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Abstract

With the increasing of energy demand and environmental pressure, Indian government has been exploring a way for different unconventional sources of energy supply. Shale gas development is becoming an important energy strategy in India in past couple of years due to significant shale gas reserves. However, the shale gas market is preliminarily shaping in India, so that many factors have great influence on its competition. To find these factors and to control them rationally is good for the growth of Indian shale gas market. Five forces model for industry analysis puts an insight into the competitive landscape of shale gas market by showing the forces of supplier power, buyer power, threat of substitution, barriers to entry, and degree of rivalry. Illustrating the key factors that affect competitive landscape provides a view into the situation of shale gas industry. The variation tendency of shale gas industry is analyzed by setting various scenarios. Finally, some suggestions are proposed in order to keep the development of Indian shale gas industry positively.

1. Introduction

Facing the pressure of resources and environment, many countries are developing new energy industry actively in the world. Shale gas (SG), as a new kind of natural gas, has received widespread concern. Especially, that India fuels chiefly Coal, Petrol and Diesel are polluting has leaded to the environmental deterioration or may further threaten the health of human life while it can deliver economic growth to developing India. Moreover, India's over dependence on oil and gas imported due to limited reserves of oil and gas. Energy security risk of India has been increasing over time. Fortunately, India with significant amounts of proven reserve of SG resources is expected to alleviate the above two problems effectively.

Unconventional sources of oil and gas have become increasingly important for the quest of energy security. There is a need to look for alternative options other than conventional oil and gas as they will be unable to meet the growing demand requirements in future. In a volatile oil price movement, unconventional resources are viewed as important and economically attractive for future continuous supply. Shale gas, an important unconventional source of natural gas that is stored in organic rich, matured fine sedimentary rock. With geological time, depth it results in conversion of organic matter into oil and gas. Major part of generated oil and gas is migrated while some of it is retained in reservoir itself. Gas which has remained in reservoir is stored in natural fractures, pore space and in adsorbed phase as well.

The global oil and market has transformed in recent years, the plan to make renewables energy a success is still not implemented, and the oil market is fixed which is determined by oil rich nations, while the gas market is at its nascent stage in many countries. US made it through because of the advancements in horizontal drilling technology and hydraulic fracturing. The impact of US shale gas has been felt throughout the world. It is one of the prime reasons for the drop in crude oil prices in 2014. Many countries have good amount of recoverable reserves, and if they are able to commercially and economically produce it, it would revolutionize the energy market and it may provide energy security to many nations like India.

India is the fourth largest consumer of oil and gas in the world and the demand and supply gap has been widening over the years. Assuming the current energy mix (29% oil and 11% gas) to continue, the requirement of the country will surely be going to increase and hence there is need to find alternatives that helps in filling the gap between demand and supply. In India there are huge proliferous basins that have shale deposits and can be extracted.

All the countries are aggressively in competition with each other to exploit Shale gas reserves and preparing their own strategies for timely extraction of Shale gas. Our project is about planning and proposing a strategy for assessment phase 1, as proposed by government for all the NOCs like ONGC and OIL. We have used of MS project software to carefully manage and keep a track of activities in the given timeline. It is important to make a good plan within certain time boundaries along with a proper flowchart so that one knows the dependency of one task on another.

The SG resource is more than proven reserves of conventional natural gas resources in India, equivalent to nearly 2000TCM. It is mainly distributed in Cambay Basin in Gujarat, the Assam-Arakan basin in northeast India, and the Gondwana Basin in central India. Marine shale strata, sea–land-interaction strata and land-coal strata also have certain reserves. Cambay area and Asam Arakhan basin located in the upper Indian region have the best development prospects. However, Indian SG resource is shallow burial and most is situated in folds and faults areas results in considerable exploitation difficulty.

Indian government starts to develop SG in 2012. And it has experienced a wave of investment from PSU exploration companies since 2013. How- ever, Indian SG market influenced by many factors is not mature, which is just in infancy stage, so that it may cause monopoly capital. In order to prevent monopoly and attract more investments, the government allowed the private enterprises to enter this industry in 2012. The winning enterprises found that there are still a variety of resistances to achieve SG commercialization, such as technology, policy and capital.

Nowadays, there are many enterprises in the SG industry, including state-owned company, private company and multinational petroleum company. The competition landscape of the SG industry changes fast in India. What are factors affecting Chinese SG industry? How do they affect the industry? What's the development trend? All of these are the core problems to be solved in this study. But comprehending the role of SG in the natural gas market is difficult due to the complex interactions of various forces. In this respect, using Porter's five forces model can provide a perspective on the SG industry and shed light on the myriad forces affecting SG market competition. The actual commercial utilization of natural gas in domestic sector commenced with the direction of Hon'ble Supreme Court in 1992 when public sector gas company GAIL India was directed to start pilot projects in Delhi, Mumbai and Vadodara. In the private sector Gujarat Gas Company started implementing City Gas Distribution project in Surat during the same period. The journey of city gas in India continues with the progress being monitored by Hon'ble Supreme Court with a noble social cause of providing clean air to the people. The major pollutant the transport sector has been responsible to pollute urban air to the tune of 70% and CNG which helps to curtail vehicular pollution for transport sector is a business segment of city gas and has been the most successful application. Apart from social objective the city gas also provides the most beneficial business model primarily because the city gas replaces the high end priced fuels such as LPG, Petrol, Naphtha, Propane and Diesel. Based on the success of pilot projects there have been many entities pursuing city gas in India. Incorporation of Gujarat Gas in 1992, Mahanagar Gas in 1995 followed by Indraprastha Gas in 1998, and as of now 23 entities including CUGL are pursuing 48 Geographical areas in India. We have now almost 1.95 million vehicles running on CNG and 1.3 million households being served by CGD. The contribution of EPCA (a Statutory body) constituted by the Supreme Court has been quite helpful to resolve the issues concerning implementation of CGD. May it be pollution norms, CCOE clearance, CNG kit retrofitters, endorsement on RC book, allocation of gas for CGD, price for CNG, Safety issues EPCA has been involved to resolve the issues.

1.1 City Gas Distribution (CGD):

Beginning with the coal gas based domestic gas supply system the successive growth of domestic supply of energy resource in the form of coal gas, synthetic gas, bio gas, natural gas etc. took place as the technology advanced and more and more alternative fuels were found. The CGD is not exactly implied as a distribution function as is done for govt. controlled ration and other commodities but is a retailing function of the energy resource. That is to say the access to energy resource is made to households which could be economically, technically and safely connected to the supply system and CGD business. City Gas Distribution (CGD) companies provide piped natural gas (PNG) to commercial and industrial establishments for heating and power generation purposes and to households for cooking and heating purposes. CGD companies also retail compressed natural gas (CNG) for use as auto fuel. For distribution of PNG to consumers, CGD companies set up a network of steel and medium density polyethylene pipelines across its geographical area (GA) that transports the gas from its City Gas Station (where gas is received from the supplier) to the consumer; for retailing CNG, companies sets up dispensers either at their own exclusive stations or at the fuel pumps of Oil Marketing Companies (OMCs). As large upfront capex and numerous approvals are required for setting up the pipeline network and CNG stations, the credit risk profile of CGD companies depends on the size of capex, means of funding, extent of approvals already obtained and current stage of operations.

1.2 City Gas (CGD) Evolution in India:

In 2007, the Government of India (GoI) set up a regulator, the Petroleum and Natural Gas Regulatory Board (PNGRB), which has, among other mandates in the hydrocarbon sector, the mandate of regulating the CGD business. The PNGRB invites bids for different GAs and four such rounds have been conducted till date. However, the attractiveness of a particular GA is dependent upon the potential for gas sales and a favorable mix of industrial, commercial, domestic and CNG segment. Additionally, aggressive bidding by companies may make them vulnerable to competition from third party marketers once the exclusivity period is over. Accordingly, the credit risk profile of a CGD entity depends upon the current gas consumption and potential of its GA, consumption mix and bid parameters. In the initial years, the regulatory mandate was the real demand driver for CGD business growth; however, subsequently the sheer cost economics of gas vis-a-vis alternate fuels has spurred demand growth. Recently the Govt. of India has mandated provision of domestic gas for the consumption of the CNG and PNG (domestic) segments, which being cheaper than imported Re-gasified Liquid natural gas (RLNG) makes the economics of switching to gas more attractive for the end consumers. On the other hand, the gas demand of the commercial and industrial segments is met by the costlier RLNG wherein the economics of using gas vis-a-vis alternate fuels vary with the type of fuel. Hence, the assessment of credit risk profile of CGD companies involves a study of volume growth and gross margins achievable which in turn is a function of price competitiveness with alternate fuels.

1.3 The beginning of present shape of CGD:

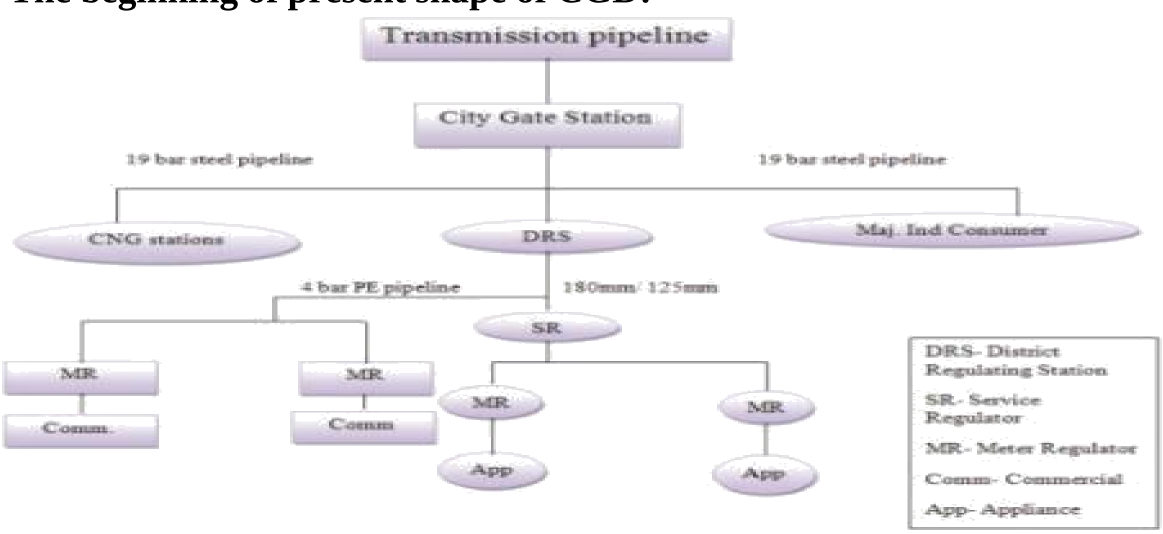


Fig 1.1 Schematic Diagram Of CGD

The CGD as it popularly described comprises of a pipeline gas supply through transmission pipeline from which a tap off or a connection is taken for supplying gas to city gas distribution system. This pipeline has been assigned a name as sub-transmission pipeline (STPL). This name was coined while laying a pipeline from Uran-Trombay transmission pipeline to city gate station at Wadala of the CGD project in Mumbai. From STPL gas is received at a place called city gate station (CGS) from where the gas pressure is controlled suitable for CGD. The CGS would inter alia have pressure regulator, filtering unit, gas heater (if pressure reduction is such that temperature drop goes outside acceptable limit), gas metering and odorizing unit. For better utilization of space and available pressure, the CGS may also have a compressor station getting gas from STPL.

1.4 Various Models of CGD:

There are several different types of CGD models depending on the access for gas to any existing pipe network infrastructure and the type of fuels currently being used. Such models are:

- Conversion of existing pipe network
- Requiring new infrastructure where no pipeline exist
- New infrastructure development where existing transmission pipeline exists
- Existing network and extension thereof.

1.5 Energy resources for CGD

The City Gas Distribution Project is primarily to supply gaseous fuel for cooking and transport. There could be many forms of gaseous fuel which may be used for application, such as the use of gas from any source-from conventional E & P, unconventional resources CBM, Shale Gas and gas Hydrates. Even the Synthetic gas, reticulated LPG system, Bio Gas etc. could serve as fuel options for CGD.

1.6 Natural Gas as feed to CGD: -

Natural Gas is defined as "a mixture of Hydrocarbons predominantly containing Methane". However, to be more specific in Indian context, the definition of natural gas as described in the Petroleum and Natural Gas Regulatory Board at, 2006 is "Natural gas means gas obtained from bore holes and consisting primarily of hydrocarbons and includes:

- Gas in liquid state, namely, liquefied natural gas and re-gasified liquefied natural gas, Compressed natural gas.
- Gas imported through trans-national gas pipelines including NG or liquefied natural gas.
- Gas recovered from gas hydrates as natural gas.
- Methane obtained from coal seams, namely, Coal Bed Methane, but does not include Helium occurring in association with such hydrocarbons.

1.7 Natural Gas

- Natural gas is among one of the primary sources of energy.
- It is recovered from oil and gas field.
- It contains mainly hydrocarbons.

There are many theories behind the formation of Natural Gas-

- Transformation of Organic matter by tiny micro-organism can also form Natural Gas; this kind of Methane is known as biogenic methane.
- The natural Gas obtained from Shale bed is known as Shale gas.
- Coal seams produce coal bed Methane.
- Natural gas can also be found in oceans in the form of gas hydrates.

1.8 Composition of Natural Gas

- **Organic Components**

Table 2.4 Organic Components of Natural Gas

COMPONENT	COMPOSITION (%)
Methane	87.0-96.0
Ethane	1.5-5.1
Propane	0.1-1.5
Iso-Butane	0.01-0.3
Normal Butane	0.01-0.3
Iso-Pentane	Trace-0.14
Normal Pentane	Trace-0.04

- **Inorganic Components**

Table 1.5 Inorganic Components of Natural Gas

COMPONENT	COMPOSITION (%)
Nitrogen	0.7-5.6
Carbon Dioxide	0.1-1.0
Oxygen	0.01-0.1
Sulfur	4-50 ppm
Hydrogen	Trace-0.02
Helium	Traces
Mercury	Traces

As already mentioned above that Natural Gas contains these all components and each component has its own property and various kinds of uses. These components are removed from Natural Gas through various extraction processes.

1.9 Type of Natural Gas

Natural gas is a mixture of some organic and inorganic compounds such as methane, ethane, propane, butane, hydrogen, oxygen, carbon Dioxide and sulfur. It has water content up to the saturation limit. Natural gas is of two types-

- **Free Gas**-When well is being drilled at a higher depth of around 5000 meters then free gas is found at a higher temperature of about 140°c.
- **Associated Gas**-When a well is being drilled associated gas is come along with crude oil. It is separated from oil crude oil and water content. Possibility of getting this gas is higher as compare to free gas.

1.9.1 Various Forms of Natural Gas

- NGL
- PNG
- CNG
- LNG

2.0 Natural Gas Properties:

Natural gas is a mixture of hydrocarbon having 90% plus of Methane,

- It is lighter than air in almost 18/29 ratio.
- It is colorless and odorless mixture. The combustion products as exhaust are much better than that from alternative fuels like petrol, Diesel, LPG and Naphtha.
- Natural gas has gross calorific value of around 10,000 kcal/scm.

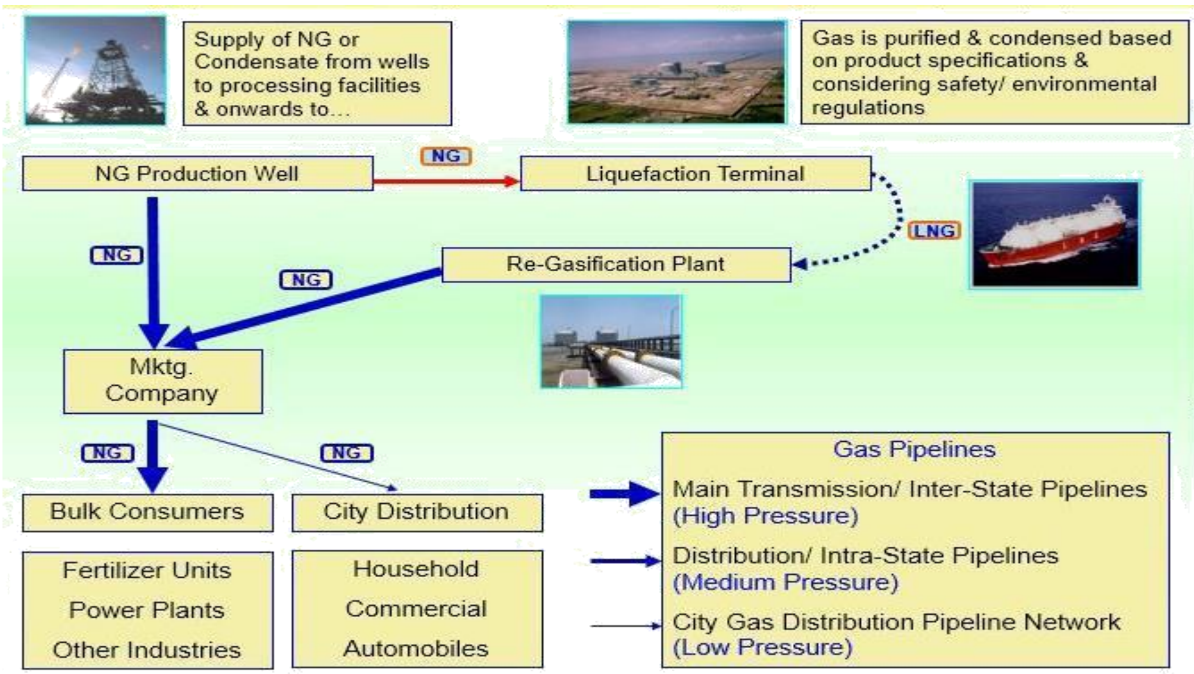
2.1 Natural Gas Uses:

The use of natural gas is manifold as given below:

- Power generation
- Feedstock to fertilizer plant- production of Ammonia, Urea
- Production of Methanol
- Petrochemical feedstock
- LPG
- Sponge Iron production –feedstock
- Cooking purpose
- Refrigeration and Air conditioning with VAR process
- Transportation fuel

2.2 Natural Gas Value Chain

Natural gas is an energy resource having environmental friendly emissions as compared to other fuels being used for domestic, industrial, commercial or transport sectors. The natural gas value chain means the exploration and production of natural gas, it's processing to make natural gas transportable through pipeline, the natural gas processing for extraction of value added products for other applications to maximize the profits, the application of natural gas in industry including domestic sector.



2.3 Natural Gas as CNG:

According to the estimates of the Petroleum and Natural Gas Regulatory Board, currently, there are 7 lakh natural gas vehicles in the country. This is expected to increase to 58 lakhs over the next 10 years. Delhi alone has more than 2 lakh vehicles. Around 30 cities have access to CNG and some of them have implemented the program of varying scope. It is also expected that the pipeline network will increase to 15,000 Km and implementation of city gas distribution network will cover around 150 to 200 cities by 2014. This potential can be further exploited if the natural gas distribution network is expanded and strengthened.

2.4 Value addition by combination of application:

One of the most desirable application of natural gas in CGD is a concept of single switch solution (SSS). In many countries which have understood the value of natural gas, this concept has been practiced. Japan is one of such countries which has taken lead because natural gas as energy source is very dear to them. Under this concept the first application of gas is to generate power in a house and exhaust of this is utilized either for refrigeration or air conditioning of the house. This being second and third application. Further, the same exhaust with or without secondary firing can be utilized for space heating or water heating in the house. These constitute fourth and fifth application. The gas can on standalone basis be utilized for cooking as sixth application. Gas can also be used as CNG for vehicle of the house owner by employing a small fuel maker which compresses gas to required pressure. This is the seventh application. Gas can also be used for lightening on the concept of Petromax lantern as its eighth application. All these applications can be secured by switching on the gas supply to the house and the house owner is not dependent on any external energy supply. This is, therefore, called single switch solution and gives highest efficiency of natural gas application.

2.4 Gas Demand and Supply Scenario In India

2.4.1. Energy mix

Energy is critical, directly or indirectly, in the entire process of evolution, growth and survival of all living beings and it plays a vital role in the socio-economic development and human welfare of a country. Energy has come to be known as strategic commodity' and any uncertainty about its supply can threaten the functioning of the economy, particularly in developing economies. Achieving energy security in this strategic sense is of fundamental importance not only to India's economic growth but also for the human development objectives that aim at alleviation of poverty, unemployment and meeting the Millennium Development Goals (MDGs). Holistic planning for achieving these objectives requires quality energy statistics that is able to address the issues related to energy demand, energy poverty and environmental effects of energy growth. A projection in the Twelfth Plan document of the Planning Commission indicates that total domestic energy production of 669.6 million tons of oil equivalent (MTOE) will be reached by 2016-17 and 844 MTOE by 2021-22. This will meet around 71 per cent and 69 per cent of expected energy consumption, with the balance to be met from imports, projected to be about 267.8 MTOE by 2016-17 and 375.6 MTOE by 2021-22. India was the fourth largest consumer in the world of Crude Oil and Natural Gas, after the United States, China, and Russia. India's energy demand continued to rise inspire of slowing global economy.

Primary energy mix for India

Source	2010	2025
Coal	53%	50%
Oil	30%	25%
Gas	11%	20%
Hydro	5%	2%
Nuclear	1%	3%
	100%	100%

Figure 4.1

The Indian economy has experienced unprecedented economic growth over the last decade. Today, India is the ninth largest economy in the world, driven by a real GDP growth of 8.7% in the last 5 years (7.5% over the last 10 years). In 2010 itself, the real GDP growth of India was the 5th highest in the world. This high order of sustained economic growth is placing enormous demand on its energy resources. The demand and supply imbalance in energy is pervasive across all sources requiring serious efforts by Government of India to augment energy supplies as India faces possible severe energy supply constraints

2.4.2 DEMAND AND SUPPLY SENARIO IN INDIA

In recent years the demand for natural gas in India has increased significantly due to its higher availability, development of transmission and distribution infrastructure, the savings from the usage of natural gas in place of alternate fuels, the environment friendly characteristics of natural gas as a fuel and the overall favorable economics of supplying gas at reasonable prices to end consumers. Power and Fertilizer sector remain the two biggest contributors to natural gas demand in India and continue to account for more than 55% of gas consumption.

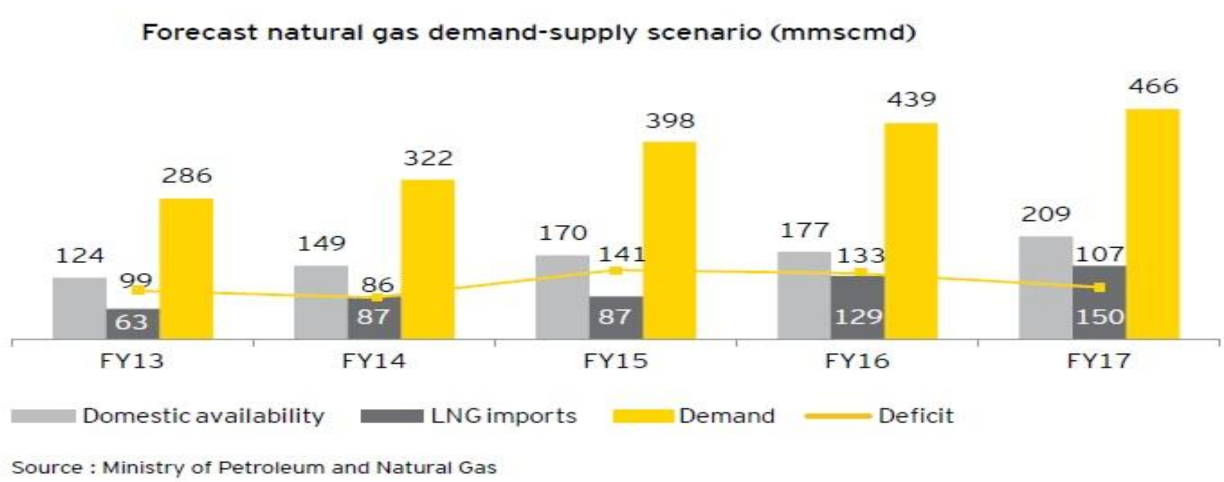
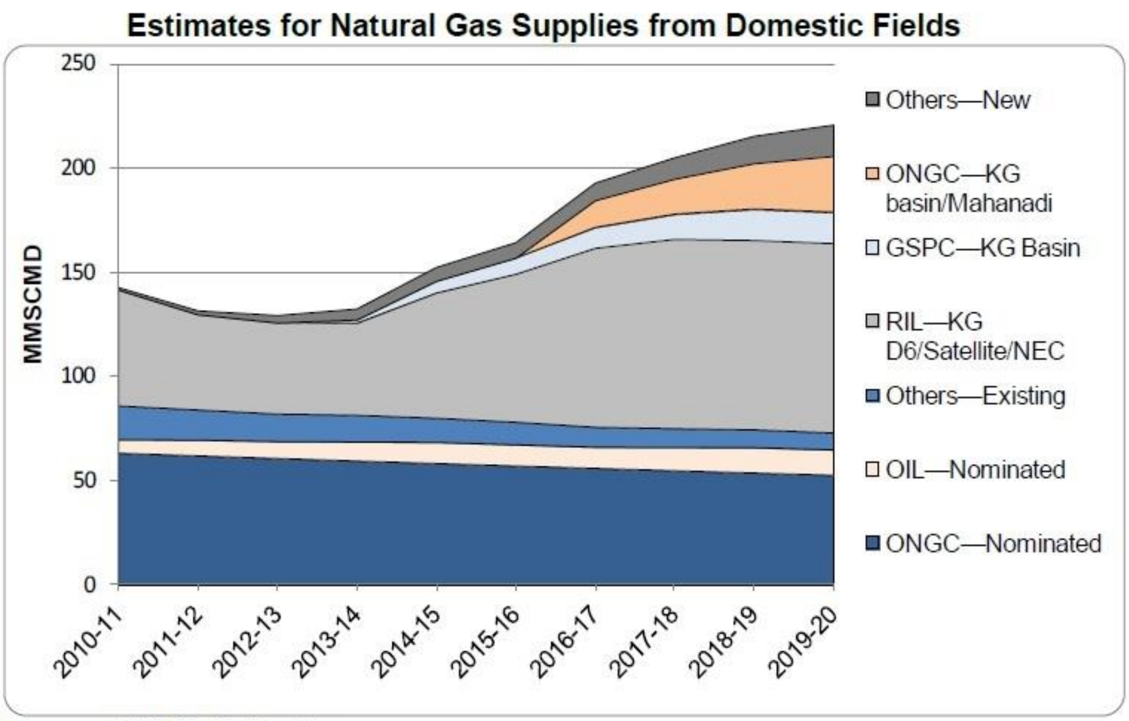


Figure 4.2

2.4.3 DOMESTIC PRODUCTION

The supply scenario of India is not very good with depleting indigenous production of natural gas from major gas reserves such as Bombay High the availability of APM gas is almost at its very end. The non-APM gas production is increasing with some major discoveries like KG-D6 basin and some new discoveries in KG basin. The interstate pipeline TAPI is still not commissioned due to geopolitical factors which is also limiting the India gas supply. Though India meets some of its demand through LNG and there are some new LNG projects in India which have already started and some are in commissioning phase. The supply side of India is still not sufficient to meet increasing demand of natural gas due to which some gas related projects such as power plants and fertilizer plants are not working due to unavailability of gas.



Source: ICRA's Estimates

Figure -4.3.1

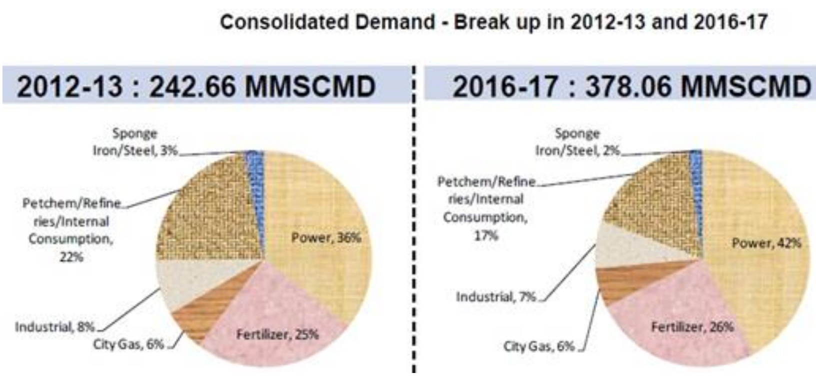
Chart 4.3.2(Source : PNGRB)

Total gas availability - 12th and 13th five year plan

	12th plan					13th plan				
MMSCMD	**2012-13**	**2013-14**	**2014-15**	**2015-16**	**2016-17**	**2017-18**	**2018-19**	**2019-20**	**2020-21**	**2021-22**
Domestic Sources	101.1	102.5	110.9	120.4	156.7	161.4	166.2	171.2	176.4	181.6
LNG Imports	44.6	64.4	85.0	123.6	143.0	188	188	188	188	188
Gas Imports (Cross border Pipelines)	0.00	0.00	0.00	0.00	0.00	30.00	30.00	30.00	30.00	30.00
Total	**145.7**	**166.9**	**195.9**	**244.1**	**299.7**	**367**	**384**	**389**	**394**	**400**

2.4.4 SECTOR – WISE DEMAND

Sector	2012-13	2013-14	2014-15	2015-16	2016-17
Power	135	153	171	189	207
Fertilizer	55	61	106	106	106
Demand (Price elastic)	**190**	**214**	**277**	**295**	**313**
City Gas	15	19	24	39	46
Industrial	20	20	22	25	27
Petrochemicals/ Refinery	54	61	67	72	72
Sponge iron / steel	7	8	8	8	8
Demand (relatively price inealstic)	**96**	**108**	**121**	**144**	**153**
TOTAL DEMAND (mmscmd)	**289**	**322**	**398**	**439**	**466**



India has developing market for natural gas but there is infrastructure constraint in the country due to which proper optimization and transportation of natural gas is a major issue. The demand is also sensitive to price though government provide subsidies to some sector depending upon the preference set by the government such as fertilizer and power sector; but demand projections have high variation.

Chart 4.4.2 Consolidated demand growth trajectory (Source: PNGRB)

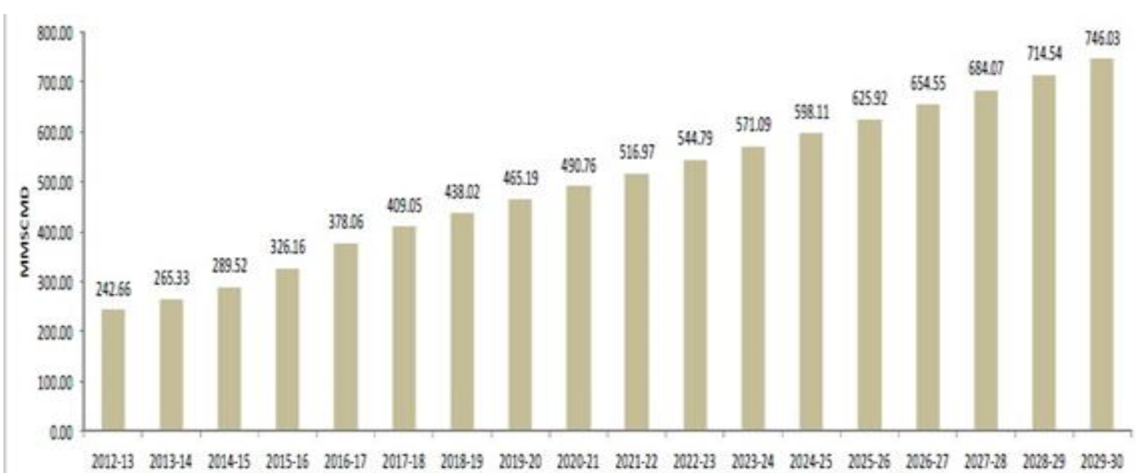


Chart 4.4.3(Source: PNGRB)

2.4.5 Regional Gas Market :

Figure: 4.5.1(Source:Soumita Choudhary Report on Policy for pulling of natural gas prices)

Regional gas markets in India

Region	% of consumption	States with infrastructure and consuming gas	States lacking pipeline infrastructure
Western	53%	Gujarat, Maharashtra	Goa
Northern	26%	Delhi, UP, Haryana, Rajasthan	Punjab, J&K, Himachal Pradesh, Uttarakhand
Central	3%	Madhya Pradesh	Chattisgarh
Southern	14%	Tamil Nadu, Andhra Pradesh	Kerala, Karnataka
Eastern	NIL	-	Bihar, West Bengal, Jharkhand, Orissa
North Eastern	4%	Assam, Tripura	Meghalaya, Sikkim, Arunachal Pradesh, Mizoram, Manipur, Nagaland

Source - Saumitra Chaudhuri report on Policy for pooling of natural gas prices and pool operating guidelines

Chart 4.5.2 Regional Demand Distribution

MMSCMD	2012-13	2016-17	2021-22	2026-27	2029-30
North	62.98	88.40	144.66	188.74	215.11
East	10.35	21.66	31.03	53.24	60.68
West	102.80	165.13	191.78	207.50	236.50
North East	5.13	5.29	10.47	20.67	23.56
South	48.20	81.28	116.71	151.89	173.11
Central	13.21	16.29	22.33	32.52	37.07
Total	**242.66**	**378.06**	**516.97**	**654.55**	**746.0**

Chart 4.5.3((Source:Soumita Choudhary Report on Policy for pulling of natural gas prices)

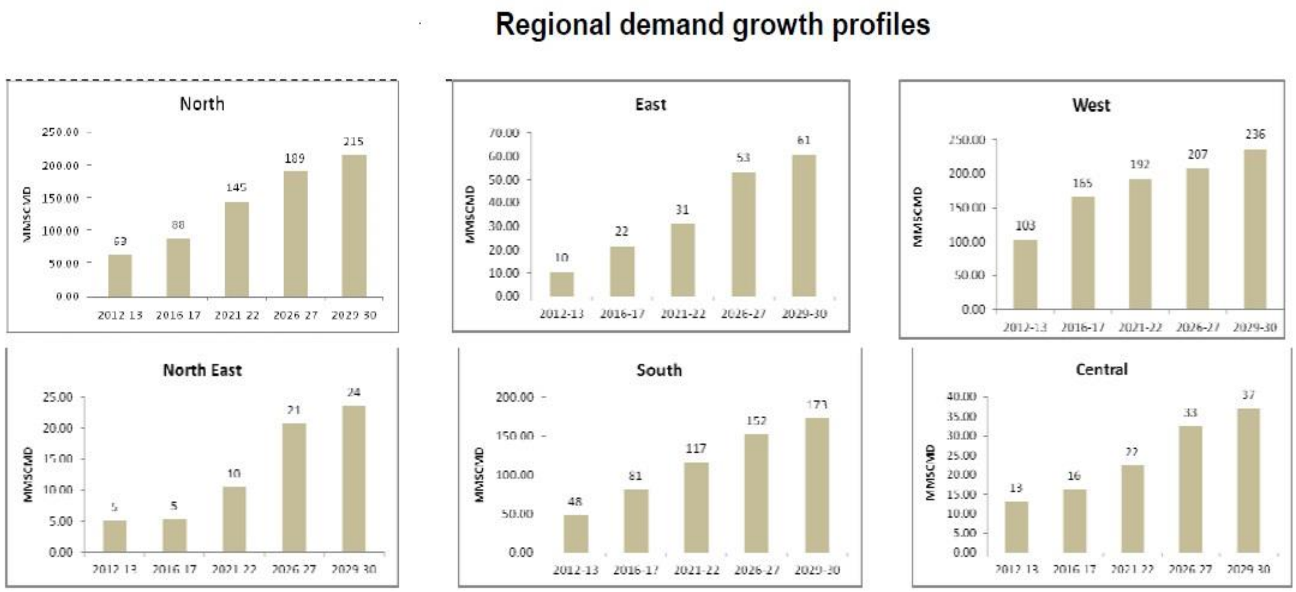


Chart 4.5.4((Source:Soumita Choudhary Report on Policy for pulling of natural gas prices)

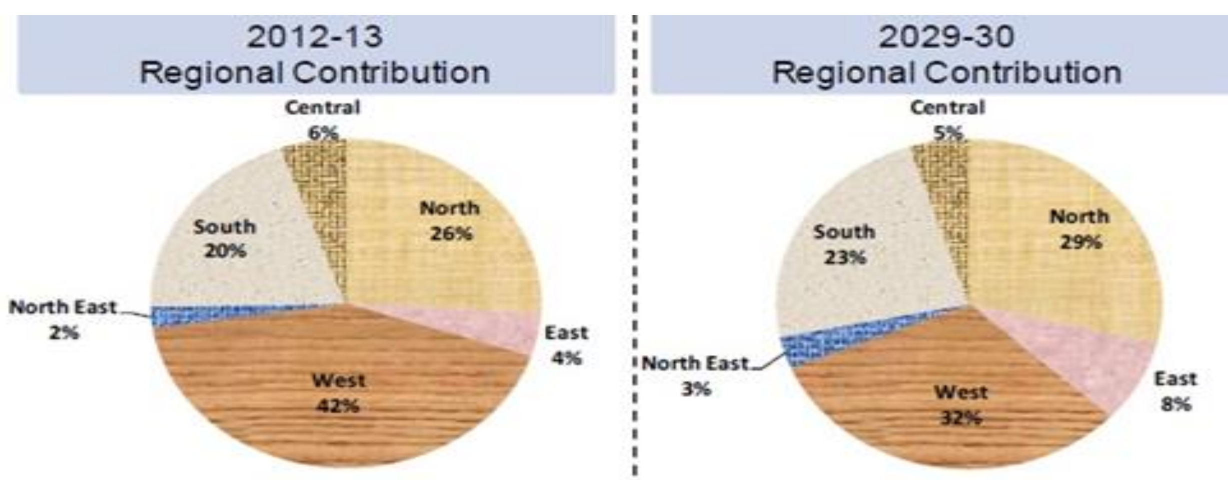


Chart 4.5.5 Regional Contribution of demand ((Source:Soumita Choudhary Report on Policy for pulling of natural gas prices)

2.4.6: DEMAND DRIVER FROM DIFFEREENT SEGMENT

Demand drivers for various end user segments

Sector	Demand Drivers
Power Sector	✓ Rising cost of imported coal ✓ Constrained domestic coal supply ✓ Supply of domestic gas ✓ Power sector reforms ✓ Fast-growing economy
Fertilizer Sector	✓ Greater emphasis on Food Security ✓ Increase in import price of Urea ✓ Rising price of crude oil ✓ Subsidy burden ✓ Conducive Govt. Policy for new investment in urea manufacturing units
Industrial User Segment	✓ Rising price of crude oil ✓ Environmental concerns
City Gas Distribution	✓ Environmental concerns ✓ Subsidy burden ✓ Enabling policy framework ✓ Supply of domestic gas ✓ Availability of affordable RLNG ✓ Requisite infrastructure ✓ GDP / Household income

2.4.7 LNG terminals : Chart 4.7.1

India's upcoming LNG terminals

Terminal	Re-gasification capacity (mmscmd)	Estimated completion date*
Dabhol	19	2013-14
Kochi	19	2012-13
Ennore	19	2015-16
Mundra	19	2015-16
Other east coast terminals	19	2016-17

Source: Ministry of Petroleum and Natural Gas

Projected LNG Capacity in India

(in MMTPA)	2011-12	2012-13	2013-14	2014-15	2015-16	2016-17	2017-18	2018-19	2019-20
PLL Dahej	10	10	10	10	10	10	10	10	10
PLL Kochi	0	1.25	5	5	5	5	5	5	5
Shell Hazira	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7
Dabhol	0	2	5	5	5	5	5	5	5
Mundra	0	0	0	0	5	5	5	5	5
Ennore	0	0	0	0	0	5	5	5	5
Total capacity	13.7	16.95	23.7	23.7	28.7	33.7	33.7	33.7	33.7
Possible supplies at 100% capacity (MMSCMD)	48.0	59.3	83.0	83.0	100.5	118.0	118.0	118.0	118.0

Source: ICRA's estimates; Note: 1 MMTPA= 3.50 MMSCMD of LNG

Chart 4.7.2

2.4.7 Natural Gas Pipeline Infrastructure

The present gas pipeline infrastructure is mainly in the northern and western regions of the country 60% of the total pipeline network and about 80% of the country's gas consumption is confined to the western and northern parts of the country. Pipelines were initially laid from the source of gas to nearby developed markets and to major consumers like fertilizer and power plants. As a result, states closer to the gas source have had benefits of higher utilization of gas and local development of gas market e.g. Gujarat, Maharashtra and Andhra Pradesh. In contrast, the Eastern region has no gas pipeline network and hence no consumption of gas.

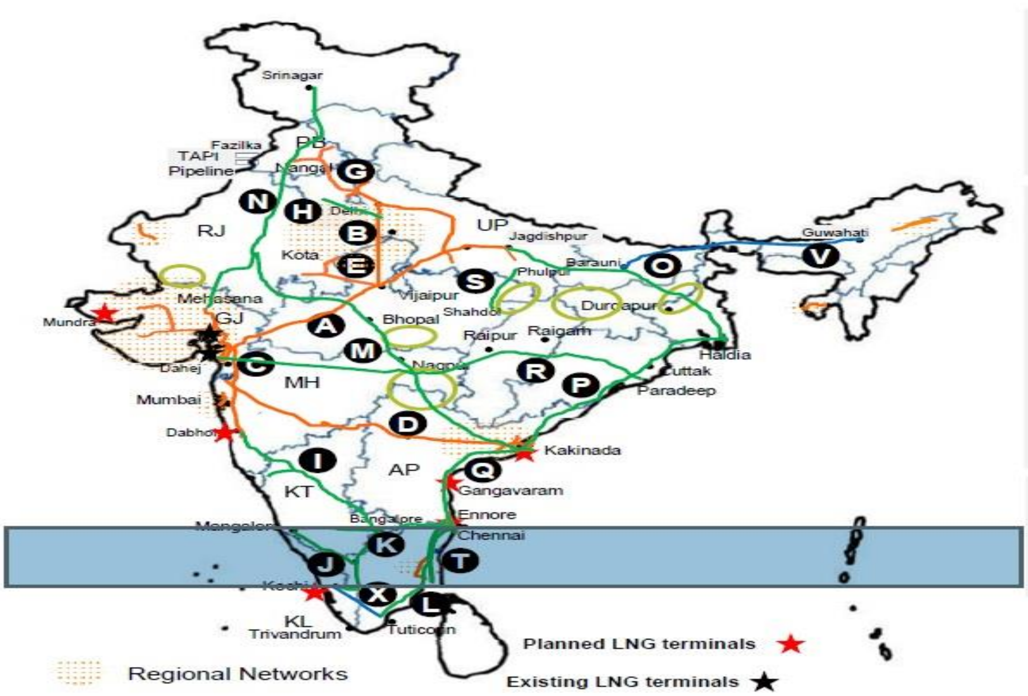


Figure: 5.1(Source: GAIL)

Existing Pipelines (at the end of 2013)
A : HVJ - Hazira Vijaipur Jagdishpur PL (GAIL)
B : GERP - Part of HVJ PL (GAIL)
C : DUPL/DPPL - Dahej – Uran – Dabhol PL (GAIL)
D : E-W PL - East West PL (RGTIL)
E : VKPL - Vijaipur Kota PL (GAIL)
F : Regional Networks
G : DBNL- Dadri Nangal PL (GAIL)

New Pipelines in 12th five year plan
H : Chainsa – Jhajjar – Hisar (GAIL)
I : DBPL - Dabhol Bangalore PL (GAIL)
J : KKMBPL – Kochi Bangalore Mangalore Pl (GAIL)
K : CBMPL – Chennai Bangalore Mangalore PL (RGTIL)
L: CTPL – Chennai Tuticorn PL (RGTIL)
M: MaBPL – Mallverum Bhilwara PL (GSPC)
N : MBPL / BSPL – Mahesana Bhatinda Srinagar PL (GSPC)
O : JHPL – Jagdishpur Haldia PL (GAIL)
P : KHPL – Kakinada Haldia PL (RGTIL)
Q : KCPL – Kakinada Chennai PL (RGTIL)
R : Surat – Paradip (GAIL)
S : Shahdol – Phulpur
T: Ennore - Nagapattinum

New Pipelines in 13th five year plan
V : Guwahati - Barauni
X : Kochi – Tuticorin
Regional network

Additional Regional Networks (around CBM blocks)

Summary of Planned additions to pipeline infrastructure

Pipelines	Design Capacity (mmscmd)	Length (Kms)
Existing till 2012	306	12144
Expected addition in the 12th plan	416	15928
Expected addition in the 13th plan	60	3360
Capacity addition MBBVPL/MBPL/Surat Paradip/pipelines beyond 13th plan & till 2030	33	1295
Total	**815**	**32,727**

Chart 5.1.1(Source: GAIL)

NETWORK/REGION	Entity	Length (Km)	Design Capacity (MMSCMD)
HVJ GREP - DVPL & Spur (Hazira - Vijaipur- Jagdishpur) HVJ / VDPL	GAIL	4435	57.3
DVPL - GREP Upgradation (DVPL-2 & VDPL)	GAIL	1112	54
Chhainsa - Jhajjar - Hissar P/L (Including Spur lines) commissioned up to Sultanpur, Jhajjar- Hissar under hold (111 Km) Flow Jhajjar- Hissar under hold (111 Km) Flow of 5 Million up to 2011-12	GAIL GAIL	262 262	5 5
Dahej - Uran - Panvel (DUPL / DPPL) including Spur Lines including Spur Lines	GAIL GAIL	873 873	20 20
Dahej - Uran - Panvel (DUPL / DPPL) including Spur Lines including Spur Lines	GAIL GAIL	803 803	11 11
Dhabhol - Banglore - P/L (Including spur)	GAIL	1004	16
Kochi - Koottanad - Banglore – Mangalore (Phase-1) (Phase-1)	GAIL GAIL	41 41	6 6
Assam (Lakwa)	GAIL	8	2.5
Tripura (Agartala)	GAIL	61	2.3
Ahmedabad	GAIL	144	3
Rajasthan (Focus Energy)	GAIL	154	2.35
Bharuch, Badodara (Undera) included RLNG+ RIL RLNG+ RIL	GAIL GAIL	670 670	15.4 15.4
Mumbai	GAIL	129	24
KG Basin (included RLNG+ RIL)	GAIL	877	16
Cauvery Basin	GAIL	268	9
East - West P/L(RGTIL)	RELIANCE	1469	80
GSPCL Network including Spur Lines	GSPCL	1874	50
Assam Gas Company (Duliajan to Numaligarh) Numaligarh)	AGC AGC	1000 1000	6 6
Dadri – Panipat	IOCL	132	9.5

Uran – Trombay	ONGC	24	6
Sub Total		**15340**	**395.35**

Table 5.1.2: Details of major existing pipelines(Source- GAIL)

		2014-15	
SECTOR	**Domestic**	**R-LNG**	**Total**
Fertilisers	26.77	15.05	41.82
Gas Based LPG plants for LPG extractions	2.68	0.16	2.84
Power	25.37	3.43	28.8
CGD for CNG&PNG(Dom.,Ind.,Comm)	9.07	7.45	16.52
TTZ	1	0.1	1.1
Small consumers(<50000SCMD)	2.8	1.78	4.58
Steel	1.16	1.46	2.62
Refineries	1.52	11.28	12.8
Petrochemicals	1.93	1.79	3.72
Others	1.28	2.05	3.33
Internal consumptn(pipeline system)	1.21	0	1.21
Total	74.79	44.55	119.34
Total(bcm)	27.29562	16.25912	43.55474

Table 5.1.3: Sector-wise allocation and supplies of natural gas(Source: PNGRB)

At present, the Ministry has different policy provisions for utilization of different categories of domestic gas. In order to bring uniformity in allocation policy of different categories of domestic gas, Ministry is in the process of making a uniform policy for allocation of domestic gas, covering all categories. The various principles adopted for allocation & supply of domestic natural gas are as follows:

2.4.8 Allocation of APM Gas:

In 1990, Ministry of Petroleum and Natural Gas formulated "Natural Gas Use Policy" considering natural gas as a premium source of fuel and feedstock with a variety of competing demands. For effective & efficient utilization of natural gas, the production potential/availability of natural gas from various regions was considered. The potential demand of natural gas, to be used as fuel or feedstock, from various sectors, such as Fertilizer, Power, Sponge Iron, LPG, Industrial use, Petrochemicals, etc. was considered. Further, to rationalize the allocation of gas without any discrimination on the basis of sector/ region, Government of India constituted the Gas Linkage Committee (Committees of Secretaries) in July, 1991. This Committee was represented by various user departments, namely, Power, Fertilizer, Steel, Chemical and Petrochemicals and representatives from Planning Commission, Department of Economic Affairs, Department of Expenditure (Ministry of Finance) and three national oil and gas companies, namely, GAIL, ONGC and Oil India Limited. The Committee was headed by the Secretary, Petroleum & Natural Gas. The Gas Linkage Committee made allocations of gas to various consumers based on the requests received from the prospective consumers and the recommendations of the concerned Ministries in this regard, depending on the availability of gas in the concerned region. Considering the demand, availability and imputed economic value of natural gas in various sectors, GLC decided to allocate natural gas to various sectors on "firm basis" and "fall back basis". In view of the importance of the Fertilizer and Power sectors in the national economy, preference in allocations was given to these two sectors. There are occasions when the consumers do not use gas because of shutdown or due to force majeure conditions. The concept of "fallback allocations" had been created to take care of such eventualities. "Fallback allocations" are made to optimally use the temporary surplus gas in the system. Consumers are allocated gas on a "fallback – as and when available basis" as a contingency measure to ensure optimal utilization of surplus gas. These consumers normally use an alternative fuel but have the capability to switch over to gas at short notice. Priority for supply against such allocations is given only after meeting the requirement of consumers with firm allocations. As there was no further APM gas available for allocation to new consumers, GLC was wound up on 9.11.2005.

2.4.9 Allocation of Non-APM Gas:

In 2010 Government allowed freedom to NOCs viz., ONGC and OIL to sell production from new fields in their nominated blocks at non-APM rate approved by the Government. Accordingly, MOPNG, on 28.10.2010, formulated a policy on pricing and commercial utilization of non-APM gas produced by NOCs. As per the policy, the Non-APM gas is to be allocated as per following priority:

i) Gas-based fertilizers plants

ii) LPG plants

iii) Power plants supplying to the grid

iv) City Gas Distribution systems for domestic & transport sectors.

v) Steel, refineries & petrochemicals plants for feedstock purposes

vi) City Gas Distribution systems for industrial & commercial customers

vii) Any other customers for captive & merchant power, feedstock or fuel purposes.

While maintaining the sectorial priority as indicated above, preference in allocation is given to APM short fall before meeting new demand. Within a sector, priority is accorded to region where gas is produced.

2.5.0 Allocation from Small & Isolated Fields of NOCs

Government had come out with guidelines for selection of customers for domestic gas available from small/ isolated fields on 16.01.2012 in line with policy on pricing and commercial utilization of non-APM gas produced by NOCs dated 28.10.2010. NOCs were given freedom to allocate gas from small discoveries whose peak production was less than 0.1 MMSCMD. This ensured that gas was allocated to customers expeditiously resulting in early monetization of gas. Based on the experience after issue of guidelines and the issues raised by various stakeholders as well as keeping intact the initial goal of the policy aimed at early monetization of gas, the guidelines dated 16.01.2012 have been reviewed and new guidelines for selection of customers for domestic gas available from small/isolated fields have been issued on 08.07.2013. According to the revised guidelines, there is no sectorial priority and the existing as well as new customers are to be treated equally for allocation of gas. In case of additional availability of gas after providing for gas supplies to the existing customers, the additional gas has to be allocated through open competitive bidding to be carried out by National Oil Companies via ONGC & OIL. The bids have to be based on price and have to be awarded to the highest bidder. Further, the limit of peak production has been raised from 0.1 MMSCMD to 0.2 MMSCMD for the purpose of qualifying as a small and isolated field.

2.5.1 Pre NELP-Gas:

In pre-NELP PSCs, there is a provision for government to appoint a nominee for purchasing the gas from the producers and marketing it. GAIL has been appointed the government nominee in PMT fields and Ravva fields. GAIL has been marketing this gas under the directions of the government. The producers, in rest of pre-NELP blocks, sell the gas as per the terms of PSCs.

2.5.2 NELP-Gas:

Under NELP contracts, freedom has been given to the contractor to market gas subject to allocation made by the government under its policy on utilization of natural gas. The government constituted an Empowered Group of Ministers (EGoM) to take decisions on utilization of gas produced under NELP blocks (including KG-D6).

The EGoM has decided the following principles for allotment of natural gas:

i. As a matter of general policy, natural gas produced/ imported in the country should be stripped of its higher fractions, subject to availability, to ensure maximum value addition before supply to consumers.

ii. The following guidelines for sale of natural gas by NELP contractors are approved:

a. Contractors would sell gas from NELP to consumer in accordance with the marketing priorities determined by the Government. The sale would be on the basis of formula for determining the price as approved by the Government.

b. Consumers belonging to any of the priority sectors should be in a position to actually consume gas as and when it becomes available. So the marketing priority does not entail any reservation' of gas. It implies that in case consumers in a particular sector, which is higher in priority, are not in a position to take gas when it becomes available, it would go to the sector which is next in order of priority.

In case of default by a consumer under a particular priority sector and further in the event of alternative consumers not being available in the same sector, the gas will be offered by the contractor to other consumers in the next order of priority.

The priority for supply of gas from a particular source would be applicable only amongst those customers who are connected to existing pipeline network connected to the source. So, if there is a marginal or small field that is not connected to a big pipeline network, then the contractor would be allowed to sell the gas to consumers who are connected or can be connected to the field in a relatively short period (of say three to six months).

The E-GoM decided to allot gas in the following order of priority:

i) Existing gas-based urea plants
ii) Existing gas-based LPG plants
iii) Existing grid-connected and gas-based power plants
iv) City Gas Distribution (CGD) network for domestic & transport sectors.
v) Subsequently in view of the increased availability of gas, the EGoM also took a decision to supply gas to steel, petrochemicals & refineries for feedstock purposes, CGD networks for industrial & commercial customers, other gas-based fertilizers plants and to captive power plants.

2.5.3 CGD INFRASTRUCTURE

The CGD sector comprises of Compressed Natural Gas (CNG) and Piped Natural Gas (PNG) customers. With increased availability of gas in the country, the CGD network has been enlarged to cover various cities supplying gas for domestic consumers, public transport, and commercial/ industrial entities. As on 31.12.2013, there are a total of 936 compressed natural gas (CNG) stations across the country and 24, 14,288 households with Piped Natural Gas (PNG) connectivity. The consumption of gas in the CGD network during 2013-14 was around 15.48MMSCMD, of which 8.60 MMSCMD was used for CNG (transport) & PNG (domestic) and 6.88 MMSCMD was used for Industrial & Commercial PNG. At present, there are a number of entities operating in 47 geographical areas (GAs) and currently 18 GAs are under bidding process by PNGRB. The PNGRB has envisaged a rollout plan of CGD network development through competitive bidding in more than 300 possible gas in a phased manner depending upon the availability of natural gas and pipeline connectivity.

In order to promote CNG (transport) and PNG (domestic) and for a developed CGD sector in the country, Ministry has taken a decision to meet 100% requirement (to the maximum extent possible) of CNG (transport) and PNG (domestic) of all CGD entities across the nation without any discrimination amongst entities. Guidelines in this regard have been issued in February, 2014. This decision has brought down the price of CNG (Transport) and PNG (domestic) across the nation and has led to increase in the consumption of natural gas, an environmentally friendly fuel, in the sector.

Further in order to bring transparency in pricing of CNG (transport) & PNG (domestic), the Ministry has issued instructions in February, 2014 to CGD entities to display the breakup of CNG price at CNG stations and to furnish the breakup of PNG (domestic) price in the invoice issued to the customers. The Ministry is formulating guidelines relating to grant of rights to entities for sale of CNG as transportation fuel through CNG Stations. The intent of the envisaged guidelines is to promote setting up of several CNG stations in various cities/towns across the country, including along highways, and also to foster competition amongst eligible entities in the CNG segment, analogous to that in liquid transportation fuel (MS, HSD and ATF) segment. This would lead to faster rollout of large number of CNG stations across the nation.

As the name suggests, CGD is the last component in the natural gas value chain delivering natural gas to end users in towns and cities. While large customers such as the power and fertilizer industry receive natural gas directly through the high pressure interstate transmission pipelines, CGD is provided through the network of medium to low pressure distribution pipelines by a local distribution company. The tap off point from where the city distribution network takes its supply from the transmission system for the city distribution system is referred to as the city gate. CGD involves movement of small volumes of gas through small diameter, low pressure pipelines to a large number of retail customers. Typically, the network comprises compressed natural gas (CNG) dispensing stations throughout the network that supplies natural gas for automotive use, and a piped natural gas network that provides natural gas as a fuel for city-based commercial/ industrial/ domestic purposes. Since natural gas is odorless and colorless, Mercaptan is added to it and when it enters the CGD network, which gives it a typical smell of rotten eggs to ease leak detections.

2.5.4 CGD BUSINESS SEGMENT

City Gas Distribution though confined to a pre-determined Geographical Area (GA), has much winder opening with GA and contiguous to GA. The business segments where gas is supplied cover four main segments as outlined below but CGD business has other upside such as making use of the space at retail outlets for convenience stores and other services like ATM, PCO and workshop.

2.5.4.2 PNG:

This segment of the CGD business relates to the supply of natural gas to domestic consumers. The domestic consumers may use gas for one or more of the following applications.

a. Cooking of Food
b. Power Generation
c. Space Heating
d. Water Heating
e. Refrigeration
f. Air conditioning
g. Lightening

Domestic segment is capital cost intensive on per unit gas sale volume basis. The cost involved in connecting individual household through combination of GI pipe, Gas Meter, valves, Copper tubing, Rubber tubing from transmission fitting to the burner is much higher than the deposit from the domestic consumers allowed by the Board.

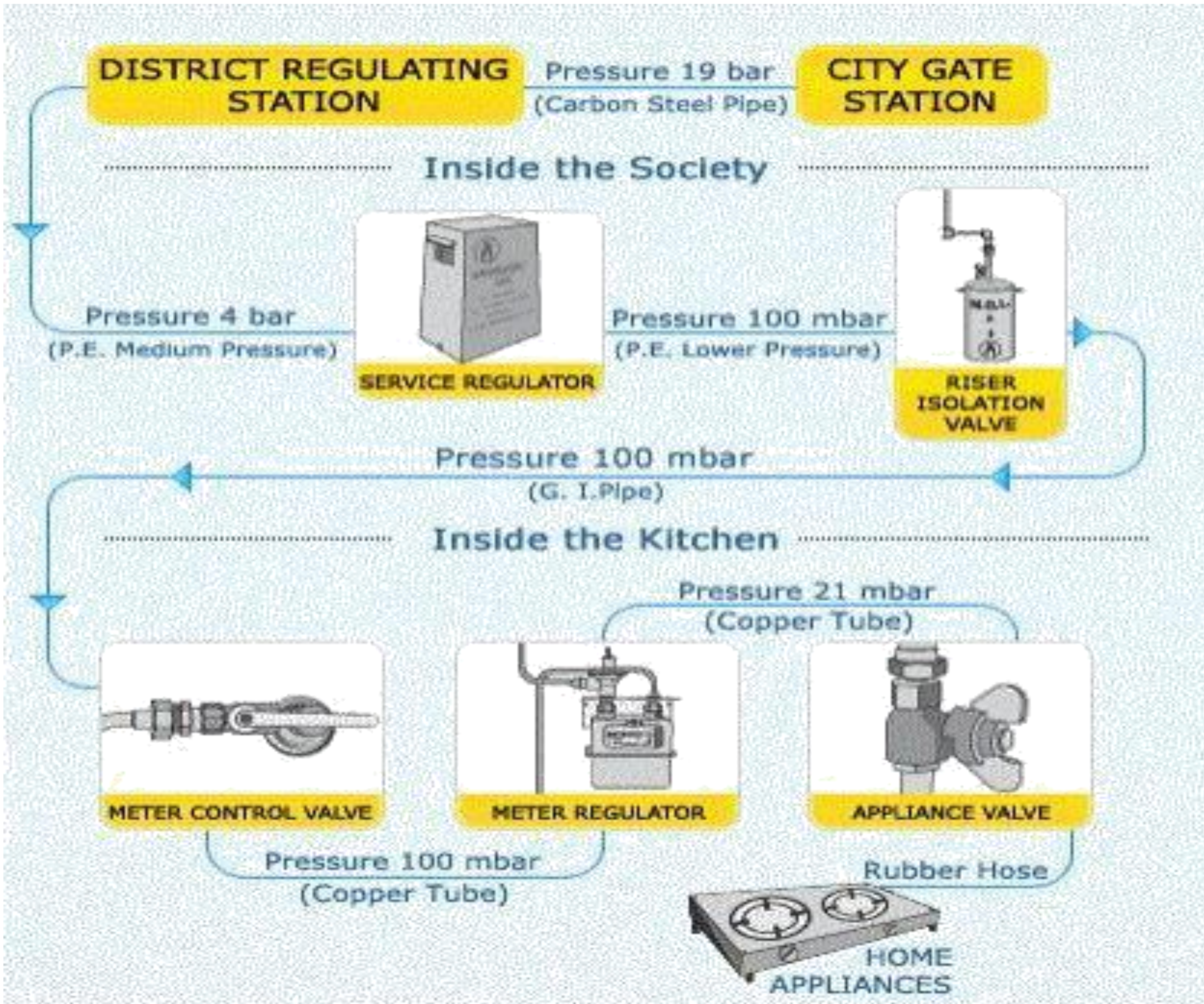


Fig. 7.1: Domestic connection

With the provision of balcony or other facility for access to gas meter, it is advisable that the gas meter with isolation valves be installed outside the kitchen for ensuring more safety as compared to installing gas meter inside kitchen

- Latest Data having total number of PNG customers in India:

State	City Covered	Company	Domestic PNG	Comm. PNG	Ind. PNG
Delhi	DELHI, NOIDA, GREATOR NOIDA, GHAZIABAD.	IGL	434009	1277	585
MAHARASHTRA	MUMBAI, THANE, MIRA-BHAYANDAR, NAVI MUMBAI, PUNE, KALYAN, AMBERNATH, PANVEL, BHIWANDI	MGL, MNGL	718550	2320	136
GUJRAT.	AHEMEDABAD, BARODA, SURAT, ANKELESHWAR	GSPC, SABARMATI GAS, GUJRAT GAS, HPCL, VMSS,ADANI	1297068	16028	3828

		GAS			
UTTAR PRADESH	AGRA, KANPUR, BAREILLY, LUCKNOW,	Green Gas Ltd. (Lucknow), CUGL(Kanpur)	11298	129	444
TRIPURA	AGARTALA	TNGCL	14650	254	45
MADHYA PRADESH	DEWAS, INDORE, UJJAIN, GWALIOR	GAIL GAS, AGL	2583	21	60
RAJASTHAN	KOTA	GAIL GAS	189	1	17
ASSAM	TINSUKIA, DIBRUGARH, SIBSAGAR.JORHAT	ASSAM GAS CO. LTD	26043	890	371
ANDHRA PRADESH	KAKINADA, HYDERABAD,VIJAYWADA,RAJAMUNDRY	BGL	2102	37	2
HARYANA	SONEPAT, GURGAON, FARIDABAD	GAIL GAS, ADANI GAS, HARYANA CITY GAS	17124	69	154
Total			**2523616**	**21026**	**5642**

Table 7.1: Total PNG customers in India

2.5.4.3 CNG:

It stands for compressed natural gas. It is a gaseous fuel and is a mixture of hydrocarbons, mainly methane (simplest hydrocarbon) in the range of 95%, it is much cleaner and efficient fuel. Due to its low density, it is compressed to a pressure of 200 bar to enhance the vehicle on-board storage capacity. It is safe owing to its inherent property of being lighter than air, and therefore in case of leakage it disperses into the atmosphere rapidly. Its high auto-ignition temperature of 540 degrees centigrade as against petrol's 360 degrees centigrade makes it even more safe fuel. CNG also has a narrow inflammability range of 5% to 15%, making it much safer than other fuels. CNG emissions being non-toxic, non-corrosive and non-carcinogenic, its usage improves public health, as harmful exhaust gas emissions like carbon monoxide, nitrogen dioxide and Sulphur dioxide which causes harmful diseases like cancer, asthma etc. are significantly reduced. CNG also affects in reducing the effect of global warming or dilute crank case oil, giving engine an extended life besides increased life of lubricating oils. Due to the absence of any lead or benzene content in CNG, the lead fouling of spark plugs is eliminated.

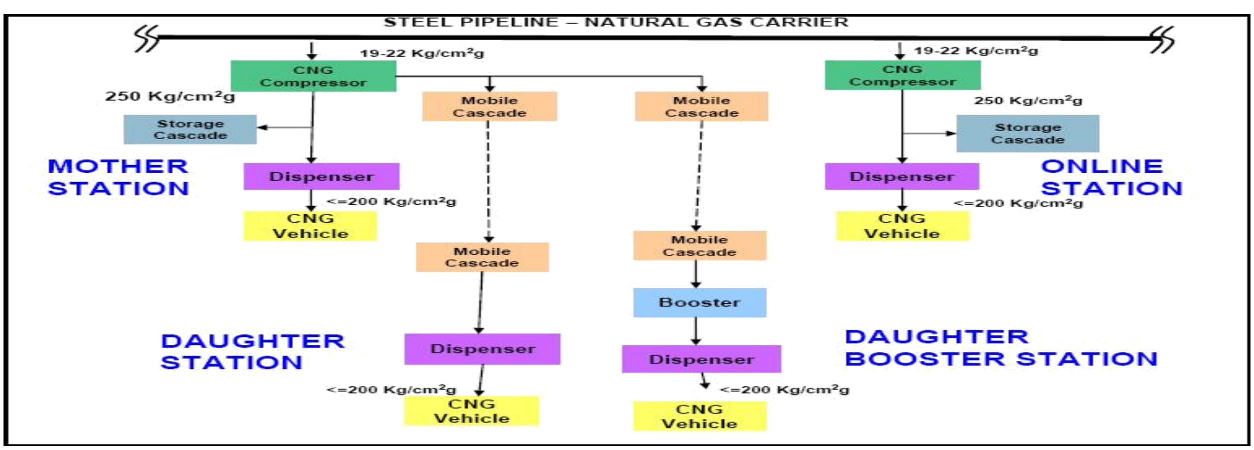


Fig: 7.3

All spark-ignited engines can be converted to CNG, for which a specially designed conversion kit is required for the conversion process. The kit consists of a cylinder to be fixed in the boot space/ under carriage of the vehicle and other equipment's to allow gas flow into the engine. Petrol-based engines, on conversion have added advantage of dual-fuel flexibility. The cost of converting a vehicle to CNG depends on the type of the vehicle and CNG kit and the cost of conversion ranges between Rs 25,000 to Rs 40,000 for a three-wheeler to a four-wheeler small vehicle. CNG cylinders are manufactured from a special steel alloy and are seamless in construction. Their compact size allows them to easily fit into a small car. An empty CNG cylinder with a 50 liter-water-carrying capacity weighs 48 kg (approximately), and has a length of 835 mm and a diameter of 316 mm. The 50-liter capacity cylinder is the one most regularly used in CNG kits but cylinders with 45 liters, 55 liters, 60 liters and 65-liter capacity are used as well. A cylinder with a 50-liter water-carrying capacity is capable of carrying approximately 9 kg of CNG. This is equivalent to 12.5 liters of petrol and will allow a run of about 150-160 km for a medium sized 1300 CC car. An electronic fuel gauge fitted on the dashboard which is part of the conversion kit indicates the quantity of CNG left in the cylinder. On an average, vehicle owners lose about one third of their boot space when a car is converted to CNG. The boot space also depends upon the size of vehicle and cylinder make.

CNG cylinders are designed and built in such a way so as to withstand high pressure. The maximum pressure in a CNG cylinder is up to 200 bar. CNG cylinders are safe as they are manufactured as per specific requirements and tested before use, in accordance with international specifications and standards, and are duly approved by the Chief Controller of Explosives. Moreover, they are provided with a pressure relief device (PRD) that consists of a fusible plug and a burst disc that ruptures in case of extremely high pressure and temperature. CNG kit is safe and simple and is designed to give years of trouble free operation without frequent servicing. As per Gas Cylinder Rules, 1981, the cylinder should undergo hydro-stretch testing every 5 years to check pressure tolerance. Cylinders used for storing gas are designed with very high safety factor in accordance with global standards. These cylinders are tested and certified for usage by statutory authorities and each cylinder is defined with an expiry date of usage after which they are to be tested again for safe use and can also be retrofitted into another vehicle. These cylinders have been designed to take impact of collision in case of accidents. Price of CNG is lesser than other fuels and also it enhances the mileage, making it the more economical fuel. However, CNG prices are of late becoming highly sensitive to natural gas prices (domestic natural gas prices are increasingly getting impacted to high LNG prices), taxation, cost of laying pipeline network and expensive CNG compressors and dispensing facilities, CNG kit costs, etc.

2.5.4.4 Factors that influence demand for CNG:

a) Legislative enablement for use of cleaner fuel to reduce pollution

b) Long-term price differential and economics between CNG and MS/ HSD/ Auto LPG price, particularly with reference to taxation on CNG

c) Cost of conversion/ retrofitting

d) Ease of CNG availability

e) Effective check on alleged diversion of domestic LPG cylinders for commercial and transport usage

f) Effect of CNG conversion on performance of a vehicle, i.e., increase in the weight because of the increased weight thus reducing pick up

g) Assurance of supply and price

h) Usage of retro fit CNG kit vis-à-vis OEM kit

i) Initiatives by vehicle manufacturers to launch CNG variants as OEMs.

2.6 Shale Gas Scenario

2.6.1 Formation of shale gas:

Shale is a common type of sedimentary rock formed over centuries from deposits of mud, silt, clay and organic matter. As mud turns into shale near the earth's surface, bacteria feed on the organic material – also called kerogen – to release biogenic methane as a by-product. Deep under the earth's crust there is intense pressure and temperature that cracks the kerogen into smaller hydrocarbons and creates thermo genic methane. Some of the oil and gas escapes from shale into the more porous conventional reservoirs but some of it does not. Shale gas consists of thermo genic methane and other gases which have been trapped in shale with very low permeability and the gas can't readily flow.

2.6.2 Extraction of Shale gas:

Shale gas remains adsorbed in the laminations, fractures and in the pore spaces. Shale acts as the source, reservoir and the cap rock for natural gas. Since it is characterized by low permeability & porosity hence it is extracted through fractured horizontal well. Hydraulic fracturing or "fracking" is used to enhance the permeability of shale rock so that gas can be extracted profitably. Fracking cracks the well from where the gas is to be extracted. Various sections of well are perforated and fracturing fluids consisting of water, sand, proppants & chemicals are injected at a high pressure.

The injection of fracturing fluids generates stresses in the rock that force open the existing fractures and also creates some new fractures that are propped open by sand. After fracturing the well is depressurized to create gradient so that gas starts escaping out of the well. Fracturing fluid and formation water return to the surface over the lifetime of the well (produced water).

2.7 Stages in Shale gas:

- **Exploration and pilot production**, when few wells are drilled and fractured for determining that whether shale gas is present could be extracted, then followed by more wells for characterization and check the economic viability.

- **Production** involves the commercial development of shale gas. Commercial reserves are often found in shale over a hundred meters thick, covering hundreds of square kilometers The vertical wells access very small economic zone hence wells are drilled horizontally and then fractured. The initial fracturing of a well might take a month and it differs from geology to geology. Post fracturing the gas will be produced for many years or decades, although the well may be fractured again at a later stage to improve throughput.

- **Abandonment** takes place when the well reaches the end of its life and extraction is no longer economic. Sections of the well are then filled with cement to prevent gas flowing into water bearing zones or up to the surface, and a cap is put in place and then buried.

2.7.1 Key elements of Petroleum Geology:

The various elements of petroleum system that are provided by the interpretation of data from reflection seismology and electromagnetic geophysical methods are:

- Source Rock: This rock contains the precursors of hydrocarbon formation, organic matter which are subjected to high temperature for longtime. The source rock host the processes that is responsible in forming oil and gas until they start migrating upward to reservoir rock due to fluidity of rock.
- Reservoir Rock: It is porous or permeable rock which retains the immigrating oil and gas from source rock. Reservoir rocks are analyzed by their porosity & permeability, and various other factors like stratigraphy, structural analysis, sedimentology etc.
- Cap Rock or Seal: This rock has low permeability that restricts the hydrocarbon to escape out of the reservoir. It's made of chalks, shale or evaporates. There are various types of cap rock formation based on efficiency of oil and gas retention.
- Trap: A trap is a structural or stratigraphic feature that ensures a fixed and firm position of seal and reservoir that avoids escape of oil and gas.
- Maturation: The assessment of the reservoir quality is analyzed by the duration of time of petroleum generation or expulsion.
- Migration: The process of movement of oil and gas from source rock to reservoir rock. Factors responsible for migration are compression, buoyancy, thermal expansion, maturation, gravitational force etc.

But unlike conventional petroleum system "Shale Gas" have a self-contained continuous large petroleum system where source rock is reservoir and seal as well.

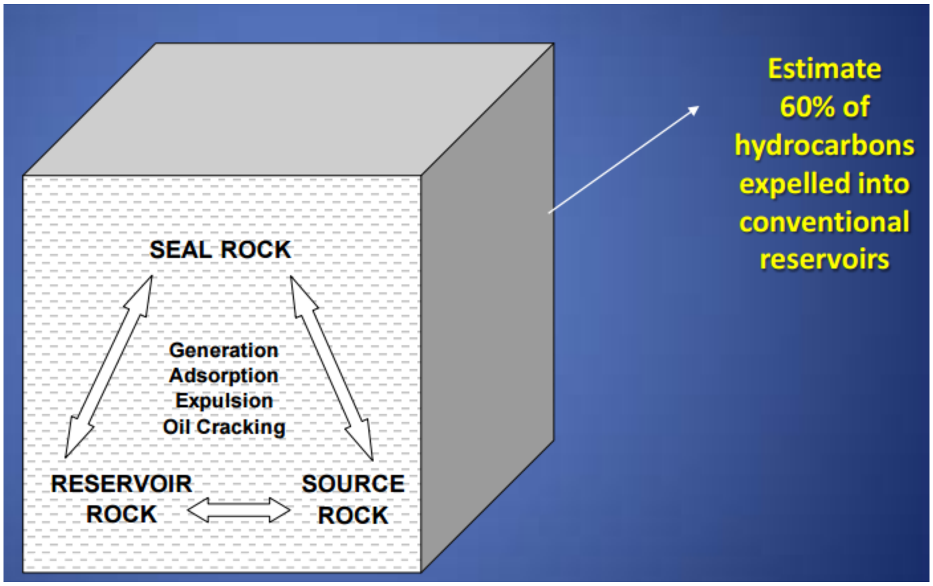


Figure 1.1 Shale gas Petroleum System

Shale gas was first commercially produced in Fredonia, New York in 1821 using shallow, low pressure fractures. For almost 100 years shale gas was extracted from shallow depths located in Appalachian & Illinois basin. In1947, the first hydraulic fracturing took place in Kansas. Two years later Hydraulic fracturing was used to produce shale gas commercially in Oklahoma, and by mid-1950's Hydraulic fracturing was widely accepted with almost a lakh treatment in operation.

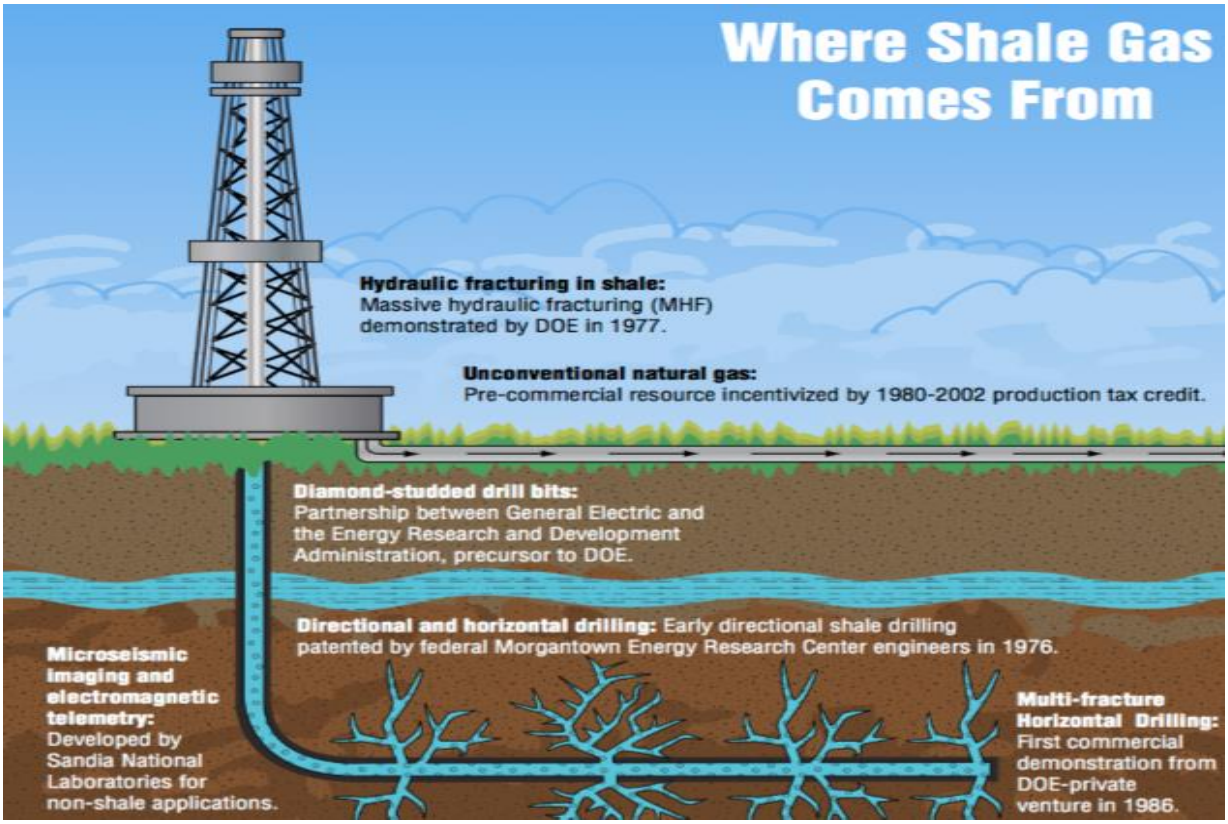


Figure 2.1: The role of Government in Fracking

By 1970's only marginal volume of natural gas came from shale and later on over the years various small companies and government agencies worked on developing the technology for commercially and economically produce gas from shale reservoirs. The shale gas seemed to have lost its spark and intense pressure on finding new gas resources led DOE to launch Unconventional Gas Research Program including Eastern Gas Shale project that studied on the deposits along with various universities and private firms for demonstrating gas recovery techniques for improving gas extraction. DOE funded lot of money on R&D and for almost a decade DOE and its partner agency developed early shale fracturing, directional drilling technologies, and 3-D seismic mapping.

With the support from federal government, the father of Shale, a private entrepreneur and head of Mitchell Energy, George Mitchell developed the Hydraulic Fracturing technique on a large scale for efficient gas recovery. For many years Mitchell relied on federally funded mappings of the reserves of shale and continued extracting those that were commercially viable. In 1991 Mitchell Energy started working with DOE and GRI (Gas Research Institute) for fracturing of the wells in addition of drilling a horizontal well in the Barnett Shale Play. By late 1990's, this firm was economically producing shale gas, and Barnett Shale region soon became one of the most active gas producing regions in US.

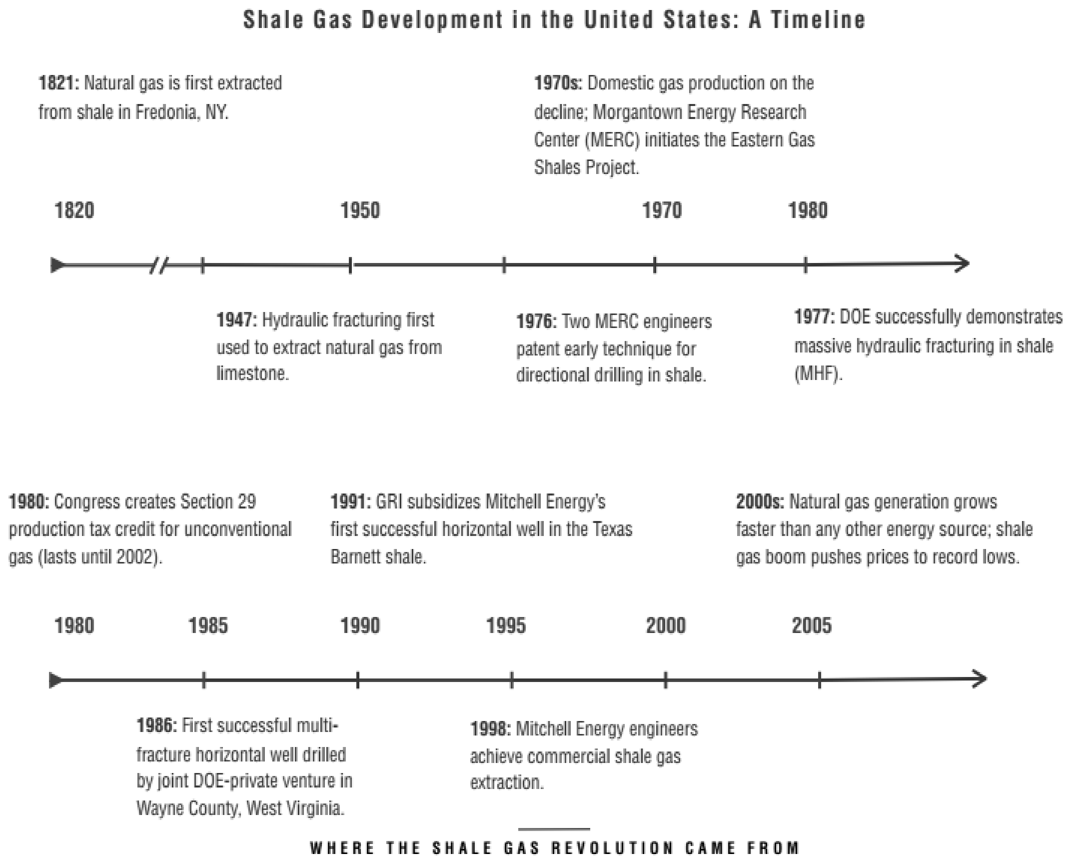


Figure 2.2 Timeline of Shale gas revolution

In summary, federal investments and involvement in the development of shale gas extraction technologies in the last three decades comprised of:

- The eastern shale gas project, a series of public-private shale drilling in the year 1970's.
- A collaboration with GRI that received funding for R&D from Federal Energy Regulatory Commission (FERC).
- Development of shale fracturing and directional drilling technologies by department of energy (DOE).

Various prospective areas for shale gas were recognized and were being exploited by many companies.

2.7.2 Global Presence of Shale Gas

Estimated Shale gas resources throughout the world are very large. It is seen that there are large shale gas resources in the United States, Canada, Mexico, Argentina, China and Australia. Estimates of technically recoverable shale gas resources (TCF), based on 48 major Shale formations in 32countries and is shown in below picture. According to the latest updates by EIA, Poland (187 TCF) has the largest technically recoverable shale resources in Europe, while China (1275 TCF), South Africa (485 TCF), and Argentina (774 TCF) lead the resource base in Asia, Africa and South America respectively. Estimated resources for US accounts for 13% of the global total. Shale gas exploration is all around the globe but what impacts the growth is the environmental, social, legal and technical constraints. China has the world's largest Shale reserves, accounting for almost 20% of global reserves and approximately 92% of the reserves in Asia.

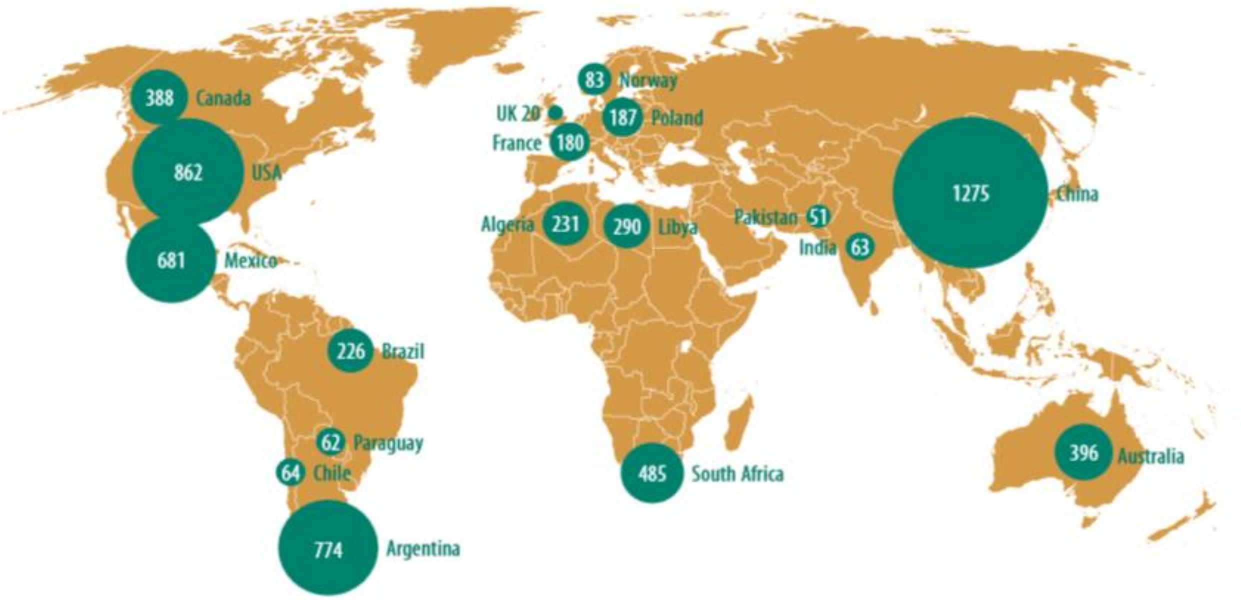


Figure 3.1 World Shale Gas Resources

Around 57% of he estimated shale reserves in Europe are concentrated in two countries- Poland & France. Factors that majorly drives Shale gas development is reducing the dependency on Russian gas supplies and meeting carbon emission targets. However some of the countries like France and Bulgaria have banned hydraulic fracturing due to environmental concerns. Argentina accounts for 63% of reserves in South America. The Argentinian government is encouraging investments in the shale gas industry to reduce dependence on imports.

2.7.3 US Scenario

There are many key elements for shale gas growth in the US. The first factor that drove the revolution is the limited gas reserves which was driving increased prices. From the 1970's until the 1990's, the US faced declining reserves due to which the dependence on import from Canada increased. Hence alternative exploration methods were created that resulted in the dramatic growth in Shale gas development that began in late 1990's and continued aggressively in the 2000's.

Advancement in technologies like hydraulic fracturing, horizontal techniques, is the second factor that drove the gas market. The technology coupled with lean, factory like practices used in field development, has reduced many components like drilling time, completion time, and cost and have maintained a considerable production levels. Many small E&P companies along with the service providers to advance conventional technologies into unconventional gas, were the next factor in Shale gas development. Profitable results were obtained by these good decision making due to advancement. Another contributing factor in US Shale growth was the availability of capital. With progress in this area, shale gas operators found another way to raise capital by entering into Joint Venture partnerships with foreign based international oil companies and National Oil companies.

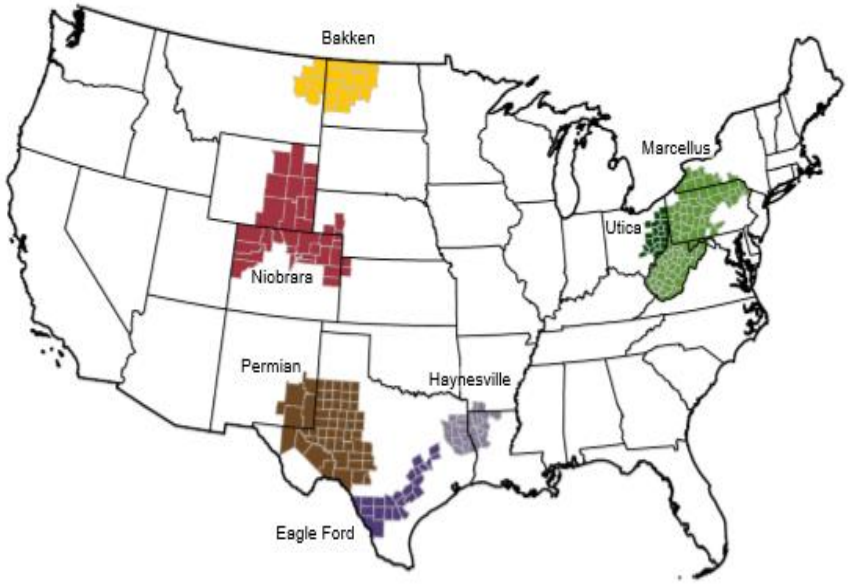


Figure 3.2 Shale Gas Scenario in US

Almost 34 states in the US have vast deposits of rocks rich in shale gas. Production of the Shale gas has added about 20 percent to domestic gas availability and over 20, 0000 wells have been drilled. From being an importer of LNG, the country has become self-sufficient and now it has become a net exporter because of advent of Shale gas.

2.7.4 Indian Scenario

As per the EIA study 4 Indian basins namely Cambay, Krishna-Godavari, Cauvery, Damodar are recognized as the prospective area that holds 63 TCF. There is a possibility that both Shale oil and gas can be explored in those areas due to thermal history of basins. These 4 basins are currently in focus for shale oil/gas exploration.

Other sedimentary basins such as Assam & Assam Arakan, Pranhita Godavari, Bengal, South Rewa, and Satpura also have attention for shale gas exploration. In all there are 26 sedimentary basins in India for oil and gas exploration. Among them all the onland basins have significant thickness of shale sequences which needs to be evaluated for shale potential. Basins classified as Category-1 and 2 looks interesting from shale gas exploration point of view.

Basin	Area (Sq. miles)	Prospective Area (Sq. miles)	Risked Recoverable Reserves (TCF)
Cambay	20,000	940	20
Krishna-Godavari	7800	4340	27
Cauvery	9100	1005	9
Damodar	1410	1080	7

Table 3.1 Prospective area of Sedimentary basin and Recoverable shale gas reserves

2.7.5 Latest Development in India:

The Government of India, along with Indian Companies has undertaken various initiatives to accelerate the development of Shale gas reserves in the country. As a part of this initiative, the government had setup a multi organizational team (MOT) comprising the Directorate General of Hydrocarbon (DGH), Oil and Natural Gas Corporation (ONGC), Oil India Limited (OIL), and GAIL (India) limited for analysing the existing data set and suggesting a methodology for shale gas development in country. Further, in April 2012, the DGH submitted its draft policy on exploitation of shale gas to the Ministry of Petroleum and Natural Gas (MOPNG). ONGC and OIL are aggressively implementing pilot projects to assess the shale gas potential in the country. In addition to that Reliance Industries Limited (RIL) and GAIL have entered the US Shale Industry to gain technical expertise and then apply those techniques in India.

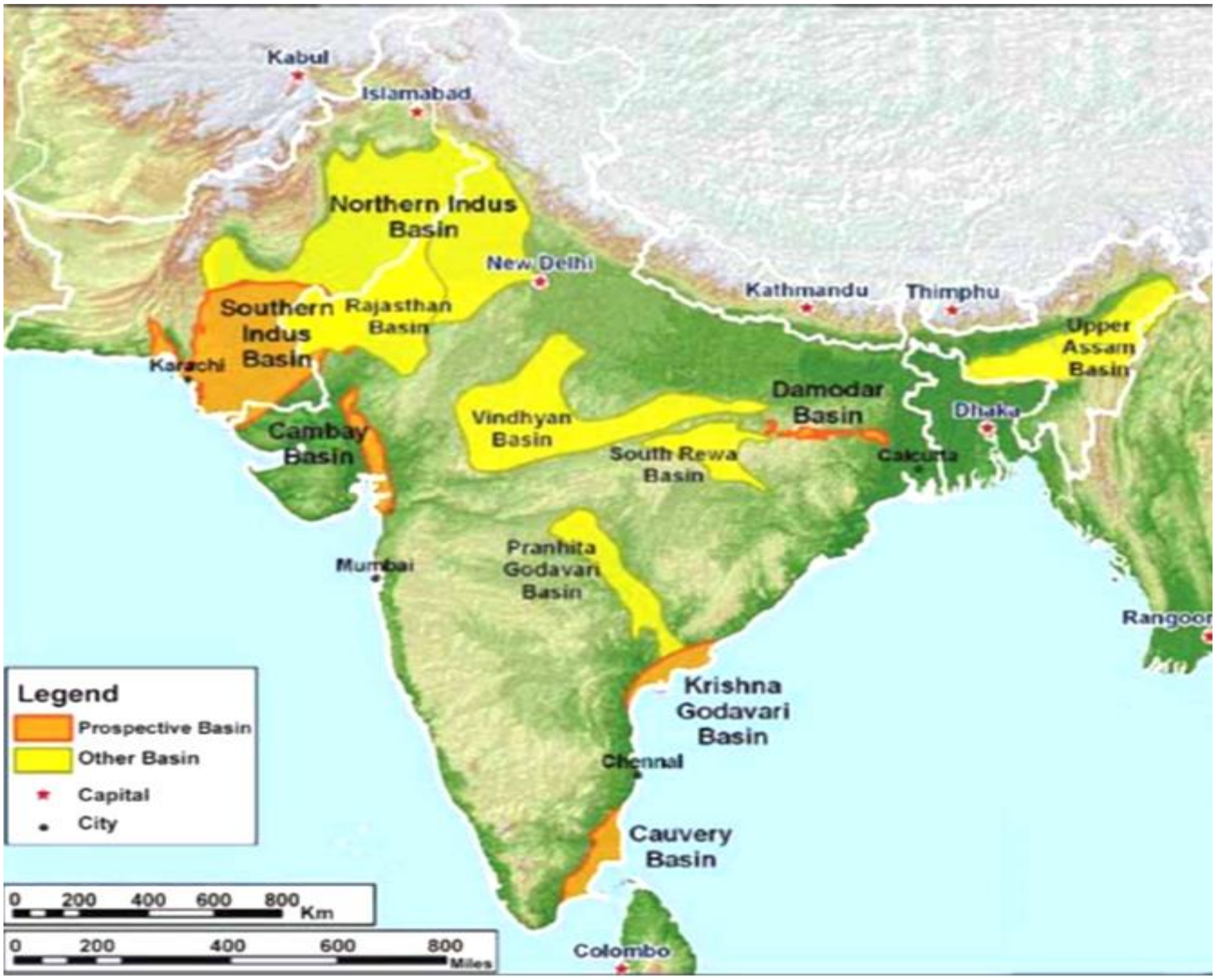


Figure 3.3 Shale Gas Sedimentary basins in the Indian sub-continent

- In January 2011, ONGC discovered first pilot hale gas drilling venture in Damodar basin. The company has planned to carry out exploration in basins having shale gas potential. ONGC signed an agreement with Conoco Philips in March 2012, for corporation in the exploration and development of shale gas resources in India and other regions. Under phase 1 both companies planned to explore Damodar, Cambay, Kaveri and Krishna-Godavari basins.
- OIL has hired Schlumberger to conduct feasibility study of Shale gas potential in the Assam- Arakan and Rajasthan basin.
- RIL signed three joint ventures (Chevron, Pioneer Natural Resources and Carrizo Oil & Gas) for carrying out operations in the US.
- GAIL signed an agreement with Carrizo Oil & Gas to acquire a 20% stake in Eagle Ford acreage.

2.7.6 Shale Gas Policy in India

2.7.6.1 Background

Seeing the enormous success in US, there exists an interest in exploring for shale gas domestically. The MOPNG has identified six basins that have potential of producing Shale gas. They are- Cambay, Assam-Arakan, Gondwana, Krishna Godavari, Kaveri and the Indo-Gangetic plan. During a study conducted by United States Geological Survey (USGS), it was estimated that 3 out of 26 sedimentary basin have 6.1 TCF of recoverable resources. A draft policy on exploration and exploitation of shale gas was issued on 14th October 2013.

2.7.6.2 Salient features of the policy

- The Policy guidelines for Exploration and Exploitation of Shale Gas and Oil is only for National Oil Companies (NOCs) under Nomination regime.
- The terms and conditions of the Policy will be in accordance with the permission letter issued by the Government to the concerned PEL/PML holding NOC.
- The NOC have to undertake Minimum Work Program (MWP) in some fixed timeline so that there is optimum accretion and development of Shale resources.
- Under Tax Incentives, Income tax would be payable according to Act 1961. Exemption from basic custom duty and additional duty of customs for the goods related to petroleum operations would be available for exploration and exploitation of Shale Gas & Oil. Excise duty will also be exempted as per the policy.
- The NOC would be submitting a monthly report to DGH for keeping a track of ongoing activities.
- Health, Safety and Environment, Site Restoration and adapting best industry Practice is the responsibility of the PEL/PML holder.
- Royalty, Cess and taxes for Shale Gas and Oil would be payable at par with conventional gas/oil being produced, at prevailing rate.
- A committee comprised of DG-DGH, Joint Secretary and Director of MOPNG should be there to address unforeseen circumstances caused by technical, operational or other regulatory causes that affect the timeline proposed in policy.

2.7.6.3 Assessment phase and Work Programme for Shale Gas and Oil

1. The company will be having three assessment phases of maximum period of three years. Phase-1 will start from date of receive permission to company. Phase -2 begin after expiry of Phase-1. Phase -3 after expiry of Phase-2.
2. Company shall carry out the below mentioned activities with respect to target shale section, toward assessment work program during period:
   a. Baseline Environment Impact Assessment (EIA)
   b. G&G studies
   c. Drilling of pilot well
   d. Coring, hydro-fracturing
   e. Geo-chemical studies

f. Geo-mechanical, geo-hazard

3. During assessment phase, company shall drill as committed work program, at least one pilot well in single PEL/PML block having continuous area up to 200 sq.km & two pilot well in single PEL/PML having area more than 200 sq.km.
4. Company undertakes to complete committed work program during assessment phase. In case if company fails to complete committed work program, then company shall pay to government, within 60 days end of assessment phase an amount equivalent to liquidated damages(LD) of US$ 0.25 MM per PEL/PML area. Assessment phase can extend by one year by payment of liquidated damage.
5. Withdrawal from shale gas & oil operation after G&G studies, without LD would be permitted in case assessment does not establish shale gas & oil resources. It is permitted in consultation with DGH.
6. The work program during assessment phase shall submitted to DGH for monitoring and at end of assessment phase, company shall submit a report along with data giving details of work carried out in assessment phase.
7. Upon completion of assessment phase, company shall prepare an estimate of potential production of shale gas & oil envisaged to achieve WP, and submit Field development plan (FDP) to DGH within a period of 12 months, yearly production profile with number of producing well also be submitted.
8. Upon submission of yearly production profile WP, company shall commence development activities within 6 months. In case company is unable to commence development and production operation within stipulated time period, company shall pay an amount to 1/10th royalty amount on total quantity of committed annual production to GOI.
9. Company may revise production profile, as required by the geological behavior of shale formation and such revised production profile shall be submitted to DGH.

2.7.7 Proposed Strategy for Shale Gas Exploration

2.7.7.1 unconventional hydrocarbon perspective

In the current scenario the rapidly growing energy demand worldwide and the higher depletion rates of existing reserves as compared to the discoveries are the driving factors of the huge gap in demand and supply. This has impelled the world to explore and develop unconventional source of gas. Three of the Unconventional sources of gas are Gas Hydrates, Coal Bed Methane and Shale gas. Extensive work has been done in these three fields as they have great potential. However, the technological advancements, environment advantages and gas pricing makes them attractive than oil and are termed as the energy future. With the increasing demand, high living standards, environment issues the gas is playing an important role for future purpose. Consumption of the gas will be increased and it will be the key factor in future economic performance and strategic stability of the nation.

2.7.7.2 Advantages of Shale Gas

India is an energy starved nation and it heavily relies on the imports so it becomes important to utilize the domestic oil and gas properly and efficiently including Shale gas. The access to this unconventional source of energy will not only reduce the expensive import bill but also help India to meet its Energy demand. The impact of Shale gas development can be seen through a live example which is happening in US. It increases the economic activities in the country which leads to employment and thus boosts up the government revenues. It is evident by looking at the recent development happening in Gujarat where the growth in gas infrastructure led to the applicability of gas in industrial and commercial industries.

Demand from household and automobile segment also has potential. Initial investment of extraction of Shale gas is very high and might not seem attractive or economically viable for industries like power and fertilizers. However, it is viable in case of meeting the peak and captive power units and in other sectors like transportation, refineries, steel where the substitute fuel is far more expensive.

2.7.7.3 Capabilities required to develop the domestic Shale gas

In order to produce Shale gas domestically, the country needs strong infrastructure capabilities along with a favorable policy framework that promotes the exploration and production activities along with the environment and social concern. Some of the pre requisites are:

- Supportive Regulatory Policies: Having a favorable policy structure will attract foreign investors to show interest in exploitation of Shale gas activities. Along with this a liberal fiscal regime should be considered for shale gas operations since this industry is at its nascent stage of development and the cost of operations are higher than the conventional oil and gas.

- Favorable Pricing Mechanism: In order to promote shale gas in India a proper pricing strategy shall be adopted since the initial cost of production is very high. According to IEA (The International Energy Agency) the production of shale gas is almost US $3/MMBtu and US $7/MMBtu in North America. It is analyzed that the cost of production in India will be comparatively higher in India because of geological terrain, water disposal costs, and unstructured domestic service industry. Gas processing cost and installation of Gas gathering station will also be on higher side for India. But by implementing the new advance technology the breakeven point can be reached early.

  Example: The government of Argentina has introduced a "Gas Plus" program, under which gas produced from unconventional sources can be sold at higher prices.

- Promoting development of service capabilities: The main bottleneck in preventing development of Shale gas in our country is the oilfield service sector capacity. It is one of the main challenges that is encountered.to develop the resource potential. The intensity of service level is higher than that of conventional oil and gas activities. Another drawback is the absence of critical oilfield equipment in India. Moreover, the equipment that are imported from other countries needs to be modified according to the difference in geological terrain which varies across regions. Hence exact replication of technology used by US is difficult to achieve in India.

- Awareness on Environmental concerns: Before initiating the Shale gas activities in India it is necessary that we know its adverse effects on our country. Shale gas use Hydro Fracturing technique for Shale gas production and the used water and chemicals along with that have huge impacts on the public health, drinking water and the environment. As India has scarce resources of water and in fracking huge amounts of water is required so there is a great pressure on sourcing of water and its disposal as well. Areas that are ecologically sensitive might have a public opposition on exploitation of Shale gas reserves.

- Social Concerns: In US the availability of land is not an issue, but in India where population density is high land acquisition is a big problem. The current well pad needs to be large enough so as to contain drilling rig equipment, storage tanks, pipeline infrastructure and facilities for staff. In some places Super pads should be used where the population density is high so as to reduce the usage of land. Multi well pad system enables the drilling of multiple wells from a single location due to which it will be easily acceptable by public as it will use less area although there will be an increase in operational costs.

- HR issue: There is shortage of talent in oil and gas industry due to which many projects are delayed and it also affects the performance of the producing reservoirs. According to Ernst & Young's estimates, approximately 50% of the current workforce in oil and gas industry has more than 20 years of experience and out of which majority will retire in next 5 to 10 years. Attrition levels are very high and about 5% people might quit in another 5 years. Hence there is some significant efforts to attract new talent.

2.7.7.4 Flowchart for Shale Gas E&P activity

1. **Acquisition of block**
    - Invitation to bidding for blocks
    - Award of the block
    - EIA Study
    - Environment clearances from MOEF
    - PEL
2. **Assessment phase for exploration**
    - Seek Permission to exploit Shale gas (Mining Lease)
    - Check Availability of Geologic Structure (Source Rock)
    - Seismic Survey (2D, 3D)
    - Geophysical Survey, Geochemical Survey
    - Studying of Maps- Isopach Maps
    - Resource Assessment of Area (on land or off shore)
    - Carrying out Work Program
3. **Appraisal of Well**
    - To check extent of reservoir
    - DOC (Commerciality of Discovery)
    - FDP (Field Development Plan)
4. **Development of Well**
    - Infrastructure Build up (Type of rig)
    - Set up of Water Facility for Fracking
    - Approval of CGWA (Central ground water authority) & SGWA
    - Set up for Effluent Water Treatment.
    - Gas Gathering Station
    - Laying Pipeline
5. **Drilling Activity**
    - Surface hole drilling
    - Casing and Cementing
    - Logging
6. **Well Stimulation**
    - Perforation
    - Acid/Chemical job to crack
    - Hydro Fracking
7. **Production**
    - Dewatering
    - Producing gas
8. **Well Completion**
    - Installation of Pumps
    - Valves setup

9. Site Restoration

- Removal of topsides
- Disposal of well fluid waste, chemicals
- Isolation of wells
- De-commisioning and removal of pipelines
- Removal of seabed structures

Seeing the above mentioned factors and overall scenario it is clear that Shale Gas production is time intensive activity and its development needs to be done in India as early as possible to fill the demand supply gap hence a proper planning must be done for timely extraction of recoverable resources by proposing a feasible plan that can be accomplished within a stipulated time frame.

2.7.7.5 Planned Strategy for Assessment Phase

The policy issued has three assessment phases, each of 3 years each in which a certain number of blocks will be issued to the NOCs- ONGC and OIL. We have proposed a plan that is best suited for this assessment phase to end in 3 years of timeline. The block diagram for proposed strategy for three years is mentioned below.

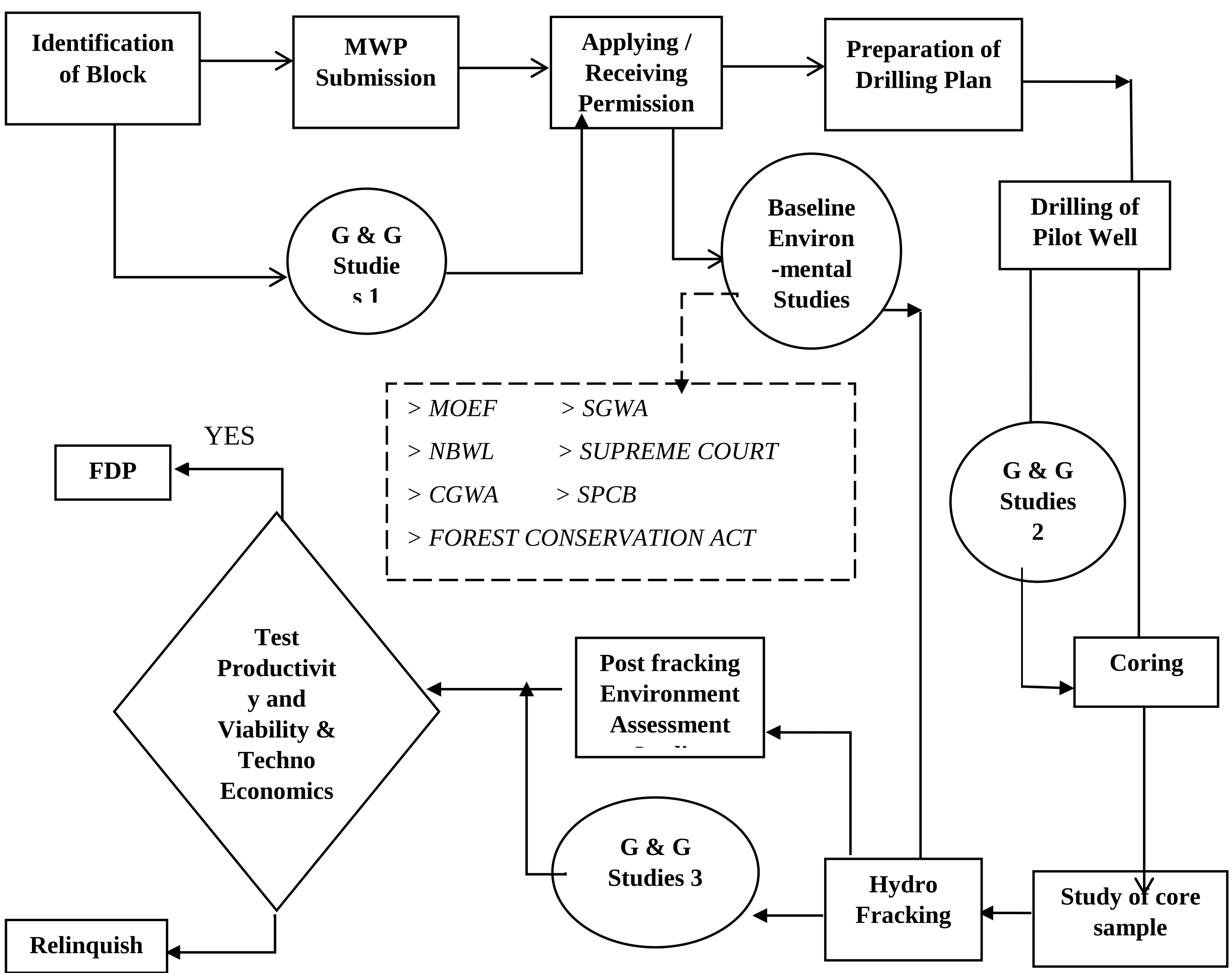


Figure 5.2 Proposed Plan for Assessment Phase-1

2.8 Project Management for Shale Gas Exploration

The project activities can be tracked and managed in several ways. One of the ways is by manually managing the project, another is by managing in excel and last one is by tracking it through Microsoft Project which is a product application sold by Microsoft.

2.8.1 Project

It is an interrelated set of tasks that have a starting point and an end point that results in the unique product or a service.

2.8.2 Project Management

It is a scientific process of planning activities that uses various resources like material, working capital, time, manpower etc. and then implementing them in an organized fashion followed by its monitoring and controlling to get maximum output.

2.8.3 Network Planning

<u>There are basic four steps to manage a project with network planning method:</u>

- Describing the project
- Diagramming the network
- Estimating the time of completion
- Monitoring the Project Progress

<u>Methods used for planning a network are:</u>

- PERT
- CPM

<u>Guidelines for making a network diagram are:</u>

- Before a start of any new activity make sure that its preceding activity is completed.
- A logical relationship between the activities is shown by arrows.
- The flow of the network diagram is from left to right.
- No intersection in between the arrows.
- The diagram should be neat and clean.

2.8.4 Critical Path Method

It is a way of arrangement of activities between a project's start and end that takes the maximum time to finish set of activities.

<u>Steps in determining Critical Path:</u>

- Specify the individual tasks.
- Determine the individual sequence of tasks.
- Draw its network diagram.

- Estimate finishing time for each activity.
- Identify the critical path.

2.8.5 PERT

A PERT chart is the graphical representation of a project's schedule that shows the sequence of tasks that can be performed simultaneously and the critical path of the project should be completed on time to meet the project's deadline. The chart has various attributes such as:

1) Total completion Time.
2) Earliest Start Time: It is the earliest time at which the activity can start when the precedent activity has already been finished.
3) Earliest Finish Time: It is equal to the ES for the activity added to the time required for finishing the activity.
4) Duration or Expected Time: The expected time required to complete an activity is the duration time.
5) Latest Finish Time: It is the latest time in which a task can be completed without any delay in the project.
6) Latest Start Time: It is equal to the LF for the activity minus the time required to finish the activity.
7) Slack Time: The difference between the earliest and the latest start time or between the earliest and latest finish time is called as the Slack time for that activity.

   "Critical Path is the path of activities that have zero slack time.

A PERT chart documents the entire project or just a phase of a project like in the case of Shale gas exploration- Assessment Phase 1. The chart allows the team to avoid unrealistic timelines and schedules and also helps to identify and shorten tasks that are bottlenecks and then to focus more attention on those tasks.

2.8.5.1 Application of PERT & CPM in Shale Gas Exploration

As PERT is primarily a project management tool, hence it is used mostly for planning and tracking entire projects for scheduling and also for following the implementation phase of a planning and improvement effort.

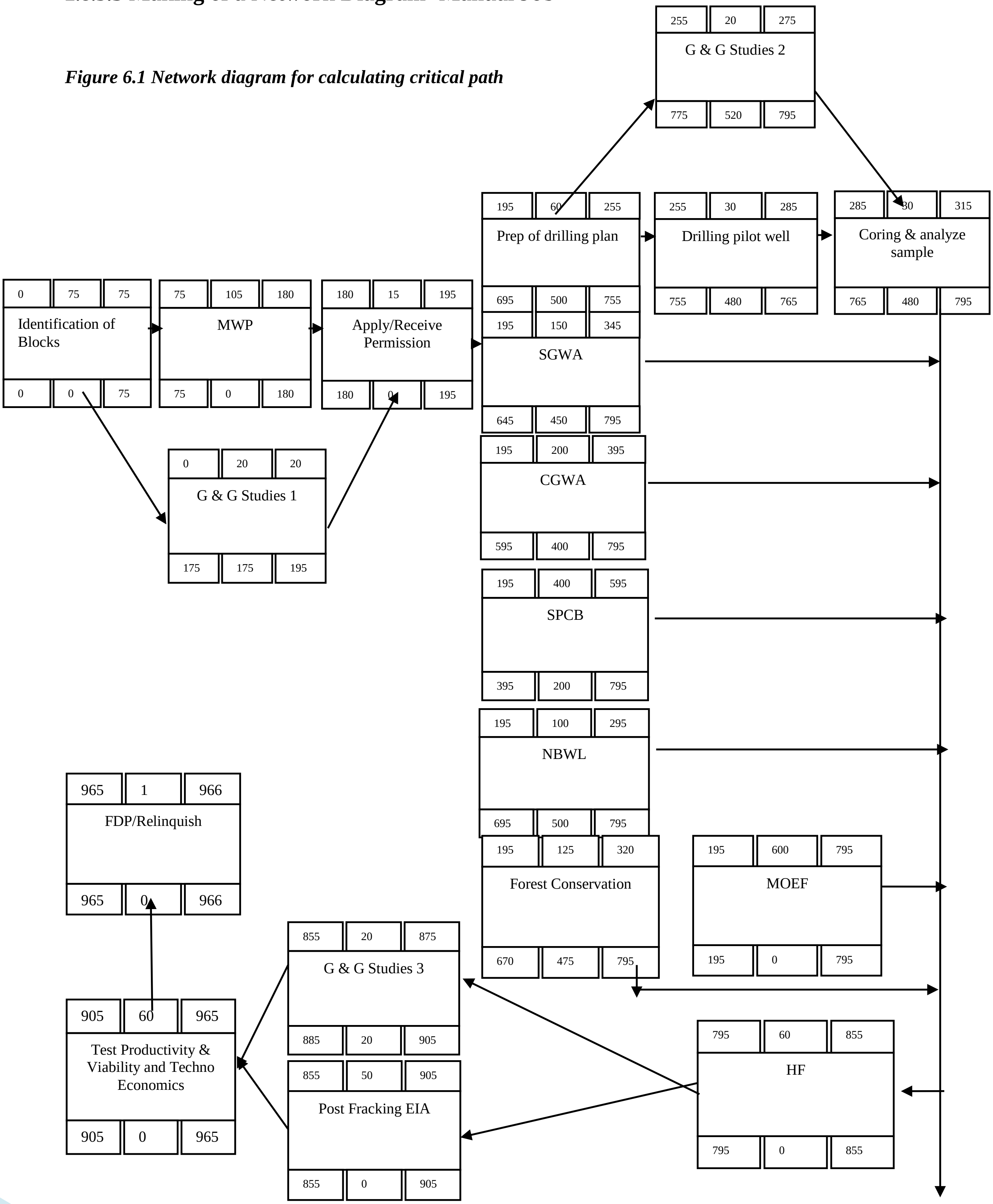
2.8.5.2 Setting up of Estimated Duration and Precedent activity

SL.No	Tasks	Days	Precedence
1	Identification of Blocks	75	-
2	G& G Studies 1	20	1
3	Minimum Work Program Submission	105	1
4	Apply/Receive Permission	15	2,3
5	Clearances from MOEF	600	4
6	SGWA	150	4
7	CGWA	200	4
8	SPCB	400	4
9	NBWL	100	4
10	Forest Conservation	125	4
11	Preparation of Drilling Plan	60	4
12	Drilling of Pilot Wells	30	11
13	G& G Studies 2	20	12
14	Coring , Study of core sample	30	12,13
15	Hydro Fracking	60	5,6,7,8,9,10,14
16	G& G Studies 3	20	15
17	Post fracking Environment Studies	50	15
18	Test Productivity & Viability and Techno Economics	60	16,17
19	Decision on FDP or Relinquish	1	18

Table 6.1 Activities with expected time and predecessors

2.8.5.3 Making of a Network Diagram- Manual Job

Figure 6.1 Network diagram for calculating critical path



2.8.5.4 Calculation of Critical Path

For calculation of critical path, the various attributes like ES, EF, LS, LF Slack, and Duration should be calculated for each activity.

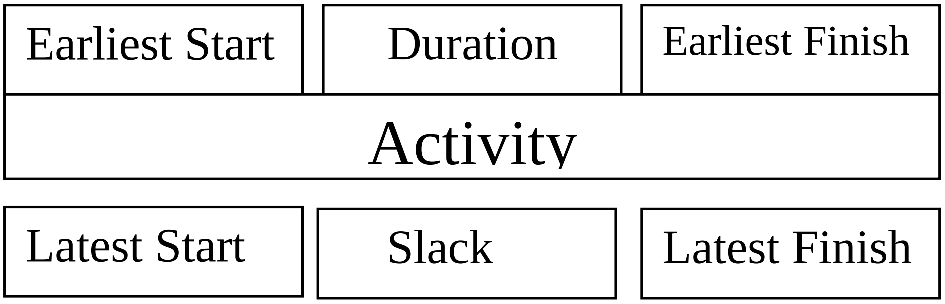


Figure 6.2 Diagram depicting blocks in network diagram

To find critical path those activities whose slack comes zero is the path that takes maximum time to get completed. (Slack= Latest Finish- Earliest Finish).

The critical path for the Shale Gas Exploration is mentioned below:

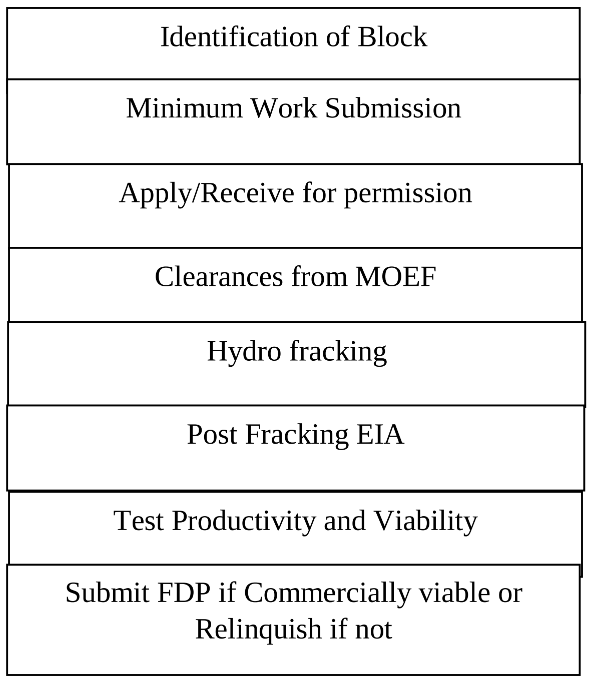
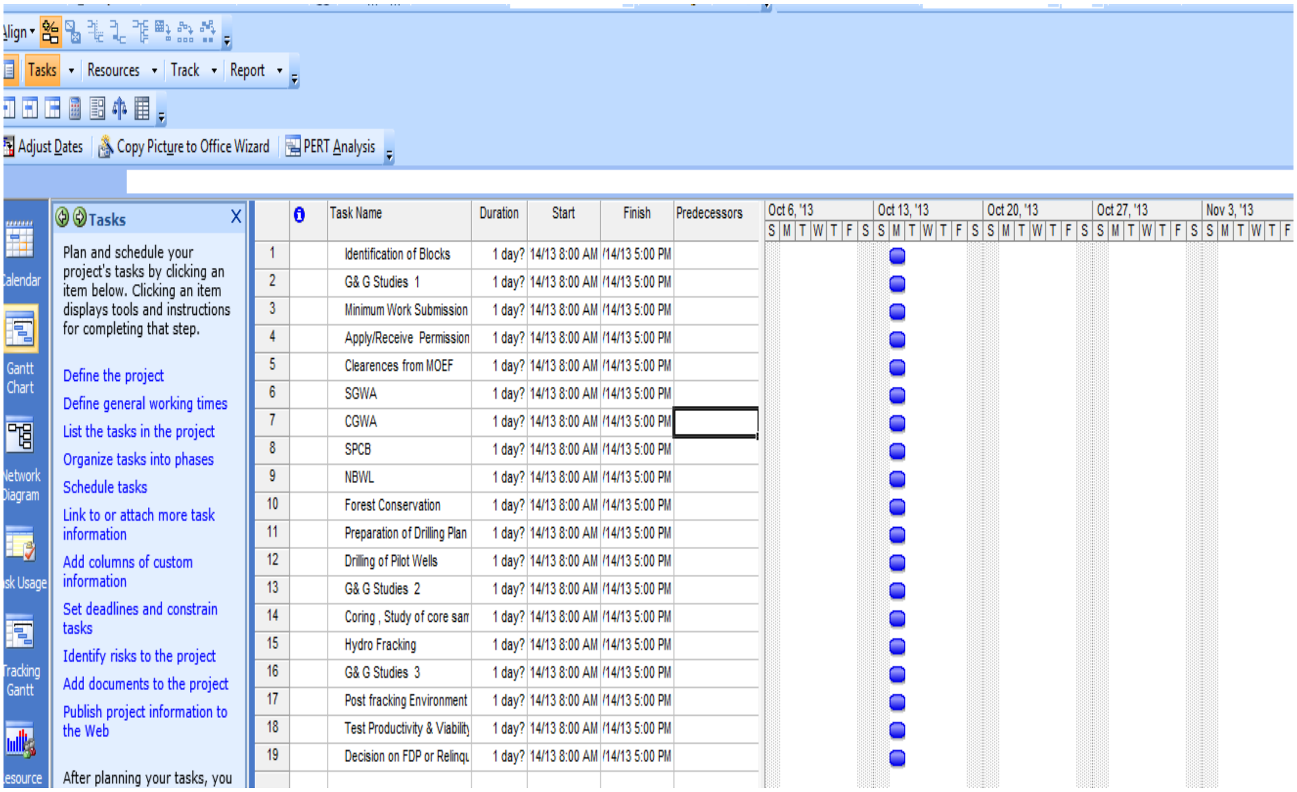


Figure 6.3 Critical Path for Shale gas activity

2.8.5.5 PERT and CPM Analysis using MS project- Automatic Job

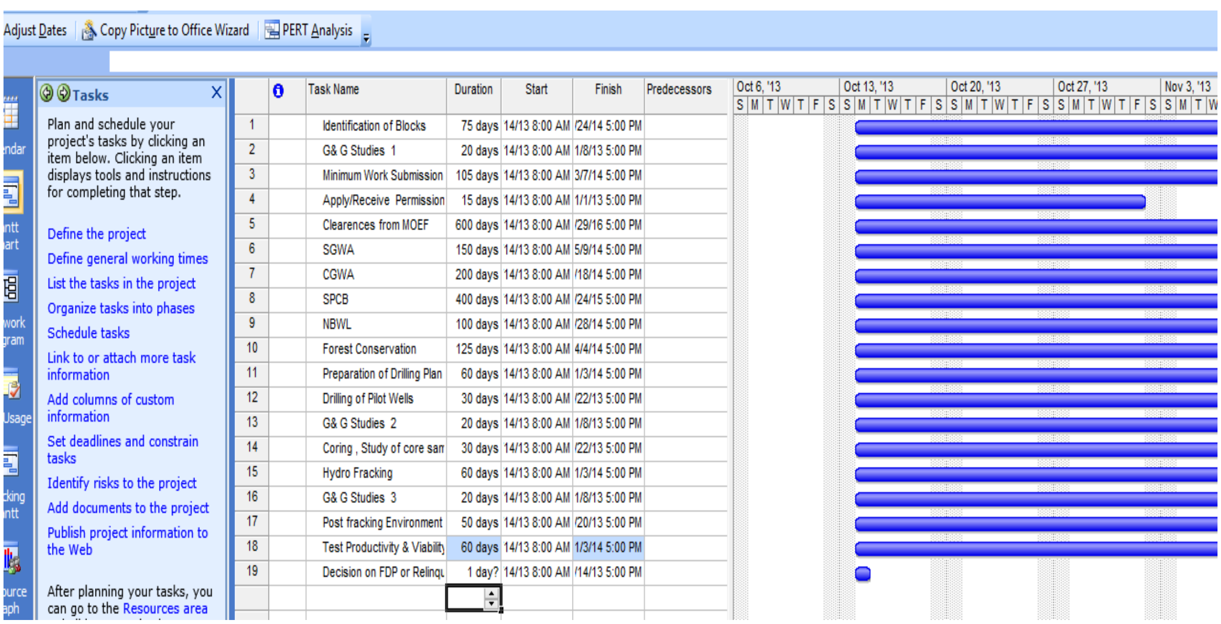
It is easy to plan a project or just a phase on MS project as tracking becomes easy. Any changes regarding manipulation in days of an activity does not required to be edited in every field, as it automatically gets updated. The visualization is proper using this tool.

Step 1: Import all the activities from Excel sheet into MS project:



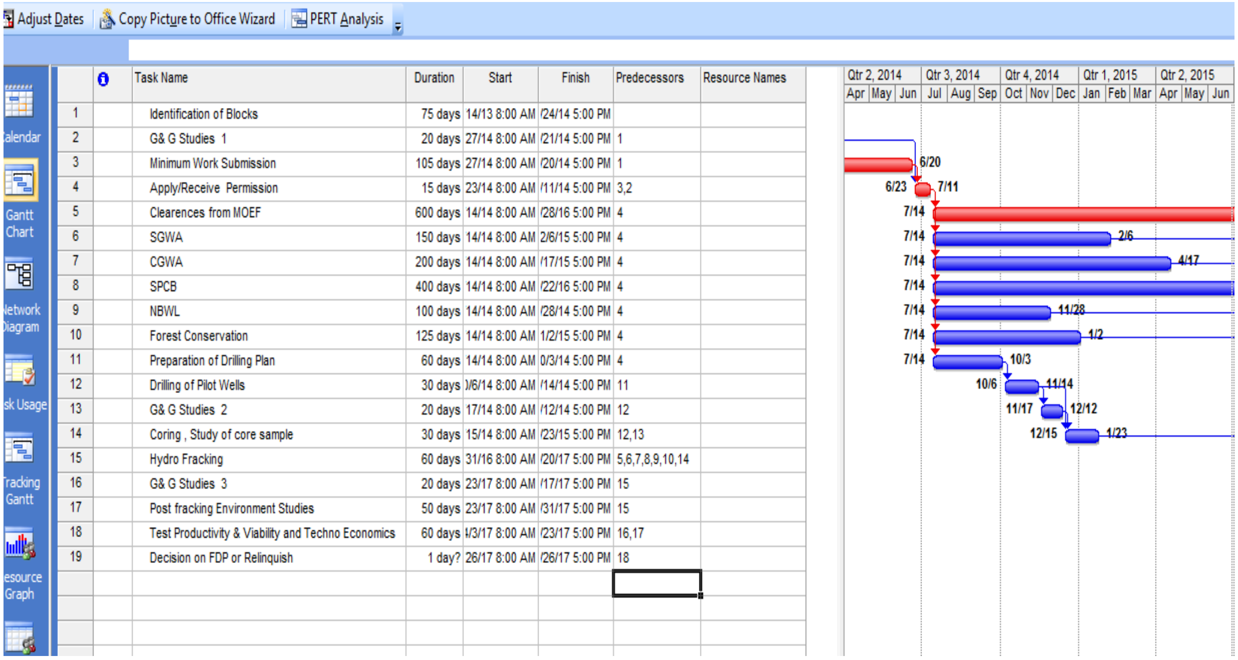
	Task Name	Duration	Start	Finish	Predecessors
1	Identification of Blocks	1 day?	14/13 8:00 AM	/14/13 5:00 PM	
2	G& G Studies 1	1 day?	14/13 8:00 AM	/14/13 5:00 PM	
3	Minimum Work Submission	1 day?	14/13 8:00 AM	/14/13 5:00 PM	
4	Apply/Receive Permission	1 day?	14/13 8:00 AM	/14/13 5:00 PM	
5	Clearences from MOEF	1 day?	14/13 8:00 AM	/14/13 5:00 PM	
6	SGWA	1 day?	14/13 8:00 AM	/14/13 5:00 PM	
7	CGWA	1 day?	14/13 8:00 AM	/14/13 5:00 PM	
8	SPCB	1 day?	14/13 8:00 AM	/14/13 5:00 PM	
9	NBWL	1 day?	14/13 8:00 AM	/14/13 5:00 PM	
10	Forest Conservation	1 day?	14/13 8:00 AM	/14/13 5:00 PM	
11	Preparation of Drilling Plan	1 day?	14/13 8:00 AM	/14/13 5:00 PM	
12	Drilling of Pilot Wells	1 day?	14/13 8:00 AM	/14/13 5:00 PM	
13	G& G Studies 2	1 day?	14/13 8:00 AM	/14/13 5:00 PM	
14	Coring , Study of core san	1 day?	14/13 8:00 AM	/14/13 5:00 PM	
15	Hydro Fracking	1 day?	14/13 8:00 AM	/14/13 5:00 PM	
16	G& G Studies 3	1 day?	14/13 8:00 AM	/14/13 5:00 PM	
17	Post fracking Environment	1 day?	14/13 8:00 AM	/14/13 5:00 PM	
18	Test Productivity & Viability	1 day?	14/13 8:00 AM	/14/13 5:00 PM	
19	Decision on FDP or Relinqu	1 day?	14/13 8:00 AM	/14/13 5:00 PM	

Step 2: Set the Expected Duration of each activity:



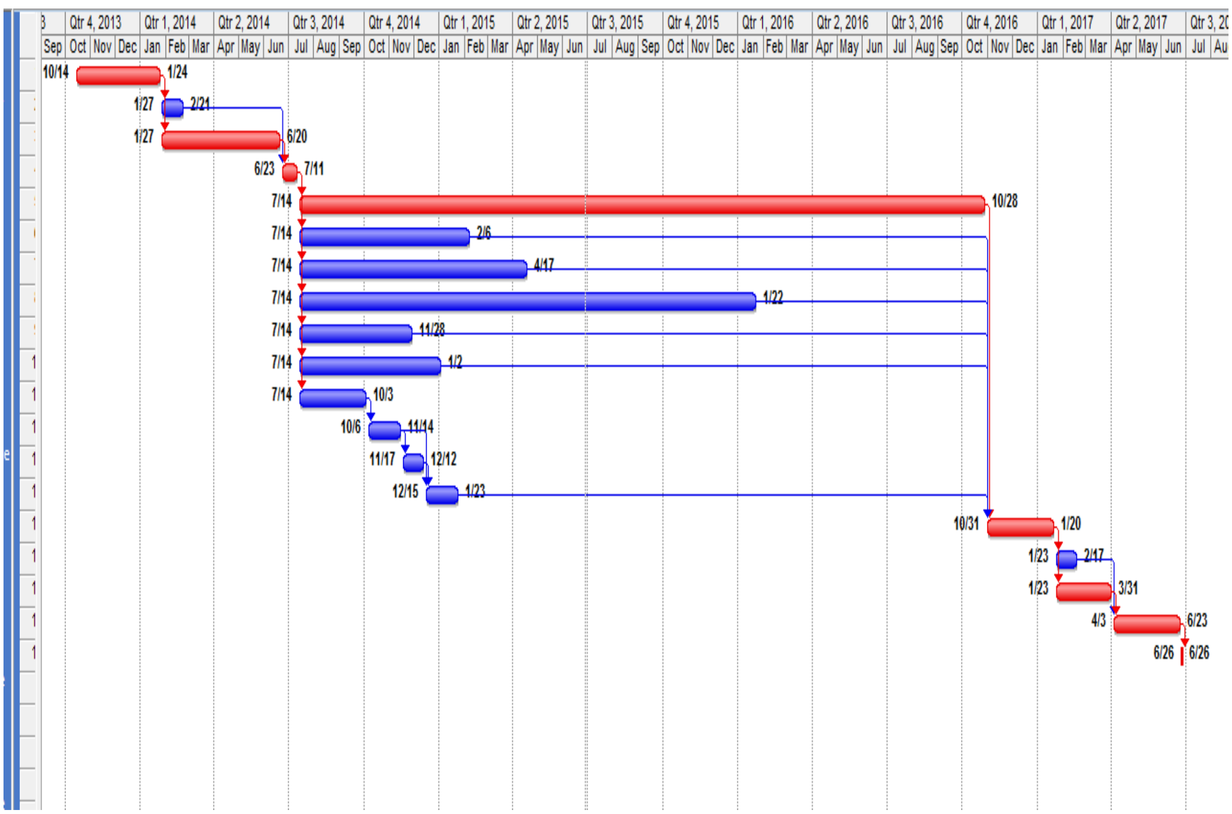
	Task Name	Duration	Start	Finish	Predecessors
1	Identification of Blocks	75 days	14/13 8:00 AM	/24/14 5:00 PM	
2	G& G Studies 1	20 days	14/13 8:00 AM	1/8/13 5:00 PM	
3	Minimum Work Submission	105 days	14/13 8:00 AM	3/7/14 5:00 PM	
4	Apply/Receive Permission	15 days	14/13 8:00 AM	1/1/13 5:00 PM	
5	Clearences from MOEF	600 days	14/13 8:00 AM	/29/16 5:00 PM	
6	SGWA	150 days	14/13 8:00 AM	5/9/14 5:00 PM	
7	CGWA	200 days	14/13 8:00 AM	/18/14 5:00 PM	
8	SPCB	400 days	14/13 8:00 AM	/24/15 5:00 PM	
9	NBWL	100 days	14/13 8:00 AM	/28/14 5:00 PM	
10	Forest Conservation	125 days	14/13 8:00 AM	4/4/14 5:00 PM	
11	Preparation of Drilling Plan	60 days	14/13 8:00 AM	1/3/14 5:00 PM	
12	Drilling of Pilot Wells	30 days	14/13 8:00 AM	/22/13 5:00 PM	
13	G& G Studies 2	20 days	14/13 8:00 AM	1/8/13 5:00 PM	
14	Coring , Study of core san	30 days	14/13 8:00 AM	/22/13 5:00 PM	
15	Hydro Fracking	60 days	14/13 8:00 AM	1/3/14 5:00 PM	
16	G& G Studies 3	20 days	14/13 8:00 AM	1/8/13 5:00 PM	
17	Post fracking Environment	50 days	14/13 8:00 AM	/20/13 5:00 PM	
18	Test Productivity & Viability	60 days	14/13 8:00 AM	1/3/14 5:00 PM	
19	Decision on FDP or Relinqu	1 day?	14/13 8:00 AM	/14/13 5:00 PM	

Step 3: Set the predecessors according to the plan suggested:

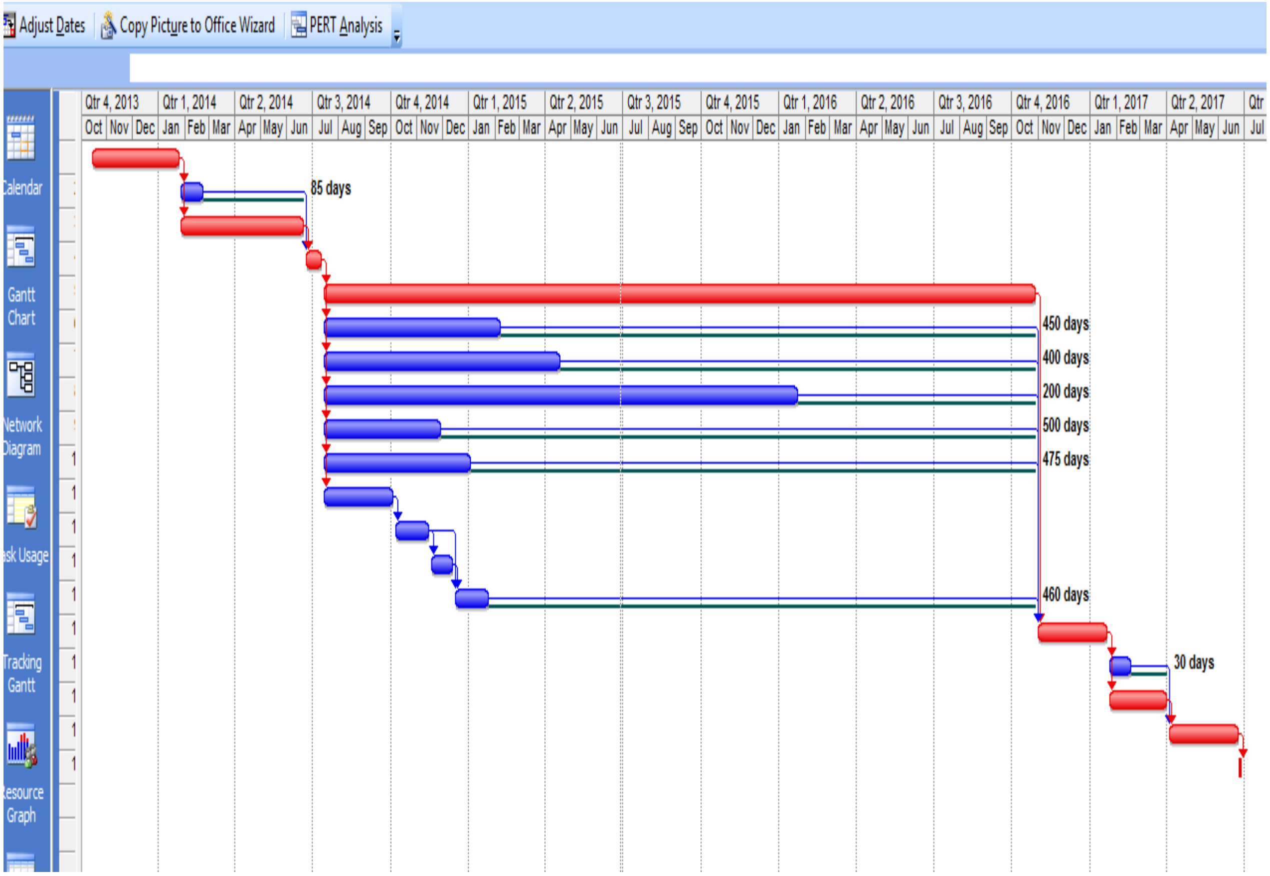


	Task Name	Duration	Start	Finish	Predecessors	Resource Names
1	Identification of Blocks	75 days	14/13 8:00 AM	/24/14 5:00 PM		
2	G& G Studies 1	20 days	27/14 8:00 AM	/21/14 5:00 PM	1	
3	Minimum Work Submission	105 days	27/14 8:00 AM	/20/14 5:00 PM	1	
4	Apply/Receive Permission	15 days	23/14 8:00 AM	/11/14 5:00 PM	3,2	
5	Clearences from MOEF	600 days	14/14 8:00 AM	/28/16 5:00 PM	4	
6	SGWA	150 days	14/14 8:00 AM	2/6/15 5:00 PM	4	
7	CGWA	200 days	14/14 8:00 AM	/17/15 5:00 PM	4	
8	SPCB	400 days	14/14 8:00 AM	/22/16 5:00 PM	4	
9	NBWL	100 days	14/14 8:00 AM	/28/14 5:00 PM	4	
10	Forest Conservation	125 days	14/14 8:00 AM	1/2/15 5:00 PM	4	
11	Preparation of Drilling Plan	60 days	14/14 8:00 AM	0/3/14 5:00 PM	4	
12	Drilling of Pilot Wells	30 days	)/6/14 8:00 AM	/14/14 5:00 PM	11	
13	G& G Studies 2	20 days	17/14 8:00 AM	/12/14 5:00 PM	12	
14	Coring , Study of core sample	30 days	15/14 8:00 AM	/23/15 5:00 PM	12,13	
15	Hydro Fracking	60 days	31/16 8:00 AM	/20/17 5:00 PM	5,6,7,8,9,10,14	
16	G& G Studies 3	20 days	23/17 8:00 AM	/17/17 5:00 PM	15	
17	Post fracking Environment Studies	50 days	23/17 8:00 AM	/31/17 5:00 PM	15	
18	Test Productivity & Viability and Techno Economics	60 days	4/3/17 8:00 AM	/23/17 5:00 PM	16,17	
19	Decision on FDP or Relinquish	1 day?	26/17 8:00 AM	/26/17 5:00 PM	18	

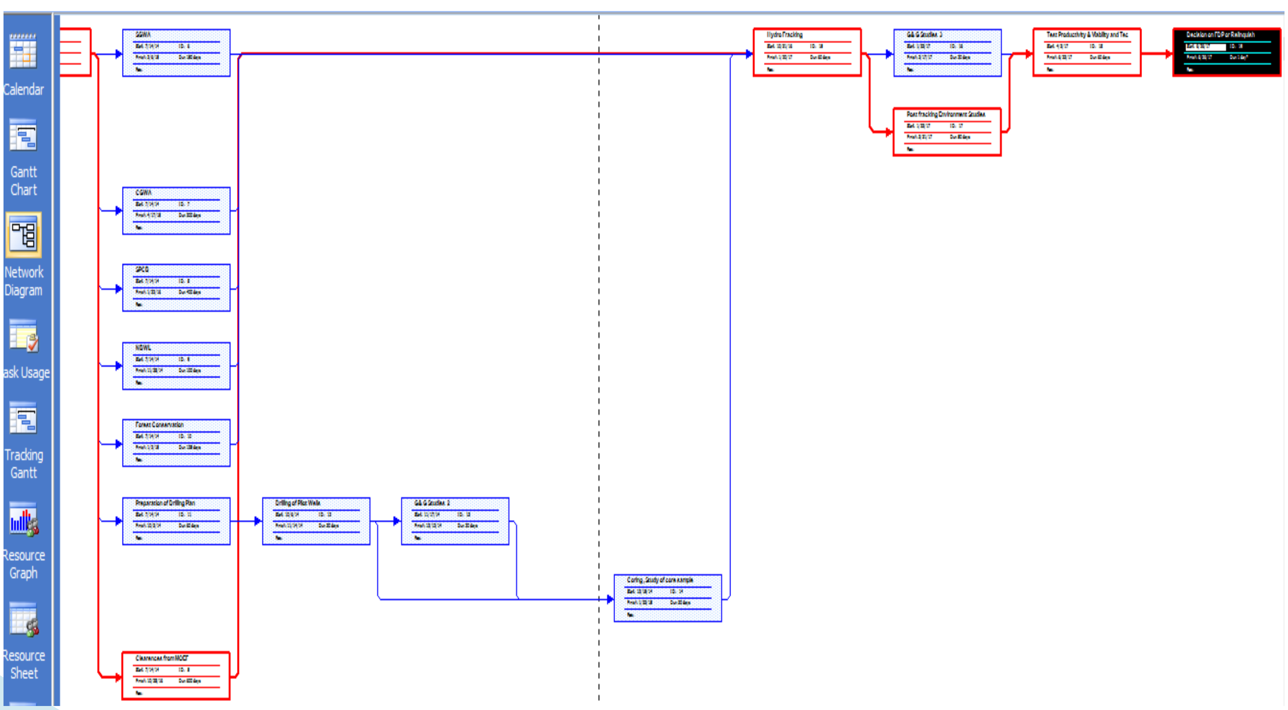
Step 4: Click on Gantt Wizard and set the attributes to view Chart according to your specifications:



Step 5: To see detailed Gantt Chat go on more views:



Step 6: View on Network Diagram and the critical path can be seen through this, which is highlighted in red.



2.9.1 Expenditure till date on various shale blocks by ONGC

Sl No	Basin	Block Name	TD (m)	Main objective	Approx. Cost (Rs. Crs)
1	Cambay	Gandhar Ext-III	4000	Cambay Shale	40
2	Cambay	Gandhar Ext-V	3800	Cambay Shale	38
3	Cambay	Gandhar Ext-VII	3800	Cambay Shale	38
4	Cambay	Gandhar Ext-IX	4000	Cambay Shale	40
5	Cambay	Pakhajan Ext-II	4500	Cambay Shale	42
6	Cambay	Nawagam	2700	Cambay Shale	27
7	Cambay	Nandej East	2300	Cambay Shale	23
8	Cambay	Paliyad – Kalol	2800	Cambay Shale	28
9	Cambay	Kalol W Ext-I	3200	Cambay Shale	32
10	Cambay	Jotana Warosan	2800	Cambay Shale	28
11	Cambay	Nandasan Langhnaj	3000	Cambay Shale	30
12	KG	W Godavari	3300	Raghavapuram/Kommugudem	35
13	KG	Mahadevapatnam	4300	Raghavapuram/Kommugudem	46
14	KG	Bantumilli Ext.	4200	Raghavapuram/Kommugudem	45
15	KG	Mandapeta	4000	Raghavapuram/Kommugudem	44
16	KG	Suryaraopeta	4400	Raghavapuram/Kommugudem	47
17	Cauvery	Kuthalam	3200	Andimadam/Sattapadi	32

2.9.2 Shale gas in India future efforts and suggestions:

- It is clearly visible through the network diagram that the most time taking activity (critical path) is the Clearances required from various government agencies, which is a legislative issue and is a hindrance in completing the project within stipulated timeframes.

  Suggestion: Prior Clearances/One-time clearance should be granted by the government bodies as soon as the blocks are identified for auction. This will reduce the number of days spent in seeking clearances for commencement of exploratory activities. Deep study of the area should be done by hiring best consultants which certifies the true information which would in turn create a transparency between DGH & the contractor company.

- Inordinate delay has been observed in granting clearances from MOEF/State Pollution Control Board/State Government. Apart from complicacy of select issues, the delay may be attributed to anachronistic and redundant paper works and routine file movements amidst departments.

  Suggestions: MIS (Management Information System) should be adopted by government agencies for effective handling and management of files/documents.

- India is deficient in potable water supply, Hydraulic Fracture of shale gas reservoirs requires huge volumes of water and may result in depletion of ground water/contamination of nearby water resources.

  Suggestions: It is felt prudent to first make a plan and take various clearances that are time taking and check the viability in terms of sourcing water. This should be done at the initial stage at the time of seeking clearances, just after the issue of policy.

- Lack of information regarding the blocks.

  Suggestions: Availability of geological data regarding the identified blocks should be freely available so that the operator company has information regarding each well and can plan out its drilling activity to commercially produce the well in an effective manner.

- The Assessment phase that is for 3 years should be properly managed and a strategic plan must be made for the completion of project on time.

  Suggestions: Management of the project can be done either in excel or in MS project but as we have compared both of them and found that MS project is time saving, more organized, proper visualization, easy tracking and its dynamic nature in making any changes makes it attractive and feasible for such projects.

3. Research Methodology:

3.1Type of Research

It's a **descriptive and analytical** research as it includes surveys and fact-finding enquiries of different kinds of energy consumption pattern of different fuels is observed and analyzed. Industrial, Domestic etc.

3.1.2 Research Process

As limited historical data is available with us, main focus was on collecting the Primary data from survey reports and from industries, commercial consumers, transport agencies and third party publishers etc. Collected data will be analyzed to reach to a conclusion.

3.1.3 Research Problem

- To identify porter's five forces model on shale gas production
- To mapping potential shale gas exploration reserves

3.1.4 Research Surveys (Primary Data*):*

Surveys represent one of the most common types of quantitative, social science research. In survey research, the researcher selects a sample of respondents from a population and administers a standardized questionnaire to them. The questionnaire, or survey, can be a written document that is completed by the person being surveyed, an online questionnaire, a face-to-face interview, or a telephone interview. Using surveys, it is possible to collect data from large or small populations. Research surveys played the role of primary data. The surveys were conducted to be prepared for the purpose. The survey included the specified set of the area for conclusion to a particular result. The overall evaluation based on the data collected was then, properly arranged and analyzed with the help of questionnaire. The purpose of the collection of the primary data was to analyze the fulfilling conditions of the checking the feasibility of shale gas production in few selected areas in India. In order to get the complete analysis of the actual scenario of present demand scenario and level of awareness among the people, the most appropriate source of primary data seemed to be survey of Industries, industry leader for Industrial sector and Transport unions, hotel and restaurants and household. The prime concern was to know the cost effectiveness of this project, how this will benefit consumers of various sector financially. Apart from that, various other factors led to the decision of beholding survey as the positive measure of data:

- The awareness of cost effectiveness of using shale gas
- The data of current shale gas exploration and natural gas consumption pattern can be precisely estimated
- Primary data and articles are the most authoritative method of data collection.
- We wanted to demonstrate the primary data results and to analyze the reports, with reports and other collected data, the results were automatically sorted out for comparison.

Thus, the purpose of actual analysis of the feasibility study of shale gas exploration in those selected locations were comfortably completed by questionnaire survey.

3.1.5 Data Collection (Secondary Data):

Data collection is the process of gathering and measuring information on variables of interest, in an established systematic fashion that enables one to answer stated research questions, test hypotheses, and evaluate outcomes. The data collection component of research is common to all fields of study including physical and social sciences, humanities, business, etc. While methods vary by discipline, the emphasis on ensuring accurate and honest collection remains the same.

The secondary data collection included the task of collection of the previous researches' data. It required the thorough study and analysis of the previous research and work on this field or related field. The main task included the sorting and selection procedure of the relevant data that seemed useful for the project. Moreover, the secondary data also facilitated the comparison of our method with the previous methods. The secondary data was analyzed and arranged in order to establish a correct relevance with the project.

3.2. Porter's contribution to industry competition

In 1980, Michael Porter introduced a model of competitive strategy to explain an industry's position in a complex strategic environment. Porter's five forces model provides one way to present the current position of the SG industry which is called the potential stocks in the energy sources. The five forces presented in this model are the supplier power, the buyer power, the entry barriers to entry, the threat of substitution and the degree of rivalry. Placing the industry of SG in a framework offers a unique insight into the bargaining position.

3.2.1. Force 1: Supplier power

The power of suppliers refers to the ability of bargaining power and controlling power of resources.

3.2.1.1 Tendering and Bidding

This paper analyzes the main differences of tendering and bidding of SG exploitation rights in 2011 and 2012. It can reflect the situation of supplier power. The number of tendering blocks is considered as 4 in initial phases. State-owned enterprises are only allowed to participate in exploration activities of shale gas for the first tendering in 2012 according to shale gas policy of India. The main reasons of this allocation restrictions phenomenon are immature technology and huge investment risk. Unforeseen costs may continue arise because of immature technology. And the investment income has big uncertainties. Therefore, these enterprises generally tend to wait technology development and cost reduction. If the technology is matured or there is a successful case in India as with US, they may accelerate their investments. Even after bidding notifications advertised worldwide there is no positive response from foreign multinational oil company. Even there are no significant efforts from both domestic exploration companies and other MNC's for possible joint venture for sharing resources and technology required for shale exploration in India.

3.2.1.2 Policy and regulations with respect to supplier

India's constitution stipulates that land and the underground resources are owned by the Central authority. Therefore, SG resources as the national resources belong to the country. Enterprise just can obtain the mining right through bidding and tendering. Therefore, SG suppliers are affected by the Indian government policy greatly. If enterprises want to enter SG industry, they should have strong capital or technological strength and be recognized by government.

3.2.2. Force 2: Buyer power

Buyers can threaten the industry by bargaining down prices or raising the costs by demanding better quality.

Initial news of a possible Compensated Transfer Mechanism will come after effectively 25 years as per shale gas policy, in order to reduce risk of winning enterprises. In other words, government tries to help enterprises to do some primary works for sharing the risk of SG exploitation. Then enterprises repay relative exploitation cost to the government with no taxes and royalties are applicable for 25 years. In details, the government will do the preliminary seismic and drilling exploitation to confirm gas reserves and relative data. The enterprises will repay the cost to the government in production phase which is 7 years after the completion of actual 25 years of exploration phase which is maximum period subject to discovery and production in economy of scale. The competitors in SG investment have changed with development of national policies to develop shale gas business. That private and foreign enterprises may begin to enter this industry makes the SG market more competitive. In the traditional model of pure competition, additional players will enter the market until the profits are nominal and the risk is predicable, unless there are specific barriers to entry. The most obvious barriers to entry may be technology, policy and financial barriers.

Year	*SG Block*	*State- owned enterprises*	*Private enterprises*	*Ratio of state-owned enterprises*	*Ratio of Private-enterprise%*
2012	*4*	*2*	*0*	*100%*	*100%*

3.2.3. Force 3: Barriers to entry

New competitors may trigger fierce market competition. Fierce market competition may decrease profit level or endanger some enterprises' survival.

3.2.3.1. Technology barrier

At present, the biggest developing barrier of SG in India is technology barrier. SG industry in India is just getting started nearly eighty years later than United States. India is lack of own proprietary exploitation technologies, like hydraulic fracture and the formulas of drilling fluid. Furthermore, it is difficult to use overseas technologies without improved because of the subsurface structure and burial depth in India. Therefore, the technology barriers limit the entrance of enterprises. It is believed that Shale releases fewer greenhouse gases (GHG) which has a global warming effect on the environment. Some basic challenges are:

- Gas in place
- The permeability of the matrix
- Determination of the intervals to frack or drill horizontal well
- Prediction of the production rates
- Prediction of the decline rates
- Screening Exploration targets

3.2.3.2. Policy barrier

Policy is a very powerful force to limit enterprises to enter this industry, seeing government policy results in 2012. In addition, the mining rights of conventional oil and gas is usually about 10 years in US, however, the SG exploitation rights in India is for 25 years. In other words, if the enterprises will easily complete the contracted exploitation within 25 years as financial or technical problems, government may loosen up further policy barriers in the exploitation. It means that the hefty upfront investments will not go into trash. Therefore, the enterprises should continue investment and exploitation every year. The policy will reduce the enterprises' risk undoubtedly.

3.2.3.3. Financial barrier

The financial barrier is the third kind of barriers. India's SG industry has been invested more than 600 crores rupees. In total 40 vertical wells and 20 horizontal wells are drilled. It is still miles off being commercial production. However, the existed SG subsidy policies are all based on the gas production. If there is no gas production, the enterprises will not receive any subsidy. So the enterprises need longer time to withdraw the capital investment. The economic risk is medium with respect to policy. Furthermore, the market withdrawal mechanism is formed in policy of India itself. The shale gas allotted enterprises cannot transfer the rights to other enterprises. It is different from the policies of United States, which can sell the SG exploitation rights for recovery the cost rapidly.

The Indian government is in steady way approach for exploring effective withdrawal mechanism, but the implementation of this policy still needs time. Fortunately, it will attract more capital to get into SG industry and decrease financial barrier as the government subsidies. The SG enterprises can receive subsidies from both central government and local government in India in terms of taxes and other relaxations. Central government gives subsidies to SG enterprises as much as 1-2.3 Rs. /m3 (almost 12-15% /m3). In order to elaborate the supportive efforts of government, we compare the subsidy policies of SG and coal-bed methane (CBM). The central government's subsidy of SG in India will definitely higher than the subsidy of CBM, due high investment cost. However, the technology of CBM is fairly mature and the productivity is higher than shale gas. Enterprises of CBM have much easier to obtain subsidies. From subsidies comparison, SG industry is given more subsidy than CBM through fiscal or tax favorable policies.

3.2.3.4 Cost of field development operations

Cost of drilling and completion is 5 times lesser in USA and Canada than the similar operations carried out in Asian countries which may be due to lack in infrastructure or government support in terms of subsidy.

3.2.3.5 Lack of fiscal incentives and infrastructure

This is not a challenge in USA or Canada but for other countries it is still a challenge.

3.2.3.6 Lack of specific information regarding wellbore

Unlike USA who has disclosed significant information about each wellbore which is readily available on public access database. Hence it is possible for operators to make a comparative analysis for large number of wells in same formation. In Asian countries due to lack of information about specific wells it becomes hard to make a good analysis for efficiently exploiting resources.

3.2.3.7 Political Issues

Every country has their own set of rules and regulations. Some of the reasons why projects are cancelled or delayed are corruption, political instability, regulatory framework, bureaucracy. These are the prime reasons for a project's success or failure.

3.2.3.8 Competition from alternative resources

Companies that are into shale gas projects faces huge competition from the existing companies that are serving the same purpose of providing gas. They also are in the competition with the gas rich countries that have monopoly in the market.

3.2.3.9 Sourcing of Water

Huge volumes of water is required to hydraulically fracture a well. During the early stages of Shale gas operations, large quantities of water is used to fracture the well which is extracted from surface or groundwater resources. The extraction and disposal of water is a big challenge and should be maintained within regulatory processes including aquifer management plan.

3.2.4. Force 4: Threat of substitutes

The threat that substitute products pose to an industry's profitability depends on the relative price-to-performance ratios of the different types of products or services to which customers can turn to satisfy the same basic need

3.2.4.a Threat of substitution of conventional resources

3.2.4.a.1 Coal

India has more than 260 billion tonnes of coal reserves with current mine ability (ratio of technically possible exploration reserves to proven reserves) 34.6%. However, the annual production is 582 million tonnes annually. Most of the coal having calorific value 3200-3500 kcal and majorly used in production of power. Out of the total 268 GW of installed power generation capacity, 63.05% of generation is based on coal based power generation. Indian government's positive efforts of coal exploration lead to annual production in 2037 will be almost double to its current production which will be 866 million tonnes. Due to enormous availability of coal and better policy efforts coal will be still leading energy resource for India till 2030.

3.2.4.a.2 Crude Oil

Currently, India has 3.14 lakh square km. of geological area unexplored which consist of 26 basins with natural reserves as oil and gas present in that area. With 1.3 lakh square km. of area is offshore and 1.84 lakh square km. of area is onshore, 96% of total area still has to be explored. India's policy restrictions, tax regime and delay in bureaucracy decisions are the main reasons for less participation of foreign MNC's in Indian exploration of crude oil. The current exploration efforts lead to reach production level of 897 thousand barrels per day and still importing 4.19 million barrels per day. But 12th five-year plan of India makes efforts to reach the production levels 952 thousand barrels till 2017. The maximum use of refinery product in India is diesel which has 1 GW of installed capacity which runs under 60% of plant load factor production of electricity. Even after these efforts crude oil still considers as best alternative for coal in the future.

Since we need to analyze the relationship of energy resource replacement between final production of SG and the other energy productivity, we analyze the threat of substitution as follows:

3.2.4.1. Wind power

Wind power has developed quickly in India. Its capacity is near security capacity that the grid can accommodate. And wind power is mainly used for adjusting the peak-load of electricity. So the wind power can substitute the SG in power generating part. The other functions of SG cannot be substituted by wind power. Furthermore, natural gas is easier to use for power plants. And the peak adjustment of wind power needs reasonable scheduling of grid.

3.2.4.2. Solar power

The installed capacity of solar power is still small in India. It can replace the gas for power generation in a certain extent. Some small capacity of solar equipment, such as solar-home- system and solar car, can partly replace urban gas. But most people will choose to natural gas at present as limited by the installed capacity and cost of solar power. But in India huge capital is required to established power plants for electricity generation. The capital expenditure required to replace natural gas with solar is 1:5. In other words, it will cost 4000 crores to setup 5MW power plant based on natural gas but it will cost almost 20000 crores to setup solar power plant with same capacity.

3.2.4.3. Nuclear power

Nuclear power is an important energy to instead of coal. However, the safety of nuclear power is questioned all over the world after the radiation leak issue at the Fukushima Daiichi nuclear plant in Japan. Many countries stopped the development plans of nuclear power. Therefore, nuclear power will pose no threat to gas market recently. If the government vigorously promotes the development of nuclear energy in the future, it will form strong substitute of natural gas that is used as electricity and urban gas (if the price of electricity is lower than the price actually quoted through natural gas.). Even if this is scenario, nuclear based power generation plants contributes to 6GW of installed capacity and growth is much lower than other power plants installation capacity.

3.2.5. Force 5: Degree of rivalry

Intense rivalry among established companies constitutes a strong threat of profit-ability. Indian gas resource is monopolized by few large state-owned enterprises. Before 2013, natural gas market share was held by four gigantic enterprises: ONGC accounting for about 40%, OIL accounting for about 10%, RIL and ESSAR are the rest. But from the perspective of the change of bidding policies, the government may be more willing to break the monopoly.

3.3 SWOT analysis for shale gas

Internal	
Strength	**Weakness**
• Greener and cleaner fuel	• Required integrated planning and operational control
• Cost efficient	• High initial cost
• Safer and Cheaper	• High risk
• Single long term investment	• Lack of infrastructure and technologies
External	
Opportunities	**Threats**
• Replacement of conventional natural gas	• Low participation of foreign entities
• Help to reduce burden of imports	• Strict environmental policies
• Best replacement of coal in power generation	• Delay in permissions and authorizations by bureaucrats
• High returns	• Strict policies towards end sale prices

4. Conclusion

Rich SG reserves in India possible replace dominance of coal as a primary fuel for India effectively. This also help to reduce environmental risk and reduction of carbon footprints for long term environment sustainability. Indian presence of largest energy importer and the dependence on imported energy, may decrease the risk of energy and secured long term energy supply. The SG industry analyzed by five forces model of porter's clearly focuses on SG suppliers, which are in an unreliable financial and economic position in the current SG market of India. This paper analyzes the SG industry in India from five important aspects: supplier power, buyer power, barriers to entry, threat of substitution and degree of rivalry. Primary factors that will influence the SG industry in the future are:

a) Technology:
With new and efficient evolving technology help industry to attract more for exploration and exploitation of shale reserves.

b) Policy:
Efficient, business friendly and growth prospective policy enable foreign and private players to enter into Indian market.

c) Economic:
High initial investment is necessary for enter into market. With joint venture with US based companies and 100% allowable FDI help shale exploration for long term commitment with the industry

d) Risk elements:
Since Oil and gas business in high risk and high return business being into industry will increase potential for new entrants in domestic market.

SG competition will be obviously changed with following factors:

- The competition is becoming more aggressive after the government permits private companies to enter the SG industry in 2014.
- As a buyer proportion of electricity and urban gas consumers is increasing gradually, and the other parts are declining steadily. Buyers are mostly influenced by market price of sellable natural gas.
- The government allows national, public and private companies to get the block for exploration and exploitation, the technology, policy, human resource and capital barriers are major existing barriers in SG market.
- The SG has a substitution effect on the coal and oil. Wind, solar and nuclear energies may replace small parts of power-generating gas but required five folds' initial capital as investment with respect to conventional gas based plants. If the government would take harsh step on the development steps of isolated natural gas based power plant with imported natural gas as LNG, it will become a threat to SG industry as an effective substitution. This study further illustrates the influence trends from various forces in five forces model based on competitive situation of SG industry at current stage, then an experience judge of SG industry is given in this study based on actual situation and information.

The development suggestions of SG industry according to the results.

(1) Aggressive policy:

The strong policy includes making of development planning and higher reasonable subsidies to exploration companies with higher tax realization. Government should scientifically evaluate and analyze SG resource potential to make long-term development planning that will benefit for expansion of industry. The reasonable subsidy policy also can ensure the development of SG industry.

(2) Increase input of fracking and newly developed technology research:

India should make some efforts towards strong international supports to strengthen international communication and cooperation to introduce more advanced technologies. It also needs strong infrastructure support for research of the SG drilling technology to meet the special geological conditions in India. Also, environment and natural calamity scenario, such as water protection with earthquake and flood prevention, should be considered. The emergency response system should be present to stop pollution needs to be made before SG exploitation.

(3) Accumulation of knowledge and technology experienced should be preserved:

The government should pay attention to make relevant efforts for technical standards and knowledge has to be preserved as soon as possible. E&P companies should make efforts to accumulate the management experience of exploitation and operation to reduce time in decision making and monetary losses.

(4) Reduction in production cost

Since the projects required high capital expenditure, during the exploitation process, the expenditure required for exploration should be carefully analyzed. The subsequent efforts should be made to reduce high cost of exploration through technical and management improvement. This might result in higher profitability and IRR

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Annexure-1

List of Additives used in Hydraulic Fracturing

Sr. No.	Additive Type	Main Compound(s)	Purpose	General Use
1	Diluted Acid	Hydrochloric Acid and Muriatic Acid	Help dissolve minerals and initiate cracks in the rock	Used to pickle steel
2	Biocide	Glutaraldehyde	Eliminates bacteria in the water that produce corrosive by products	Used in Cosmetics
3	Breaker	Ammonium persulfate	Allows a delayed breakdown of the gel polymer chain	Radical Initiator in polymerization of alkenes
4	Corrosion Inhibitor	N, n-Dimethyl Formamide	Prevents the corrosion of pipe	Used in production of Plastics
5	Cross linker	Borate Salts	Maintains fluid viscosity as temperature increase	Used in making borosilicate glass
6	Friction Reducer	Polyacrylamide Mineral Oil	Minimizes the friction between the fluid and the pipe	Used in Paper making and screen printing
7	Gel	Guar Gum or Hydro ethyl	Thickens the water in order to suspend the sand	Textile, paper, explosive pharmaceutical industry
8	Iron Control	Citric Acid	Prevents Precipitation of metal Oxides	Used as Chelating and cleaning agent
9	KCl	Potassium Chloride	Creates a brine carrier fluid	Used for agricultural purpose
10	Oxygen Scavenger	Ammonium Bisulfite	Removes Oxygen from water to protect the pipe from corrosion	Used as a fertilizer
11	pH Adjusting Agent	Sodium or Potassium carbonate	Maintains the effectiveness of other components , such as cross linkers	Mild drying agent
12	Poppant	Silica, Quartz sand	Allows the fracture to remain open so that the gas can escape	Used in manufacturing of glass and abrasives
13	Scale Inhibitor	Ethylene Glycol	Prevents scale deposit in the pipe	Coolant and heat transfer agent
14	Surfactant	Isopropanol	Used to increase viscosity of the fracture fluid	It is a general disinfectant

Annexure-2

List of Service Providers for Hydro fracturing of Shale

Sr. No.	Name of company	Country	Email Id	Contact No.
1	GASFRAC	Calgary, Alberta - USA	lori.mcleod-hill@gasfrac.com	(403) 237-6077
2	Baker Hughes	Huston, Texas - USA		18002297447
3	Halliburton	Huston, Texas - USA		1 281 871 4000
4	GE	Fairfield, Connecticut, U.S		001 866 419 4096
5	Cuadrilla	Staffordshire, West Sussex, UK		01543 266 444
6	Total	Courbevoie, Île-de-France, France	rm.za-totalccc@total.co.za	0860 111 113
7	Centrica Plc	Windsor, Berkshire, UK		44 1753 494000
8	GDF Suez	Paris, France & Leeds, UK		09 69 324 324, 33 (0)1 56 65 65 65
9	Chevron	San Ramon, California, USA		1 925.842.1000
10	British Gas	Rotterdam, UK	customerservice@britishgas.co.uk	44 113 298 0900

Annexure-3

List of Environment agencies in India

Sr. No	Name of the Consultancy	Type of assessment	Office Location	Site	Phone number
1	Lotus Environment Technology Pvt Ltd	Mainly for waste water treatment and disposal	Pune	www.lotusenvitech.co.in	8376806482
2	Hydro Treat Technologies Inc.	Assessment of Site Contamination	Delhi	www.hydrotreat.co.in	8586944334
3	Sigma Test and Research center	Environment Impact Assessment	Delhi	www.sigmatest.in	8376808281
4	Anacon laboratories Pvt Ltd	Environment Impact Assessment	Nagpur	www.indiamart.com/anacon-laboratories	9953354942
5	Metro Enviro-Chem Associates	Environment Impact Assessment	Ahmedabad	www.environmentmanagementservice.com	8376806045
6	Ascenso Enviro Pvt Ltd	Environment Impact Assessment	Noida	www.indiamart.com/ascencomanagement	8447553416
7	Ultra Tech	Environment Monitoring Consultancy Service	Thane	www.indiamart.com/ultratech	9953352470
8	Eco Panacea	Environment Impact Assessment services	Noida	www.ecopanacea.in	9953362979
9	Enviro Tech System	Environmental Impact Assessment & Environmental clearances	Pune	www.indiamart.com/enviro-techsystems	8377800272
10	Industrial Energy Saving Company	Environmental Audit	Thane	www.indiamart.com/indesco	8447530954

11	Verde Ventures Pvt Ltd	Biodiversity and Ecology Impact Assessment, monitoring plan	Kolkata	www.indiamart.com/verde	8587099004
12	Ecosteps Laboratory Pvt Ltd	Environment Impact Assessment services	Noida	www.indiamart.com/ecostepslaboratory	7053119189
13	Spans Envirotech Pvt Ltd	Environment Impact Reports Services	New Delhi	www.indiamart.com/spansenvirotech	9643205106
14	E.Q.M.S India Pvt Ltd	Environment and Social Impact Assessment	Delhi	www.indiamart.com/eqmsindia	8447573021
15	Terracon Ecotech Pvt Ltd	Impact Assessment, Planning and management	Mumbai	www.indiamart.com/terraconecotech	8046054932
16	Rashi Design Solutions Pvt Ltd	EIA- Reporting Services	Jodhpur	www.indiamart.com/rashi-design-solutions	8045326416
17	Kadam Environmental Consultants	Environment Impact Assessment	Vadodara	kadamenviro@kadamenviro.com	9824011909