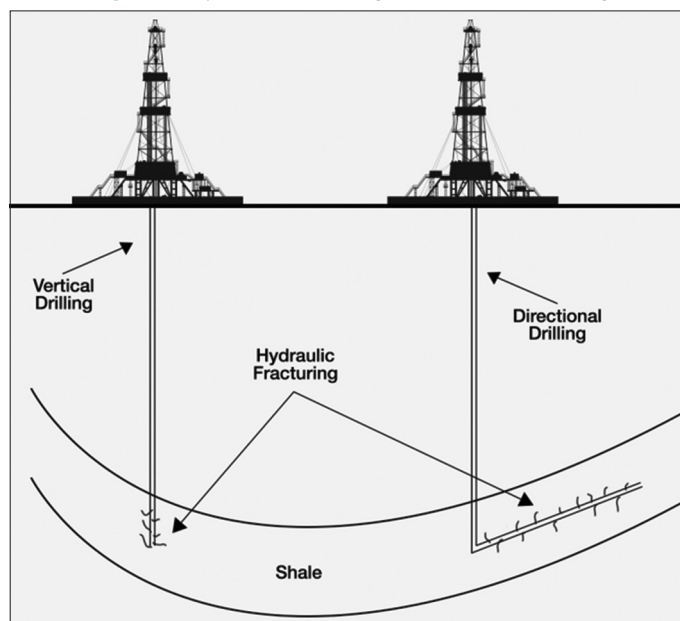
Source: Authors, Adopted from Gong (2018)

extraction. It should be noted that the slope goes to a maximum distance through the production layer. The maximum step out of a well is 14,129 m but the average is as low as 600–900 m (Fangzheng, 2019).

It is observed that horizontal drilling facilitates the best selection of shale gas. It is obtained by drilling horizontal wells using a horizontal trunk that passes through the production layer. The horizontal well can be in the shape of a fan, a fork or a spine in the same production layer that can be shallow. The number of wells drilled in the exploration phase can be between 2 and 15 in numbers. Although, it is advised to drill around thirty wells to obtain enough data about the reservoir pressure and other characteristics of the reservoir. This data can then be used to devise a model and thus help in forecasting the resource volume, production capacity and development economics which helps in determining the long-term viability of the production of shale oil and gas from the reservoir (Hamada and Singh, 2018).

To further enhance the performance of horizontal fracturing, recent developments have been made to give a direction to the well as the availability of shale in the production layer may not be horizontal. In this case, to attain maximum efficiency, it is important to drill the well such that it is inside the production layer for the maximum part. For this purpose, "Directional Drilling" served as the solution. This technique was first used in the USA were based on the Oilfield Market Report, the total revenue of the oilfield services rose by 183% from 2005 to 2015. The hydraulic fracturing segment and the directional drilling gave a massive response with an increase in revenue of 395% and 287% respectively during the same period. This is concrete proof that these two techniques are the driving force. But like almost anything else, it has a positive side as well as a negative side. The positive side is that these techniques generated a huge amount of revenues and were successful in generating sufficient energy resources leading to reduced energy prices and energy storage. The negative side to it was that such innovations require huge capital investment in its research and development (R and D) which hides behind the curtains various risks like uncertainty, financial risks, operational risks, low input-output ratio and its sustainability. Hence, it is hard to determine the profitability of the implementation of these techniques (Glass, 2011).

Xuli talks about carrying out hydraulic fracturing using a technique called "stimulated reservoir volume (SRV)" which is used for stimulation of shale oil and gas wells through fracturing technique. This technique helps in case when the effective flow channels inside the shale reserves are created, the productivity of shale oil and gas may be maximized (Gong, 2018).

Once the hole is drilled till the production layer, the fracking liquid is pumped inside the well under high pressure. The fracking liquid may consist of water and propping agents and chemicals that dissolve the carbonate reservoirs. This fracking liquid is responsible to push the oil and gas from the well upwards through the good pipe and fill the well so that it does not collapse under vacuum. It does this by making micro-cracks in the production layer. The fracking liquid is later extracted with the oil and the two are separated and transferred to isolated reservoirs as the fracking liquid cannot be used again. It is to be noted that a major part of the fracking fluid comprises of water. Hardly <1% are other chemicals. Some of the chemicals used are proppants which are sandy materials used to hold open fractures, gelling agents like xantham gum and guar gum which serve the same purpose as proppants, surfactants which are used to reduce surface friction and biocides to kill bacteria (Anjirwala and Bhatia, 2016).

After extraction, the produce undergoes pyrolysis to decompose kerogen which is a macromolecular and organic solvent-insoluble organic matter. On a general sense, pyrolysis is a process of thermal decomposition of materials at high temperature in an inert atmosphere. It involves a change in chemical composition and hence is irreversible. The pyrolysis of oil shale is a bit complicated though as it involves a large number of series and parallel reactions. This is because the kerogen exists in a complicated heterogeneous mixture which contains different types of elements like nitrogen, oxygen, sulphur, etc. and different kind of organic groups like carboxyl group, ketones and esters. To characterize the physical properties of the products obtained from pyrolysis of the oil shale, the authors (Honglei and Yan, 2020) suggest a unique method called Terahertz time-domain spectroscopy (THz-TDS). It is an optical method with the baseline idea that the method has different sensitivities to gas, oil, water and minerals (Singh and Khanna, 2012).

When it comes to successful and effective production of shale oil and gas from a reservoir, the process of evaluation of the reservoir basin holds parity with the process of extraction of the fuel. Chen et al. assert that depressions or basins with varying levels of exploration degr degree need respective evaluation methods for conducting exploration and appraisal activities with higher efficiency. The authors thereby suggest the following two methods for evaluation: Volume method is an evaluation method that is used for evaluating areas with a high degree of exploration and when the data for the same is available in abundance. It is used mostly to evaluate reserves of shale oil and shale gas using gas-bearing properties of shale. This method states that the total gas resource is equal to the sum of free gas, adsorbed gas and the dissolved gas.

The analogue method is an evaluation method used in areas with a low degree of exploration and limited availability of data. Hence, the result produced from the method is not of high accuracy but still is capable enough to guide decisions of initial exploration and investment (Hoffman, 2014).

On a general note, shale oil is considered to be more valuable than shale gas because of energy intensity, ease of storage and ease of handling and transportation. Hence, when one finds shale oil while searching for shale gas, it is like a bonus to the production of shale gas. This is because it creates a secondary stream of income. The opposite might not be true since a significant amount of shale gas is usually produced while the extraction of shale oil. The thing about shale gas is that if shale gas cannot be sold, then it creates hindrance in the shale oil production. This issue is usually sorted by employing flaring which is burning of gas in the open atmosphere but it creates carbon emissions contributing to global warming (Honglei and Yan, 2020).

The objective of this report is understanding the current Indian shale oil and shale gas scenario and assess the Indian shale market in comparison with the shale gas market of leading nations in the sector. On understanding basics of shale gas production and overview of the local and global shale gas scenarios, the report aims to provide insights on the scope of development of shale resources in India as well as the challenges faced by the sector.

3. RESEARCH METHODOLOGY

The methodology that is used to research the selected topic is to first understand the sources of data that could be available to extract the information required to fulfil the above-mentioned objective. Data is obtained from various research papers, review papers, journal articles, published articles and books that are available on online databases like Scopus and Google Scholar. Numerical or statistical data is referred from the official websites of regulating and governing bodies like Ministry of Petroleum and Natural Gas (MoPNG), Ministry of Power (MoP), Directorate General of Hydrocarbons (DGH), The Energy Research Institute (TERI), Ministry of New and Renewable Energy (MNRE), Central Electricity Authority (CEA), etc. Also, the data from websites of various international agencies like US's Energy Information Administration (EIA), Germany's Schlumberger, British Petroleum (BP), etc. are used as their studies, surveys and data collection are mostly cited by experts all around the world.

4. EFFECTS OF SHALE GAS EXTRACTION

4.1. Economic Effect
Fracking, even if it seems to be an effective technique, has its effects, both positive and negative. Alexander and Bartik found three major findings when it comes to the effects of fracking and the use of shale gas.

1. A positive effect that came out of the fracking technique was for the countries which have fracking potential has experienced a boom in energy resources. They have produced almost 400 million USD worth of oil and gas annually in three years post the discovery of hydraulic fracking techniques compared to shale producing countries which do not employ fracking. This annual increase in income also increased economic activities with an increase in income, employment and salaries. Local governments also observed an increase in revenues that are higher than the average increase in expenses

2. The authors estimate that annual willingness-to-pay for hydraulic fracking-induced changes in the local conveniences is almost -1400 USD per household yearly i.e. −2.7% of average yearly household income

3. The authors estimate that considering all the US shale plays, the willingness-to-pay for allowing hydraulic fracking equals 2500 USD per household annually i.e. 4.9% of the average income of a household (Howarth, 2019).

4.2. Social Effect
Oil and gas extraction is a process that creates a huge amount of emissions. These emissions can be in the form of harmful gases, particulate matter or even heat. These factors directly affect the health of the people who are working on the site or even those who are living in the vicinity of the operation. Reports have emerged discussing people who live close to the fracking sites being affected by the emissions and falling sick by getting in contact with contaminated water or air. Most of the emissions and chemicals involved in the process are potential threats to human health as they can severely affect the smooth normal functioning of the body. Some of the chemicals are identified to be endocrine disruptors while few others were found to be disruptive towards hormone functioning in the body. Not just the emissions from the extraction process, but the particulate matter that gets lifted off into the air from extraction as well as transportation activities has the potential to get lodged in the lungs causing silicosis. Apart from health, the extraction process very largely contributes to local air and noise pollution. The drilling activity is one which creates intense noise.

4.3. Environmental Effect
The air quality, especially that pertaining to the local area i.e. the site of extraction and its vicinity, gets severely affected by oil and gas operations. Also, equipment and machinery used during the production process create emissions that include methane releases from compressor blowdown and valves, volatile organic compounds like BTEX (Benzene, Toluene, Ethylbenzene and Xylene) which escape from oil tanks and condensates. But it is to be noted that gas has less than half carbon footprint than that of coal and carbon dioxide emissions are two-thirds of oil when combusted, making gas a better energy source from an environmental perspective (Nakano et al., 2012).

Air quality, due to oil and gas production process, in mainly affected due to emission of methane when wells are tested or flowed back as well as those from flaring of excess gas. The procedures and techniques involved in the extraction of unconventional oil and gas differ from those that are used in the extraction of conventional oil and gas. However, the amount of methane in the conventional gas and unconventional gas is almost the same, thus creating a similar climatic effect. Methane is called as a "high-leverage" greenhouse gas (GHG). One kilogram of methane can produce a radiative forcing that is multiple times higher than that produced by a kilogram of carbon dioxide. Hence, it is important to quantify this radiative forcing which the gas has on the environment. To do this, all GHGs are assigned certain values of "global warming potential" (GWP) which reflect the severity of their effect on the environment by trapping heat radiations. Higher the value of GWP, more dangerous is the gas emission for the atmosphere. This value of GWP is used to obtain the value of carbon footprint in terms of "carbon dioxide equivalent" (CO_2e). The GWP takes into account several factors like strength of radiative forcing as well as the expected time of decay of the GHG in the atmosphere. GWP is calculated on three timescales: 20 years (20y), 100 years (100y) and 500 years (500y) where GWP of CO_2 is defined to exactly 1 for each scale. Methane has a significantly high value of GHG owing to the high capacity of methane to absorb infrared radiation but a short life in the atmosphere. The IPCC has estimated that it has a GWP of 72 on 20y scale and 25 on 100y scale.(Laurent, 2018) Hence, taking into account the amount of GHG emissions in the atmosphere, methane is the second most significant GHG behind carbon dioxide contributing to global warming. As per IPCC, it contributes almost 1 W/m^2 to

global warming behind CO_2 which contributes 1.66 W/m². This has raised a concern regarding safeguarding of the planet and ecology as a whole because the concentration of methane in the atmosphere has been on a continuous steady rise for many years. (Hultman et al., 2011 and Padhy et al., 2016).

5. INDIAN SHALE SCENARIO

Indian shale oil and gas industry is at a very nascent stage. Not only are the "technically recoverable shale gas resources" in India very less, but the research and the technology employed behind exploration and extraction of shale oil and gas is also very limited in India. Although the Government of India is slowly considering shale gas resource as a viable source of energy, the Indian shale market is far behind the giants like USA and China. The exploration and exploitation of Indian shale gas will need the acquisition of advanced exploration and extraction technologies and a large amount of drilling. Hence, commercialization of Indian shale gas is at least 7 years away (Ingole et al., 2014 and MOP, India).

To identify resources of shale oil and shale gas in the country, Government of India, with the help of national organisations as well as international organisations, has undertaken research studies. Although obtained results do not show consistency, the country is said to hold promising reserves of the resources. As per the study by the US agency Energy Information Administration (EIA) in 2010, only 61 tcf of shale gas potential lied in the Indian sedimentary basins. While when the same agency did a study next year, 2011, it asserted 290 tcf of shale gas in four main basins while in 2013 they asserted the potential presence of 87 billion barrels of shale oil and 584 tcf of shale gas in the same basin areas. ONGC asserted the presence of shale gas of volume 187.5 tcf inside 5 basins while Schlumberger was very optimistic to state the shale gas presence of 300–2100 tcf all over the nation. In case Schlumberger is true, it will put India ahead of most of the shale gas producing giants in today's world. But as EIA's study is the most cited study by experts all over the world, their survey can be considered to be closest to reality.

The above mentioned possible amount of shale gas is distributed all over the Indian subcontinent but can be mainly found in the following basins:
- Krishna-Godavari Basin (KG basin)
- Indo-Gangetic basin
- Cambay basin
- Gondwana basin
- Cauvery basin
- Assam and Assam-Arakan basin.

A total of 50 blocks are distributed amongst the above-mentioned basins. The technological prowess of India in shale gas market might not be much compared to USA, China or other giants, but India, is in the initial stage of shale gas production is showing promising advancement in the future towards the development of shale gas resources. India, thus as of now, have employed following techniques and technologies in the shale gas production from the Indian sedimentary basins:

- Wide azimuth surveys
- Long offset 2D seismic surveys for deeper imaging
- Onshore carpet 3D surveys
- 3D-3C/4D seismic surveys
- Broadband surveys
- Bean PSDM processing
- Node-based wide-angle refraction cum reflection profiling
- Discrete fracture network analysis
- CSEM surveys and microgravity data for delineation
- Permeability structure analysis and fluid replacement studies
- Common reflection angle migration processing (Ariketi et al., 2015).

5.1. Shale Gas Policy of India

Directorate General of Hydrocarbons (DGH) is the upstream sector regulating body of India which was established in the year 1993. It operates under the Ministry of Petroleum and Natural Gas (MoPNG) which is the governing body that drafts the shale gas policy. Indian Shale Gas Policy was announced on 14th October 2013. Government of India has issued certain guidelines regarding "New Exploration and Licensing Policy (NELP)" in 1998. Under the policy, the first round of the bidding process for exploration blocks commenced in 1999 (Ross, 2014). The shale gas policy initially gave exploration and exploitation permission to National Oil Companies (NOCs) viz. Oil and Natural Gas Corporation (ONGC) Ltd. and Oil India Ltd. (OIL). Exploration blocks were awarded on nomination basis to the NOCs.

Following are brief highlights of the Indian Shale gas policy:
- Three assessment phases have been given to the NOCs for exploration of shale oil and gas viz. Phase-I, Phase-II and Phase-III with a time duration of 3 years each
  - The policy obligates the NOCs to follow a work program with commitment concerning the following-
  - Water sourcing and disposal EIA baseline studies
  - Geological and Geophysical (G and G) studies
  - Test well drilling
  - Hydraulic fracturing
  - Study of geochemical properties
  - Studies related to geo-hazard/geo-mechanical/geotechnical properties
  - Assessment of resource of shale oil and shale gas.

The above-mentioned possible amount of shale gas is distributed all over the Indian subcontinent but can be mainly found in the following basins (Shale Oil and Gas, 2020).: The least no. of mining lease (ML)/petroleum exploration license (PEL) areas to be taken up by NOCs are: (Shale Gas Policy, 2003)

Phase/Company	ONGC	OIL
Phase I	50	5
Phase II	75	5
Phase III	50	5
Total	175	15
Grand total	190	

- NOCs shall apply for a grant of shale gas rights for ML/PELs to be taken up in the first phase of assessment within six months of notification of this policy
- Total exemption from customs duty and additional charges on customs for specified goods needed in connection with

petroleum operations undertaken under petroleum licences or mining leases issued on nomination basis would be available for E and E of shale oil and gas resources

- The NOC shall submit, monthly, a report regarding production and sale of shale gas and shale oil to the DGH
- Holder of PEL/ML will be responsible for ensuring the health, safety and environment (HSE), the site restoration and adoption of the best industry practices and follow statutory requirements for all objectives under the license and mining lease
- Royalty, cess and taxes on shale gas and oil will be payable at par with conventional gas/oil being produced from the respective areas at the prevailing rate
- Phase-I will commence on the date of the agreement granting permission to the company. Phase-II will begin after the conclusion of Phase-I and Phase-III after the end of Phase-II
- The company shall pay to the government, within 60 days following the end of the assessment phase, an amount which shall be equivalent to the Liquidated damages (LD) of USD 0.25M per PEL/ML area. Assessment phase can be extended by 1 year
- Withdrawal from shale oil and shale gas operations after G and G studies are carried out without LD would be allowed in consultation with DGH in case the assessment shows the absence of shale gas and oil resources
- After completion of the assessment phase, the company needs to prepare an estimate of the potential production of shale oil and shale gas to be achieved vis-à-vis WP, if any, and submit "Field Development Plan (FDP)" to the DGH in 12 months. The profile of annual production with a count of producing wells has to be submitted as well
- On submission of the annual production profile vis-à-vis WP, the company has to start development activities under 6 months
- EIA study is to be carried out by the companies from the list of companies authorised by MoEF at the cost of the decided project proponent
- Company has to take care of the following before undertaking shale gas and oil exploration in any of the fields: (a) adequate water availability suitable for fracking. Approval from the Central Ground Water Authority (CGWA), the State Ground Water Authority (SGWA) and other regulatory institutions is prerequisite. (b) Taking approval of the concerned State Pollution Control Board (SPCB) for the treatment and disposal of wastewater and ensuring appropriate action (Shale Gas Policy, 2020).

5.2. Challenges for Shale gas Development in India
Challenging geological conditions concerning the wide variety of the ground and underground properties that vary from place to place. This results in a variety of shale found in different places in the country.

5.2.1. Technology and knowledge
India also lacks that level of technical sophistication and expertise in the field. Technology can be imported but it is expensive leading to higher production costs. Also, the workforce that is employed for the extraction of the oil and gas need to be skilled and should have sufficient knowledge of the processes involved.

5.2.2. Lack of competitive industry willing to take risks
The responsibility of the development of shale resources in India falls entirely in the hands of government NOCs viz. ONGC and OIL. Hence there are no private players, big or small, who can serve as a competition for these companies. Although competition is indeed necessary for the innovation to take place in the shale industry.

5.2.3. Subsurface rights
In India, the owner of the land does not own the minerals that are found under the land. Hence, there is often seen disputes regarding the same that needs to be settled first hand.

5.2.4. Insufficient pipeline network
India has less than 10,000 km of trunk pipeline in India compared to 500,000 km that of USA. This limits the areas where shale gas can be explored as exploring in new areas need ensured pipeline network in that area.

5.2.5. Restricted access to pipelines
Similar to the carriage and content separation in the electricity sector in India which happened recently, the USA has already applied the same concept in their gas network where gas producers and carriers are separate. In India, the gas producer owns the pipeline network as well and hence will not transport gas produced by other producers.

5.2.6. Regulatory framework
A concrete framework is yet to be established in India. It was only by 2013, that the government of India came up with a policy for shale gas production.

5.2.7. Historical speed of development of the industry
Indian shale gas industry is at a very nascent stage. Hence it does not have a significant history or historical records to look at for reference while working on the present and prospects of shale gas production.

5.2.8. Competition from alternatives
Shale gas revolution takes time. Although alternative unconventional resources like tight gas, coalbed methane (CBM) as well as the conventional oil and gas are much easier to produce, it is important to continue putting efforts in the development of shale gas resources as well regulated the prices of shale gas to keep it as an economically recoverable resource of energy (Umekwe, 2019).

5.2.9. Screening shale gas exploration targets
As shale gas is yet to be effectively developed in the Indian market, the government has not yet set any concrete targets that the NOCs can look forward to achieving.

5.2.10. Predicting production rate
Since India lacks advanced technology to study the reservoir and technologies involved in exploration and extraction of shale reserves, it is difficult for the NOCs to determine the rate of production of shale gas and shale oil effectively. This disturbs the forecasting and scheduling of supply.

5.2.11. Determining drainage areas

The fracking fluid used for the extraction of shale oil and gas cannot be used again since it contains a concentration of harmful and toxic chemicals. Thus, this fluid needs to be drained to a closed safe pit where it will not be in contact with any flora or fauna habitation. This is a difficult task as such lands need to be searched for and extreme care needs to be taking while disposing of fracking fluid (Shcherba et al., 2019).

5.2.12. Lack of political will

Apart from conflicts between neighbouring nations, India also needs to take care of the internal conflicts which can be in the form of corruption, political instability, bureaucracy, local mafia and prohibitive regulations that lead to delays in schedule and subsequent losses.

5.2.13. Water scarcity

In the hydraulic fracturing process, a huge quantity of chemically treated water is used which is never reused again. Hence, it needs to be disposed of and a new batch of water needs to be again chemically treated and again disposed of away. This consumes a massive quantity of water resources. India, being a tropical country is already in a waster stressed condition and as per The Energy and Resource Institute (TERI), India is approaching the drought benchmark of 1000 cubic metres per capita consumption. It is estimated that water consumption will increase by over 50% in the next 12–15 years while during the same period, the supply will increase by only 5–10%, thus, leading to a situation of water scarcity. There is a decreasing trend seen in the water availability per capita in India over the years from 1991 to present and also extrapolating the graph with estimation till 2050. As can be seen, the availability has dropped down from around 2300 L in 1991 to 1150 L in 2050 (as per the estimation). The current data sits somewhere around 1400 L per capita.

6. GLOBAL SHALE GAS

Recoverable shale resources are spread all over the world in an irregular pattern. Although shale rock is practically evenly distributed in the world, its recoverability varies from place to place depending on the depth at which the gas-bearing layer is

Table 1: Country-wise highest recoverable shale gas reserves. (Adapted from Salygin et al., 2019 and Li et al., 2019)

Country	Trillion cubic feet (tcf)	Trillion cubic meter (tcm)	Percentage
China	1115	31.6	14.7
Argentina	802	22.7	10.6
Algeria	707	20	9.3
US	623	17.6	8.2
Canada	573	16.2	7.6
Mexico	545	15.4	7.2
Australia	429	12.2	5.7
South Africa	390	11	5.1
Russia	285	8.1	3.8
Brazil	245	6.9	3.2
UAE	205	5.8	2.7
Venezuela	167	4.7	2.2
WORLD	7577	214.5	

situated, which may vary from 200 m to 7000 m. Some have ample shale gas reserves; some have few while some have none. Hence, it is important to focus our attention to the countries who have ample of shale reserves as they are the hubs of innovation and shale gas development. If the shale gas reserves have to be quantified, it takes huge efforts has many of the basins in the world cannot be accurately estimated for the shale gas content. As per the US Department of Energy, the quantity of technically recoverable shale gas is more than 200 tcm distributed mainly amongst 41 countries. Shown in Table 1 are the top 12 countries with the highest amount of recoverable shale gas reserves.

It will not be fair if we take a look at only the top countries having recoverable shale gas. To have a comprehensive study, we must look at the reserves of shale oil and gas region-wise, as studying the topic country-wise will be very difficult. Hence, the shale resources can be demographically separated into six regions as Asia and Oceania, North America, Latin America and the Caribbean, Africa, the European Union and Eastern Europe.

As you can see in Table 1, the Asia and Oceania is the region with the biggest share in the regional distribution of recoverable shale resources, thanks to China of course. Following, the second region in the list is North America because of the shale gas reserves in the United States and how they are successful in exploiting the shale resource as for the credit goes to the American Shale Revolution (Salygin et al., 2019; Li et al., 2019).

Thus, if one wants to see the bigger scenario from the perspective of Indian shale market and where it stands in the International shale market and where and why it has lagged, one needs to have a comparative study done between the shale oil and gas market of the top countries as mentioned in the above list and the Indian shale gas market. But for our ease of study and content understanding, let us study only the Chinese and the American shale gas markets.

6.1. The Chinese Shale Market versus Indian Shale Market

China has achieved the first position in the above list due to the advancement in their technical studies, techniques and procedures, thus, increasing their shale gas production prowess. They have invested heavily in R and D and have excelled in employing techniques of drilling and hydraulic fracking which enables them to dig wells till the depth of 3500 m, or even 4000 m. China has made a breakthrough in their production of shale in 2017 when successfully developed continental deposits of shale resources. The carbon dioxide gas is pushed in the reservoir at high pressure and shale gas starts to flow back into the reservoir, thus reducing the environmental impact as well as saving huge on water resources.

The US Energy Information Administration (EIA) estimates that the shale gas reserve in China is about 1247.85 tcf, while the International Energy Agency claims it to be 918.18 tcf and China National Petroleum Corporation claims it to be 1084 tcf, which is much higher than what EIA estimated for India. Hence, they have greater raw material in hand to develop as an economically viable unconventional energy resource.

Moreover, the gas pipeline network in China is far more developed than that of India. This enables the country to positively explore new areas for shale oil and gas as the transportation infrastructure is readily available. This is not the case with India where the gas pipeline network is limited and new pipelines need to be constructed till the surveyed reservoir site before the production process is started on the site.

As far as the extraction of shale is concerned, although China has all the technologies and infrastructure in place, it still is in the initial phase of assessment of resources. China, under its 12th five-year plan, 2012, aimed to complete the initial assessment of shale gas resources and confirm current reserves. Going ahead, under the 13th Five-year plan, China planned on scaling up development of shale gas and its exploration in 19 regions. It should be noted that the estimates about the reserves in China declared by various agencies are very close to each other in amount. The same is not true for India. Thus, we can safely say that India lacks effective exploration and survey techniques that China has which it can use to determine its shale gas reserves to a high level of accuracy.

China has not yet finalised its Shale gas policy which will provide guidelines for the extraction of shale oil and gas in the country. On the contrary, India has been quick in establishing a Shale gas policy which was announced by the Ministry of Petroleum and Natural Gas (MoPNG) on 14th October 2013. These guidelines addressed specifically to shale gas production. But the Chinese policy is suspected to mirror the policy related to CBM.

Similar to Chinese state-owned oil companies, Indian state-owned and private oil companies are searching for foreign investments. However, India's aggression in the same cause is not as much as that China's and it is not as widespread either. China being a country with very high economic growth rate and a trillion-dollar economy, can afford to pay huge amount of money for importing technologies and a high premium on resources. On the contrary, some foreign investments in India shale faced few complications and Indian companies are not in a state to pay a huge amount of premium for the resources either (Xuli, 2016).

6.2. The US Shale Market versus Indian Shale Market

The shale gas exploration and exploitation in the USA started much early compared to the rest of the world. The decade of 2000s is said to witness a revolution in shale gas industry of the US. By the year 2015, shale gas production had already started on a commercial scale in the US and Canada with both of them holding 87% and 13% of world shale production respectively at that time. It is because of this early head start, the USA has been successful in recovering shale resources much more effectively than the rest of the world. Current statistics show that in 2018, shale oil production reached 329 million tonnes and shale gas production reached 607.2 million cubic metres in the United States (Zou et al., 2014).

The US shale revolution has seen a rapid rise in shale oil and shale gas production and consumption in the nation. The contribution of shale resources in the American energy mix has increased by 5% in 2000 to 29.2% in 2016. This impressive growth has made the country a net gas exporter from a net gas importer. Thus, shale gas has effectively reduced the consumption of natural gas whose production reduced at an average rate of −0.14% per annum.

In a decade long development of shale resources, the US invested heavily in R and D and successfully devised advanced technologies that increased the efficiency of the operations in the production process. For instance, the technique of multi-pad drilling helped increase the economies of scale as it decreased the number of rigs required for drilling a similar number of wells. The US has also come up with a new extraction method called "anhydrous rupture method" in which a mix of water, sand, gel and chemical reagents are used along with gas in liquid form.

On a demographic perspective, the US is a huge nation with much less population compared to China and India. Hence, they have a lot of lands uninhabited by humans. Thus, making a large vacant area available for shale gas exploration. Even if it is inhabited, the local population can be easily rehabilitated to a different location. This is a herculean task when it comes to Indian demographical and population situation. Also, since the US has such low population density, the number of people who are affected by the activities of shale gas production is much less than that in India, thus reducing the risk of health issues to a great extent.

The mineral rights of the minerals found under the land remain with the landowner in the US compared to India, where it is not the case. This helps the government to easily take up the ownership of land and employ it to develop shale gas. This, along with other factors, contributing to ease of land availability, has helped the US to effectively harness the shale resources. This, in turn, has dropped the production costs involved in the whole operation. The production costs in India are much higher than that of the US.

The reduction in production costs has ultimately reduced the prices of wholesale electricity at the consumer side for both residential as well as industrial sectors. This, in turn, helps in boosting industrialisation and urbanisation on a broader scale. If shale resource is currently used to feed power into the electricity grid in India, the cost of electricity is likely to go up as the production cost in shale production in India are still high.

The boom of the shale industry in the USA has also led to job openings and thus has increased employment in the country. The sector has employed 601,000 people across the shale oil and gas value chain (Zou et al., 2013).

Some of the factors that set apart the US shale industry from the Indian shale industry are:
- Advancement in hydraulic fracturing technologies
- Advancement in horizontal drilling technologies
- Surge in gas prices in India even if there is a continuous increase in demand for the oil and gas resources, thus, increasing the cost of the services
- Investment in R and D
- Pipeline infrastructure for oil and gas throughout the country
- Easy leasing framework
- Stable fiscal regimes
- Tax credits.

7. CONCLUSION

It can be safely concluded that the Indian shale market is far behind the likes of giants like China and the US. The Government needs to, first, invest in R and D related to the exploration of shale gas and shale oil. This will help the government accurately determine the quantity of recoverable shale gas present within the national boundaries. This data will further enhance the forecasting and scheduling of production of shale resources and thus enhance the calculation of estimated revenue and costs. As a result, the government can formulate a concrete framework for the development of shale gas and shale oil resources.

Either India needs to heavily invest in R and D or import technologies from the developed countries. Either will greatly increase the capital cost but will aim to reduce the operational cost to a greater extent. Also, the thing about importing technology is that the particular technology was successful in a particular environment and operating condition. Hence, it may not operate with the same efficiency in local Indian conditions. Thus, India needs to develop technologies that are suitable for Indian conditions.

Not just for the sake of shale gas development, but for overall fluid transport, India needs to urgently work on its pipeline network which needs to be robust, safeguarded and very effectively spread throughout the Indian landmass. That way, the energy resources that are explored at any place in the country can be effectively supplied to the refineries for further processing on the upstream side as well as the transportation of fuel and its distribution on the downstream side. Also, these pipelines will be operative for a long period.

India needs to take into account the water scarcity present in the country which gets severe during the summer season. Hence, it would be great if India can come up with a technology that can replace hydraulic fracking and use much less amount of water, something like how China uses carbon dioxide as fluid to save on water.

If India looks forward to work on economical extraction of shale gas, it needs to settle disputing factors which may not be monetised but are a strong obstruction viz. bureaucracy, political opposition, land disputes and tax credits. Although not all issues, like corruption and local mafia threats, can be eliminated it should be reduced wherever possible.

One concept from the US that might be effective in India as well as the separation of ownership of carriage and content of the gas. That is, the gas generator will have the responsibility to produce the demanded amount of gas resource while the ownership of the pipeline network should be in the hands of a separate company, not the generator, and will have the responsibility to expand and maintain the pipeline network. That way, the gas generator cannot own the flow of gas in the grid and restrict the supply of gas from competition to earn more share in an unethical way.

The Government of India can sign various MoUs with national and international agencies who will contribute in exploration and exploitation of Indian shale gas resources. Proper incentives should be provided to keep their interests as well as attract more companies and increase the competition. This is will significantly increase the innovation in the shale gas sector in attempts to reduce the capital and operating costs, which in turn will reduce the final shale gas prices.

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