FACTORS INFLUENCING SHALE GAS EXPLORATION & EXPLOITATION IN INDIA

By

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DECLARATION

I hereby declare that this submission is my own work and that, to the best of my knowledge and belief, it contains no material previously published or written by another person nor material which has been accepted for the award of any other degree or diploma of the university or other institute of higher learning, except where due acknowledgment has been made in the text.

Bhagwat Singh Negi,
(Delhi, 5th April 2014)

THESIS COMPLETION CERTIFICATE

This is to certify that the thesis on **"Factors influencing Shale Gas Exploration and Exploitation in India"** by **B.S Negi** in Partial completion of the requirements for the award of the Degree of Doctor of Philosophy (Management) is an original work carried out by him under our joint supervision and guidance.

It is certified that the work has not been submitted anywhere else for the award of any other diploma or degree of this or any other University.

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EXECUTIVE SUMMARY

Energy is a critical ingredient for the development of any nation. Several studies have established a positive correlation between energy consumption and human development index (literacy, reduced poverty, access to better sanitation, health facilities, etc.). India has been experiencing accelerated growth for the last few years. With a growing influence among its hundreds of millions of population, is likely to consume more energy than ever before. Globally around 42% of primary energy is used for power generation (BP, 2014). During the year 2012, India’s primary energy consumption stood at 563.6 MTOE, of which 61% was the domestic contribution and balance 39% imports (Crude Oil, Petroleum Products, LNG and Coal). The bill for net import during 2012-13 has been $150 billion, putting a huge burden on the national exchequer (Kelkar, 2013).

Indian energy basket is heavily filled with fossil fuels (92%) comprising 53% Coal, 30% Oil and 9% Natural Gas (BP, 2013), of which, Coal and Oil are heavily polluting. Increased environmental concerns for Greenhouse gas emissions and global warming are putting additional pressure to move away from polluting fossil fuels.

India has access to substantial renewable energy sources whose potential can be tapped to bridge some of the gap in power generation and reduce the pressure on the fossil fuel based power plants. India has begun well by having a dedicated Ministry for Renewable Energy policy formulation and oversight. Several proactive initiatives from the ministry, research institutions, academia, private investors, thought leaders, financial institutions and project developers have resulted in installing over 25,000 MW of clean energy generation capacity in the power installed capacity of 202,000 MW as of April 2012. Dedicated solar energy policy called Jawaharlal Nehru National Solar Mission (JNNSM) has accelerated the solar energy market in India. Similarly, focussed policies to encourage wind energy sector has contributed to India becoming fifth in the world in terms of

installed wind energy capacity. Similar, albeit to a lesser extent, success has been witnessed in the growth of small hydro plants installed capacity. However, India has not tapped the full potential of the renewable energy up to its optimal. Its Share is only 7% now (5% Hydro and 2% renewable). Globally, too the contribution of renewables has been only 2% and that of Hydro 7% (BP, 2013). With the kind of energy demand growth projected for India, the clean energy resources; Hydro, Wind and Solar will not be able to meet the additional requirement. The possible option for India is therefore, the exploitation of environmental friendly energy resources like Conventional Natural Gas, Unconventional Resources such as Coal Bed Methane (CBM), Coal Mine Methane (CMM), Shale Gas and Gas Hydrates. Gas hydrates commercial exploitation has not yet been reported from anywhere in the world, CBM and CMM are being produced in India but in small quantities and the scope for Shale Gas is considerably good, looking from the Indian reserves (63 to 500 TCF), (*Society of Petroleum engineers,2006)*, followed by experimental data from Indian explorers (RIL, ONGC). The US success story is encouraging in the area of Shale Gas Exploration & Exploitation (E&E). India needs to understand the reasons for not having embarked on the Shale Gas E&E program.

This thesis identifies through extensive literature survey, the core elements of Shale Gas programmes, policies adopted by various countries like US, Canada, Poland, UK, China, Australia, etc. The questionnaire developed by incorporating the variables identified through the literature survey and peers survey was administered to several stakeholders of Shale Gas with interest in India. The responses received were analyzed through statistical tool to reduce the set of variables to a fewer, manageable set of factors (the dependent variables). The factors identified through the research will help the policy makers and other stakeholders for implementation of Shale Gas E&E in India.

Currently, there is limited literature available on subject. This thesis bridges some of the gaps of absence of literature in the area and adds to the body of knowledge, which would benefit policy makers, researchers and other Shale Gas stakeholders in the country.

List of Abbreviations

AMD	Acid Mines Drainage
APM	Administered Price Mechanism
Bbl	Barrel
BCM	Billion Cubic Meter
BEE	Bureau of Energy Efficiency, India
BEP	Break-Even Point
BP	British Petroleum
BTS	Bartlett Test of Sphericity
CBM	Coal Bed Methane
CDM	Clean Development Mechanism
CEA	Central Electricity Authority, India
CERC	Central Electricity Regulatory Commission
CNG	Compressed Natural Gas
CWET	Centre for Wind Energy Technology
DEW	Drilling & Engineering World
DGH	Directorate General of Hydrocarbon, India
E&Y	Ernst & Young
EA	Electricity Act 2003, India
EEA	European Environmental Agency
E&E	Exploration & Exploitation
E&P	Exploration & Production
EPA	Environmental Protection Agency, US
EPC	Engineering, Procurement and Construction
EU	European Union
FDI	Foreign Direct Investment
GBI	Generation based Incentive
GDP	Gross Domestic Product
GGS	Gas Gathering Station or Group
	Gathering Station
GHG	Green House Gases
GIS	Geographic Information System
GW	Giga Watt (= 1000 Mega Watt)
GDF	Gas de France
IEA	International Energy Agency
IOC	International Oil Company
IOGCC	Interstate Oil & Gas Commission
IPCC	Inter-Governmental Panel on Climate Change
IREDA	Indian Renewable Energy Development Agency
IRR	Internal Rate of Return
JNNSM	Jawaharlal Nehru National Solar Mission
KCF	Thousand Cubic Feet
KMO	Kaiser-Meyer-Olkin test
KW	Kilo Watt
Kwh	Kilo Watt Hour (Electricity)
LNG	Liquefied Natural Gas
MNC	Multi National Company
MNRE	Ministry of New and Renewable Energy, India
MMSCMD	Million Standard Cubic Meter Per Day
MOEF	Ministry of Environment and Forest, India
MoPNG	Ministry of Petroleum and Natural Gas, India
MT	Million Tonnes
MTOE	Million Tonne of Oil Equivalent
MW	Megawatt (= 1000 Kilo Watt)
MBAS	Methane Blue Action Substance

MTBE	Methyl Thio Benzel Ethyl
NAPCC	National Action Plan on Climate Change
NASA	National Aeronautics and Space Administration, US
NGO	Non Government Organisation
NOC	No Objection Certificate
NORM	Naturally Occurring Radio-active Material
NELP	New Exploration Licensing Policy, India
NIMBY	Not in My Back Yard Syndrome
NPV	Net Present Value
NREL	National Renewable Energy Laboratory, USA
O&M	Operations and Maintenance
OPEC	Organisation of Petroleum Exporting Countries
OfGem	Office of Gas and Electricity Markets, UK
ONGC	Oil & Natural Gas Corporation of India
PDEP	Pennsylvania Department of Environmental Pollution
PNGRB	Petroleum & Natural Gas Regulatory Board, India
PLF	Plant Load Factors
PMP Act	Petroleum & Mineral Pipeline Act, 1962 (India)
PPMV	Parts per million by volume
PCA	Principal Component Analysis
PSA	Production Sharing Agreement
PSC	Production Sharing Contract

REC	Renewable Energy Certificates
RES	Renewable Energy Sources
RO	Reverse Osmosis
ROC	Renewable Obligation Certificates
RPO	Renewable Purchase Obligation
RSS	Remote Sensing Systems
SCSP	Solar Concentrating Solar Power
SDWA	Safe Drinking Water Act, 1974 (US)
SEB	State Electricity Boards, India
SERC	State Electricity Regulatory Commission
SEZ	Special Economic Zones
SHP	Small Hydro Power
SPV	Solar Photo Voltaic
SPSS	Statistical Package for the Social Sciences (Software tool)
STE	Solar Thermal Energy
TCF	Trillion Cubic Feet
TCM	Trillion Cubic Meter
TCMTB	Thio Cino Methyl Thio – Benzothiozonle
TGC	Tradable Green Certificates
TWhr	Terra-Watt hour (Billion units of power)
UNDP	United Nations Development Programme
UPES	University of Petroleum and Energy Studies
VAT	Value Added Tax
WDV	Written-Down Value

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Chapter 1
Introduction

1.1 Background

Indian Economy has been growing at more than 9 percent since 2005-06 except during 2008-09 due to global economic meltdown when it recorded 6.72 percent increase. The economy again improved in 2010-11 onwards; however during 2012-13 it again registered a slow growth of 5 percent (Planning Commission, May, 2013). Economy is expected to continue its increasing momentum into the foreseeable future.

The economic growth has a close link with the energy requirement or to say the energy growth. To sustain this growth, the energy sector needs to prepare itself for making available required energy resources for sustainable growth.

The energy resources that contribute to the energy basket globally are:

(i) Coal
(ii) Oil
(iii) Gas
(iv) Hydro
(v) Nuclear
(vi) Other Renewable (Solar, Wind)

The contribution of each of the above energy resources varies from country to country depending upon the domestic availability of the energy resources. The energy basket as of 2012, in Global and Indian context are shown in Table 1.1.

India being Coal rich country, has a share of Coal more than 50% consistently for years [precisely 52.9% during 2010 (BP 2011) and also in 2012 (BP, 2013)].

The Coal sector is contributing primarily for power generation and also supporting other areas like process steam generation in the industry, locomotive and domestic application for cooking and heating. The exploitation of coal resources in India has been the maximum. The growth of coal sector is handicapped due to inadequacy of the development of the coal sectors with respect to advance technique, modern mining equipments, non-existence of sectoral regulator and lack of sectoral competition. Further the quality of Indian coal is not good, in as much as it contains upto 40% ash. Also, India's coal reserves are of low calorific value and hence of poor quality (NREL 2010). Figure 1.1 shows the pictorial depiction of the energy consumption pattern Global versus India for the year 2012.

Table 1.1: Primary Energy Baskets Global Versus India-2012 (BP 2013)

Primary Energy (Tradable)	**World**		**India**	
	MTOE	**% of Total**	**MTOE**	**% of Total**
Oil	4130.5	33.1	171.6	30.6
Gas	2987.1	24.0	49.1	8.7
Coal	3720.1	29.8	298.3	52.9
Nuclear	560.4	4.5	7.5	1.3
Hydro	831.4	6.7	26.2	4.6
Renewable	237.4	1.9	10.9	1.9
Total	**12476.6**	**100**	**563.6**	**100**

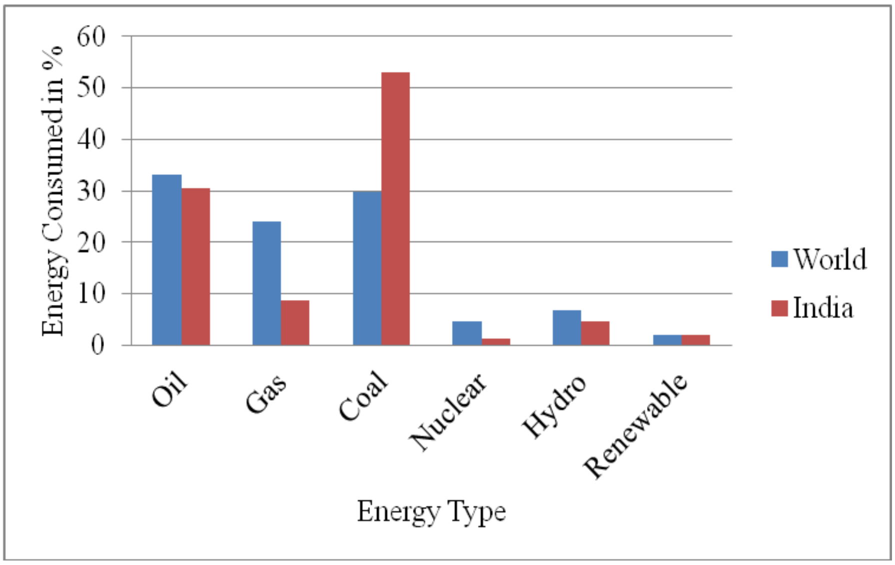

Fig. 1.1: Energy Basket India and World 2012 (BP, 2013)

India's Coal reserves are estimated to be 60.6 billion ton and with the present consumption rate, these reserves will last for 103 years (BP, 2013). Indian coal resources are of low calorific value and hence of poor quality (NREL, 2010). Because of poor quality of coal and inadequacy of the exploitation, India is importing coal from various countries like Australia, Indonesia etc. During 2012-13 Coal imports leaped 34% (137.56 million ton) and Coal import increased by 20% (105.8 million ton) during April-October 2013 (Reuters, 2013) (services, 2013). Figure 1.2 shows the energy consumption global versus India in 2010. This period has been chosen because during 2010 India reached a peak of 10.8% gas consumption which has now declined to 9% due to fall in KG D-6 production and LNG terminals readiness not matching with the demand for import of LNG.

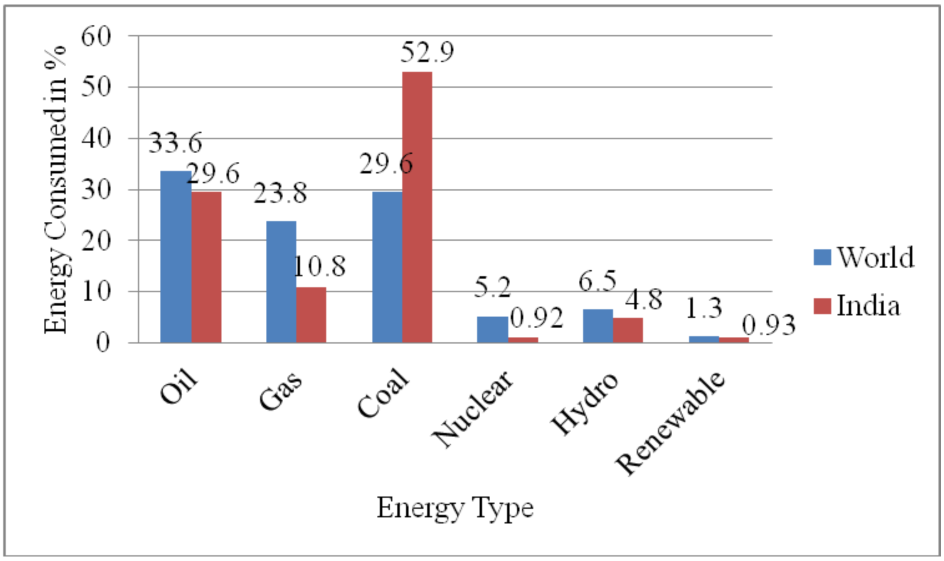

Fig. 1.2: Energy Basket India and World 2010 (BP 2011)

The second largest energy resource for India is oil. The oil exploration in India commenced with oil finds in upper Assam in 1889, however, the demand versus supply scenario of oil is totally unbalanced. India imports more than 70% of its oil consumption (75.5% imports during 2012), (BP 2013). Oil imports during 2011-12 amounted to $125 billion (MoPNG, 2013) which rose to $150 billion during 2012-13(kelkar, 2013). The proven oil reserves till date are pegged at 5.7 billion ton and with present rate of exploitation; these reserves are expected to last only 18.2 years. The share of Coal and Oil to the

Indian primary energy basket has not changed between 2010 and 2012 but the share of natural gas has decreased by 16.5% and Hydro, Renewable and Nuclear shares have increased (Table 1.2).

Table 1.2: Trend of Energy Consumption India (2010- 2012)(Ref. Fig. 1.1 and 1.2)

Fuel Share%	2010	2012	% Change
Coal	52.9	52.9	0.0
Oil	29.6	30.6	+3.3
Gas	10.8	8.7	(-)19.4
Hydro	4.8	4.6	(-)4.2
Renewable	0.93	1.9	+10.4
Nuclear	0.97	1.3	+3.9
Total (MTOE)	**524.2**	**563.6**	**+7.5**

Both the major energy resources (Coal and Oil) consumed by India contribute about 83.5% of commercial energy being consumed and are unfortunately the most polluting energy resources. The remaining four environmental friendly resources contribute only 16.5% to the Indian energy basket which creates serious environmental problem. It is with these considerations of limited resources and environmental consideration that a serious thought needs be given to the eco-friendly energy resources in India.

Although, the contribution of Nuclear, Renewables and Bio fuels in India is on increase but volume wise these resources continue to be miniscule. The contribution during 2011 of Nuclear energy in India has been 4.5 Million Ton of Oil Equivalent (MTOE) that of Renewable (Wind and Solar) is 9.2 MTOE and Bio Fuel 0.286 MTOE only. During the year 2012, these contributions raised to 7.5 MTOE, 10.9 MTOE and 0.294 MTOR respectively. (BP 2012 and, BP 2013).

In the year 2012, the natural gas proven reserves for India were 43.8 Trillion Cubic Feet (Tcf) which are expected to last 26.9 years with present rate of production ((BP 2013). The Indian basins are poorly explored and the trend now is for more gas finds then oil. Table 1.3 gives proven energy resources global versus India. Baring Coal, the share any other energy resource in India is less than 5%.of the global

Table 1.3: Energy Resources Global v/s India-2012 (BP 2013)

S. No.	Energy Resource	Global (2012)		India (2012)		
		Proven Reserves	R/P Ratio	Proven Reserves	R/P Ratio	%age of World
1	Coal	860.938 billion ton	109 years	60.6 billion ton	100 years	7.0
2	Oil	235.8 billion ton	52.9 years	0.8 billion ton	17.5 years	0.3
3	Gas	6614.1 Tcf	55.7 years	47.0 Tcf	33.1 years	0.7
4	Nuclear	560.4 mtoe	Installed	7.5 mtoe	Installed	1.3
5	Hydro	831.1 mtoe	Renewable	26.2 mtoe	Renewable	3.1
6	Wind	237.4 mtoe	Renewable	10.9 mtoe	Renewable	4.6
7	Bio Fuel	60.22 mtoe	Installed	0.294 mtoe	Installed	0.5

The energy demand and supply scenario has wide disparities globally. The conventional hydro carbon reserves are scattered as a result of the initial earth formation and subsequent vagaries of climate change which our mother earth has witnessed over millions of years. The global energy resource distribution as it appears today may also be because of the exploration efforts undertaken by various countries themselves or by the players of various other countries. (Table 1.4)

The top 10 rich countries in the energy resource of coal, oil and gas are shown in Table 1.5, 1.6 and 1.7 respectively. The Nuclear energy is based on the process and the industrial efforts and hence can be termed as secondary energy. The growth of the solar energy has been based on a national policy and the compulsion due to scarcity of the hydro carbon resources in that country. The top 10 countries using nuclear energy are tabulated in 1.8.

The contribution of renewable energy depends on the efforts undertaken by the respective country. The overall exploited renewable potential including Hydro is limited as can be seen from Table 1.9 – Hydroelectricity and Table 1.10 – Renewable energy respectively.

Table 1.4: Proven Energy Reserves - Global versus India (2011-2012) (BP 2013)

Energy Resource	World				India					
	2011		2012		2011			2012		
	Qty.	R/P	Qty.	R/P	Qty.	R/P	% of World	Qty.	R/P	% of Total
Oil (MTOE) Reserves	233700	52	235800	52.9	805	17.6	0.344	800	17.5	0.33
Oil (mmtpa) Consumption	4081.4	-	4130	-	163.0	-	3.99	171.6	-	4.6
Gas (tcf) Reserves	6631.8	57	6614.1	56.7	45.9	33	0.69	47.0	33.1	0.7
Gas (BCM) Consumption	3232.4	-	3314.4	-	55	-	1.89	54.6	-	1.64
Coal (million ton) Reserves	960938	112	860938	109	60600	103	7.0	60600	100	7.0
Coal (MTOE) Consumption	3628.8	-	3720.1	-	270.6	-	7.46	298.3	-	9.9
Nuclear (MTOE)	600	-	560.4	-	7.3	-	1.2	7.5	-	1.3
Hydro (MTOE)	794.7	-	831.1	-	29.4	-	3.7	26.2	-	3.1
Renewables * (MTOE)	205.6	-	237.4	-	9.2	-	4.5	10.9	-	4.6
Biofuel (MTOE)#	58.9	-	60.2	-	0.296	-	0.5	0.294	-	0.5

*Include Wind, Geothermal, Solar and Biomass.
#Include Ethanol and Biodiesel.

Table 1.5: Coal Reserves and Production (during 2012) - Global Majors (BP 2013)

S. No.	Country	Proven Coal Reserves (Billion Tonne)	Reserves % of Global	Production % of Global
1	US	237.3	27.6	13.4
2	Russian Federation	157.0	18.2	4.4
3	China	114.5	13.3	47.5
4	Australia	76.4	8.9	6.3
5	India	60.6	7.0	6.0
6	Germany	40.7	4.7	1.2
7	Ukraine	33.9	3.9	1.2
8	Kazakhstan	33.6	3.9	1.5
9	South Africa	30.2	3.5	3.8
10	Columbia	6.7	0.8	1.5
	Total	**860.94**	**91.8**	**3845.3 MTOE**

Table 1.6: Oil Reserves and Production (during 2012) - Global Majors (BP 2013)

S. No.	Country	Proven Oil Reserves (Billion Tonne)	Reserves % of Global	Production (Billion Tonne)	Production % of Global	Consumption % of Global
1	Venezuela	46.5	17.8	0.140	3.4	0.9
2	Saudi Arabia	36.5	15.9	0.547	13.3	3.1
3	Canada	28.0	10.4	0.183	4.4	2.5
4	Iran	21.6	9.4	0.175	4.2	2.2
5	Iraq	20.2	9.0	0.152	3.7	3.4*
6	Kuwait	14.0	6.1	0.153	3.7	0.5
7	UAE	13.0	5.9	0.154	3.7	0.8
8	Russian Federation	11.9	5.2	0.526	12.8	3.6
9	Libya	6.3	2.9	0.071	1.7	0.6*
10	Nigeria	5.0	2.2	0.116	2.8	2.9*
	Total (10 majors) /world)	**197/235**	**83.8**	**4.119**	**100**	**20.5**

Table 1.7: Natural Gas Proved Reserves, (Top 10 Countries during 2012), Production & Consumption (BP 2013)

Country	Proved Reserves by 2011			Production BCM		Consumption BCM	
	Tcf	R/p years	% of Total	BCM	% of Total	BCM	% of Total
US	300	12.5	4.5	681.4	20.4	722.1	21.9
Venezuela	196.4	>100	2.7	32.8	1	34.9	1.1
Russian Federation	1162.5	55.6	17.6	529.3	17.6	416.2	12.5
Turkmenistan	618.1	>100	9.3	64.4	1.9	23.3	0.7
Iran	1187.3	>100	18	160.5	4.8	156.1	4.7
Qatar	885.1	>100	13.4	157	4.7	26.2	0.8
Saudi Arabia	290	80.1	4.4	102.8	3.0	102.8	3.1
Algeria	159.1	55.3	2.4	81.5	2.4	30.9	0.9
Nigeria	182	>100	2.8	43.2	1.3	-	-
UAE	215.1	>100	3.3	51.7	1.5	-	-
China	109.3	28.9	1.7	107.2	3.2	143.8	4.3
India	47	33.1	0.7	40.2	1.2	54.6	1.6
World	5351.9	55.7	81	2052	61	1710.9	51.6

Table 1.8: Nuclear Power Production (During 2012) - Global Majors (BP 2013)

S. No.	Country	Nuclear Power (MTOE)	% of Global
1	US	183.2	32.7
2	France	96.3	17.2
3	Russian Federation	40.3	7.2
4	Japan	4.1	0.7
5	South Korea	34.0	6.1
6	Germany	22.5	4.0
7	Canada	21.7	3.9
8	Ukraine	20.4	3.6
9	China	22.0	3.9
10	UK	15.9	2.8
	Total	**460.3**	**82.1**

Table 1.9: Hydroelectricity Production (During 2012) - Global Majors (BP, 2013)

S. No.	Country	Hydroelectricity (MTOE)	% of Global
1	China	194.8	23.4
2	Brazil	94.5	11.4
3	Canada	86.0	10.4
4	US	63.2	7.6
5	Russian Federation	37.8	4.5
6	India	26.3	3.1
7	Norway	32.3	3.9
8	Japan	18.3	2.2
9	Venezuela	18.6	2.2
10	Sweden	17.8	2.1
	Total	**589.6**	**71**

Table 1.10: Renewable Energy Resources Global versus India

S. No.	Renewed Energy	Global	Indian
1	Wind *	238(GW)	16.1 (GW)
2	Solar & other#	194.8(MTOE)	9.2 (4.7% of world)
3	Hydroelectricity#	791.5(MTOE)	29.8(MTOE) (18.9%) 150,000mw

(** Renewable, 2012, #* BP 2012)

Although, any form of energy available to any country can be made use for its economic growth, historically, 16th Century became the coal era led by the Britain; it was followed by oil era lead by U.S in 18th century. Both these fuel applications created a tremendous environmental pollution including release of green houses gases thereby increasing the concern for global warming and even the possibility of a hole in the ozone layer.

However, continued dependence on fossil fuels (especially Coal and Oil) to power the growth of economy through electricity generation capacity and other applications, is hardly sustainable in the long run. The reasons are well known - environmental concerns, depleting fossil fuel resources, excessive dependency on Oil imports - that it hardly merits repetition.

In Indian context, the oil and gas reserves are in short supply while demand for oil has been galloping unabated. Every year oil imports have increased substantially draining huge amount of foreign exchange ($125 billion in 2011-12) reserves of the country (MoPNG, 2013). It has risen to $150 billion during 12-13 (kelkar2013).

1.2 Renewable Energy resources

On an average 42% of the primary energy is used for power generation to fuel the growth of the economy. The Renewable Energy Sources (RES) form a miniscule portion (25 GW, ~ 12%) of India's overall electric power consumption today (202 GW). Wind and Solar constitute major renewable energy resources. The renewable energy resources, (combining Solar and Wind) account for only 1.9% of the total energy basket. These resources are being tapped with the emphasis on their environmental benefits.

(i) Wind Energy

Wind Energy is another source of clean energy which is having reasonably good potential in India. The development of wind power in India began in the late 1980s and has progressed steadily in the last few years (World Bank, 2010). The short gestation periods for installing wind turbines, and the increasing reliability and performance of wind energy machines have made wind power a favoured choice for capacity addition in India. Currently, India has the fifth largest installed wind power capacity in the world (WISE, 2011). The official wind energy potential at 50 m hub height was 48,000 MW and at 80 m hub height is given as 102,000 MW (CWET, 2011). Excellent wind energy potential is observed in the southern and western parts of the country. The actual wind energy potential in India is expected to be much more than what is regarded till now.

To put that in perspective, the power generation in India from all the sources is 202 GW. Wind power accounts for 2/3rd of installed renewable capacity in the country and a leader by a long margin as compared to other renewable sources. Wind energy grew substantially on the back of supportive policies of Government of India (World Bank, 2010). All these capacities are from onshore. Offshore wind sector does not exist at present in India.

The growth of wind energy cannot depend just on onshore wind farms for the following reasons;

- Limited availability of contiguous parcels of land
- Unpredictable nature of wind sources on land
- Potential land litigations
- Competing uses for land from other infrastructure projects

Offshore wind farms have to be promoted to compensate for the likely challenges, as mentioned above, that would be faced by onshore wind farms. The world is aggressively moving towards tapping offshore wind energy sector to mitigate some of the challenges faced from onshore wind farms (EWEA, 2012). India's long coast-line offers a large potential; proper assessment and development of this potential would offer challenges and new opportunities to India's wind energy industry (Bhattacharya & Jana, 2009). Initial studies conducted suggest that the offshore wind energy potential for India could be between 250 GW and 500 GW, which is quite large (Lawrence Berkeley labs, 2012).

The installed capacity of wind energy in India stands at 1700MW and there is a wishful plan to generate more power through wind. But it has its own issues such as wind intensity, seasonality of the flow and connectivity to transmission grid

The share of wind energy (16.1 GW) is 68% of the total renewable energy basket and is likely to remain so for the near future. Potential of Wind energy worldwide is shown in Table 1.11 below. However the PLF of wind turbine is not very good (mostly varying between 20% to 30%) due to seasonality of wind flow and limit on the wind turbine shaft height.(Fig 1.3), China being exception. In India, average PLF for MP, Tamilnadu and Rajasthan has been 20% to 22% (*KS Oil Information Memorandum, 2013*).

Table 1.11: Wind Energy Productions - Top 10 Countries in 2011(Renewable, 2012)

Country	Total End – 2010	Added 2011 (GW)	Total End – 2011
China	30/44.7*	15/17.6*	45/62.4*
United States	40.3	6.8	46.9
Germany	27.2	2.0	29.1
Spain	20.6	1.1	21.7
India	13.1	3.0	16.1
France	6.0	0.8	6.8
Italy	5.8	1.0	6.7
United Kingdom	5.2	1.3	6.5
Canada	4.0	1.3	5.3
Portugal	3.7	0.4	4.1
World Total	**198**	**40**	**238**

*****The lower figure indicates operation capacity and the higher figure indicates installed capacity.*

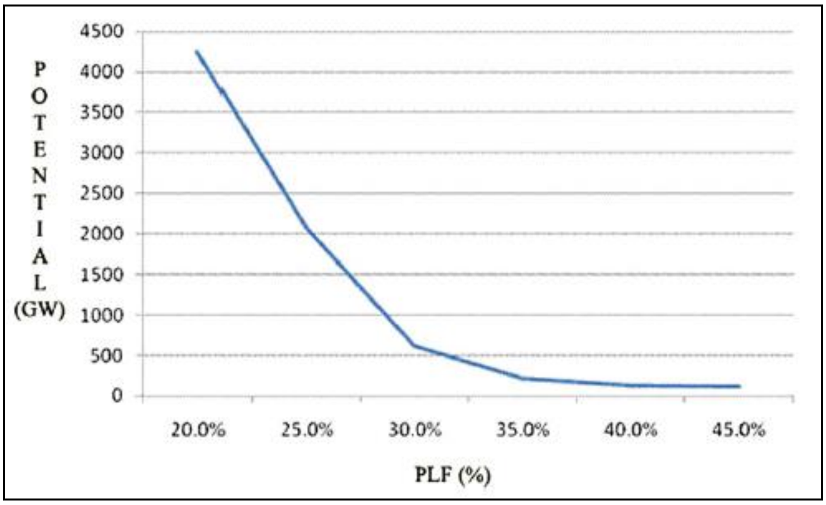

Fig. 1.3: Wind Energy PLF based achievable potential for India (Hossain et al., 2012)

(ii) Solar Energy

The installed capacity of Solar Power in India till June, 2013 had been 1760 MW which is expected to reach 2100 MW by the end of the year 2013. During 2012, Solar contributed around 9 GW of electric power. The planned figure for 2050 is 50,000 MW i.e., 25time increase in 36 years. Also the Government plan is to rise to 20,000 MW by 2022 (Mehta, 2014).

The PLF for PV solar power has been less than 19% and that for CSP it is approximately 11%. Hence the installed capacity has to be more than 5 times the energy produced, (*groups.google.com*)

Deserts of Rajasthan and Gujarat offer solar energy potential. India is the 7th largest country in the world by area, is located near the equator and hence subjected to a large amount of solar radiation throughout the year. The average solar radiation received by most parts of India range from about 4 to 7 kilowatt hours per meter square per day, with about 250-300 sunny days in a year (MNRE, 2010). The Government plans to tap 20,000 MW of grid connected solar energy by 2022 as part of the Jawaharlal Nehru National Solar Mission (JNNSM, 2008) program. Currently, around 980 MW of solar installation is already present in India (MNRE, 2011).

(iii) Small Hydro Projects

Hydro projects up to 25 MW of installed capacity have been categorized as Small Hydro Power (SHP) projects and comes under the administrative purview of the Ministry of New and Renewable Energy (MNRE, 2010). MNRE had estimated the potential of SHP as 15,000 MW of which around 3400 MW has been tapped, (2011). Hydro projects have long gestation period compared to solar and wind energy projects due to delays in getting regulatory clearances and inhospitable terrains.

(iv) Biomass and Cogeneration

Biomass is the energy source for majority of the population that are living in rural areas. About 32% of the total primary energy users are still using biomass and more than70% of the country's population depends upon it for its energy needs (Pillai & Banerjee, 2009). The Biomass technologies being promoted by the MNRE are Bagasse-based cogeneration in sugar mills, biomass power generation, and biomass gasification for thermal and electrical applications. The potential of power generation from surplus biomass was assessed as 18,000 MW (MNRE, 2010). Apart from biomass, separate potential from Bagasse cogeneration was assessed as 5000 MW (MNRE, 2010). Biomass has immense potential as India is a predominantly agrarian economy.

(v) Waste-to-Energy

Urban liquid and solid waste is used for development of waste-to-energy in India which estimated the potential of around 462 MW by 2017 from urban liquid waste and 4566 MW by 2017 from solid waste (MNRE, 2010). Apart from these bodies, industries also generate a lot of waste which has a potential of around 2000 MW by 2017. Currently around 90 MW of installed capacity exist for power generation from waste (MNRE, 2009).

(vi) Geothermal Energy

Around 350 geothermal potential regions have been identified by Geological Survey of India (GSI, 2009) which can generate 10,600 MW of power (GSI, 2009). Of this, 20% of the sites are distributed in the states of Jammu and Kashmir, Himachal Pradesh and Uttarakhand. Exact potential and commercial viability of this energy source needs to be studied further.

These official estimates are conservative. The actual potential of say wind energy (onshore) in India as per several studies (Hossain et al., Xi Lu et al., Berkeley labs) are much more than these official estimates of 102 GW.

1.2.1 Installed capacity of renewable energy sources

India has over 25,000 MW of installed renewable power generating capacity as of April 2012. Installed wind capacity has the largest share at over 17,000 MW, followed by small hydro at 3400MW. The remainder is dominated by bio-energy, with solar contributing 979 MW. Aggressive plans to scale up wind, solar, bio-mass power and small hydro projects are planned, which will net new investments of over US $ 50 Billion in the clean energy sector in the next few years (MNRE, 2011).

Table 1.12: Achievement of Renewable energy sources (in MW) in India, (MNRE, 2012)

Renewable Energy Systems	Target for 2012-13	Achievement during April, 2012	Cumulative Achievement up to 30.04.2012
Wind Power	2500	36.65	17389.31
Small Hydro Power	350	5.75	3401.06
Biomass Power	455	16.00	1166.10
Bagasse Cogeneration		7.5	1992.73
Waste to Power - Urban	20	-	89.68
- Industrial		-	-
Solar Power (SPV)	800	37.72	979
Total	**4125**	**103.62**	**25017.88**

It is felt that the optimization of the renewable resources with existing hydrocarbon resources will not be able to cope up with the energy demand of the country and therefore exploration of the unconventional resources is the option.

1.3 Conventional versus Unconventional Fossil Fuel Resources

The natural gas reserves can be explored either through conventional exploration and production techniques (E&P) or through exploration and exploitation (E&E) technique for unconventional resources. The unconventional resources constitute Coal Bed Methane (CBM), Coal Mining

Methane (CMM), Shale Gas and Gas hydrate. The environmental benefit of natural gas is best depicted by a study conducted by EPA (Environmental Protection Agency), EIA (Energy Information Administration) and IPCC (Inter Governmental Panel on Climate Change). The related emission data (in BTU) are given in Table 1.13.

Table 1.13: Emissions from Various Fuels (EPA, EIA and IPCC)

Constituents	Natural Gas	Coal	Oil Product	Remark
CO_2	56% of CO_2 from coal	Coal impact in CO_2 100%	79% of coal CO_2	CO_2 is the most common GHG.
CO	19% of CO from coal	100%	16%	CO reduces O_2 carrying capacity in the world.
SO_2	0.04% of SO_2 from coal	100%	43%	SO_2 emissions are the principle cause of Acid rate.
Particulates	0.26% of particulates from coal	100%	3.06%	Cause respiratory problem.
NO_X	20% of NO_X from coal	100%	98%	NO_X causes smog and contributes to increased incidence of asthma.
Hydrocarbon	225% of hydro carbon from coal	100%	175%	Key component of smog (burning characteristics).

The contribution of oil and gas to the world energy basket constitute more than 63.2% and that in India it contributed 40.4% in 2010 and has been declining since. As of 2012 it is 39.3% only.

1.4 Long Term Energy Outlook 2035

By 2035, global primary energy consumption is projected to increase by 41% (@1.5%pa) and all three major fossil fuel resources (Coal, Oil and Gas) consumption will converge to same (approximately 27% each) and there will be no leading energy resource in the global energy basket. Unconventional and renewable energy resources will have a share of 43% by 2035 of which Shale Gas alone will contribute 16% share. During the period 2012-2035, amongst fossil fuels, natural gas has highest growth (1.9% pa), (Oil, 0.8%, Coal, 1.1%). Similarly amongst non-fossil energy resources, renewable resources have highest growth rate of 6.4% pa, (Nuclear 1.9% and Hydro. 1.8% pa).

In respect to India, by 2035, the energy production rises by 112% while consumption grows by 132% (this growth outpaces each of the BRIC countries as Russia (+20%), China (+71%) and Brazil (+71%) all expected slower than the Indian energy consumption growth. Even with 112% rise, the energy production as a share of consumption drops from 61% today to just 56% by 2035 (a rise of 163% in imports from 2012 level).Thus leading to more imports of energy resources. Fossil fuels will account for 87% of demand (compared to 81% of the Global average) (BP, 2014).

1.5 Energy Demand-Side Management

With the limited natural resources of non renewable energy at the disposal of the world, coupled with environmental awareness, the global initiatives has been for the increase of energy efficiency, reduced energy intensity and preferential use of eco friendly fuels. The harnessing of renewable energy has been on a limited scale globally due to cost consideration (Solar), uncertainty of flow dynamics (Wind) and ecological reasons (Hydro). Even with high percentage growth, renewable resources will not be able to meet the increasing volume wise energy demand in India.

With all possible combination of energy resources, oil and gas combined continues to play a dominant role globally and there is no alternative to hydrocarbon energy resources.

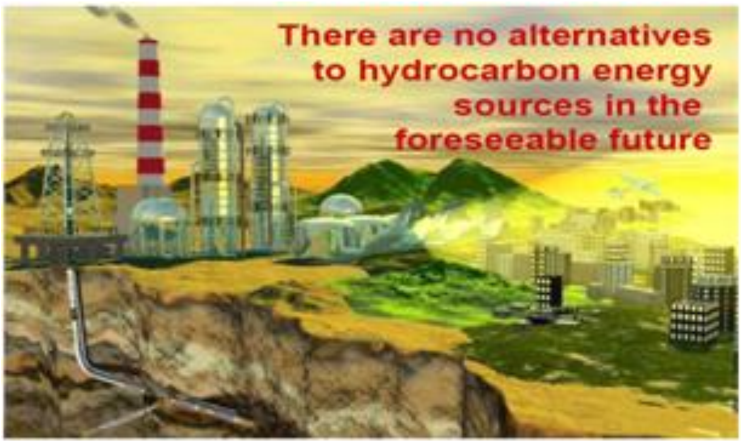

Fig. 1.4: Hydrocarbon Dominance (Internet)

Keeping in view the cost consideration and the adverse environmental impact, various countries are trying to reduce energy consumption growth, baring the developing countries like India and China whose energy growth rate is 3.1 and 2.1% year on year basis respectively against world energy demand growth of 1.2 %. Table 1.14 depicts Global energy demand growth.

Table 1.14: Global Energy Demand & Growth (IEA, 2010)

Country	1980	2000	2008	2015	2020	2030	2035	% Growth	2011
India	208	459	620	778	904	1204	1475	3.1	7.4
China	603	1107	2131	2887	3159	3568	3737	2.1	8.8
Japan	345	519	496	495	491	482	470	(-)0.2	(-)5.0
Russia	N/A	620	688	710	735	781	805	0.6	2.5
USA	1802	2270	2281	2280	2290	2288	2272	(-)0.0	(-)0.4
Europe	1493	1734	1820	1802	1813	1826	1843	0.0	(-)3.1
OECD	4050	5233	5421	5468	5516	5578	5594	0.1	(-)0.8
World	**7229**	**10031**	**12271**	**13776**	**14556**	**16014**	**16748**	**1.2**	**2.5**

For Indian hydrocarbon energy resource demand and growth specific exercise has been carried out. The first of such document has been the Hydrocarbon Vision - 2025, which indicates a natural gas demand of 313 MMSCMD in 2011-12 with a supply gap of 235 and in the year 2024-25, demand of 391 with a gap of 307 MMSCMD. The Integrated Energy Policy-2006 which attempted energy demand supply projection upto 2031-32 also shows a huge supply gap to be met with imports. Figure 1.15 (MoPNG, 2000) shows primary energy demand growth of 225% over 2010-11) and Table 1.16 (Planning Commission, 2006) show primary energy demand growth of 300% by 2031-32 over 2011-12.

Table 1.15: Indian Energy Demand Forecast (Hydrocarbon Vision 2025)

Energy Resource	2001-02	2006-07	2010-11	2024-25
Coal	50	50	53	50
Oil	32	32	30	25
Gas	15	15	14	20
Hydro	2	2	2	2
Nuclear	1	1	1	3
Oil (MMT)^	111	148	195	368
Total Primary Energy* (MTOE)#	**426.7**	**568.9**	**799.5**	**1810**

^Annexure IV of Hydrocarbon Vision 2015
**(Based on % of Oil Consumption as it is considered to be more rationale since supply is more than the demand*
#MMT=1.23MTOE

Table 1.16 Indian Energy Demand Forecast (Integrated Energy Policy 2006)

Year	Population in millions	GDP (Rs. In Billion @1993-94 prices)		TPCES (Mtoe)[1] GDP Growth Rate		TPCES (Mtoe)[2] GDP Growth Rate	
		8%	9%	8%	9%	8%	9%
2006-07	1114	17839	18171	389	397	394	403
2011-12	1197	26211	27958	521	551	537	570
2016-17	1275	38513	43017	684	748	732	807
2021-22	1347	56588	66187	898	1015	998	1142
2026-27	1411	83145	101837	1166	1360	1361	1617
2031-32	1468	122170	156689	**1514**	**1823**	1856	2289

Note: 1. Projections based on falling elasticity with respect to GDP.
2. Projections assuming no change in elasticity with respect to GDP.

1.6 Indicators of Economic Growth

The back bone of the economic growth is the Power sector. For sustainable projected growth, India needs to build additional generation capacity at an unprecedented pace. On an average, globally 42% of the primary energy goes for power generation (BP Energy Outlook 2035 released in January 2014). During 2011-12, India spent 41% of Primary energy for power generation (*MOSPI, 2013*).The total power generation capacity in India in April 2012 was 202 GW (CEA, 2012), of this, 66% was fossil-fuel (dominated by Coal-fired power plants), 19% hydroelectric power, 2% nuclear power, and 12% renewable energy. This trend of coal being the dominant fuel in the power sector and the Indian energy mix is likely to continue in the business as usual scenario (Ministry of Power, 2011). During 2013 the share of fossil fuel touched 68% as can be seen from Table 1.17 which shows various energy resources for power generation in India (as of 31-3-2013). Figure 1.5 shows this contribution in pictorial form.

Table 1.17: Power Generations by Source of Energy (CEA)

Fuel Type	Capacity (in MW)	Capacity (in %)
Coal	130220.89	58%
Gas	20109.85	9%
Diesel	1199.75	1%
Nuclear	4780.00	2%
Hydro	39491.40	18%
Renewable	27541.71	12%
Total	**223343.60**	**100%**

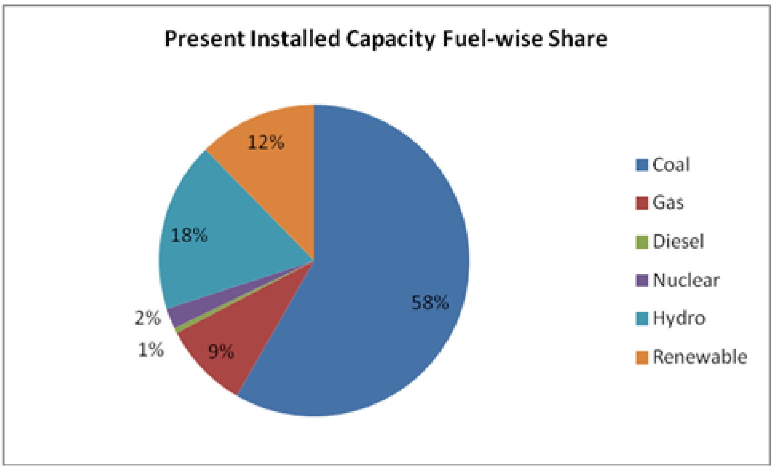

Fig. 1.5: Share of Various Energy Resources for Power Generation

However, Renewable Energy Sources (RES) form a miniscule portion (25 GW, ~ 12%) of India's overall Energy consumption today (202 GW). The share of wind energy (16.1 GW) is 68% of the total renewable energy basket and is likely to remain so for the near future. But the contribution from offshore wind farms is non-existent presently, as all the wind energy generated in India is only through onshore wind farms. With increased pressure on availability of land for development purposes, India has to quickly exploit its vast coastline (over 7000 Km) for producing power from offshore wind farms.

1.7 Natural Gas, the most benign Hydrocarbon

The environmental concerns provide preference for eco-friendly energy resource. The renewable energy resources like solar energy, wind energy, hydel power, geo thermal, tidal energy are the most preferred energy resources but they have limited availability and in some cases high capital cost. In the hydro carbon category, the natural gas which is predominantly Methane has the highest carbon to hydrogen ratio and therefore the most eco-friendly fuel.

Again going by the natural gas global proved reserves potential of 7360.9 Tcf, the possible sustained availability of natural gas with present consumption rate is only for 46 years, if no new finds are added to these reserves. The natural gas resources are scattered in different part of the globe notwithstanding the requirement of those regions. Table 1.7 gives Natural Gas Proved Reserves, Production & Consumption of top 10 Countries in terms of the reserves.

Traditionally, natural gas prices in the global trade are linked up with crude oil price (except for regional trading hubs and recent LNG contracts from US). The volatility of crude oil price in the market place is not dictated by the market sentiments but by the OPEC and other oil majors of different regions. Because of this, the search for alternative energy resources has been undertaken by several countries. The example of U.S, having followed vigorously the Shale Gas (E&E) in 2008 when gas price shot up exceeding $8/mmbtu is not only a success story of Shale Gas growth in U.S and a game changer but also is an example for such initiative globally.

1.8 The Unconventional Hydrocarbon Energy Resources

The oil and gas reserves discussed above constitute hydrocarbon from the conventional formation i.e. to say that plants and animals were buried millions of years ago and with a passage of time the thermogenic process created hydrocarbons from the same. The various layers of sedimentary rocks behave differently, those with higher permeability allowed the hydrocarbon to migrate and the rocks with no permeability acted as cap rock thereby created a reservoir of hydrocarbon. However, in case of unconventional hydrocarbon resource there is no reservoir of hydrocarbon, the source rock also becomes a reservoir. This could have either trapped hydrocarbon or adsorbed hydrocarbons. This happens when the hydrocarbons produced are not allowed to migrate and rather kept as captive in the available pores of the source rock. In view of this the unconventional hydrocarbon requires secondary process to extract the hydrocarbon.

In case of CBM (Coal Bed Methane) water need to be pumped out to enable absorbed methane released from the coal seam. In the case of Shale rock (popularly known as Shale Plays) the secondary process is the fracking of the

Shale Plays with a high pressure fluid enabling more areas releasing the trapped gas. Figure 1.6 depicts the Shale Gas Exploitation Concept.

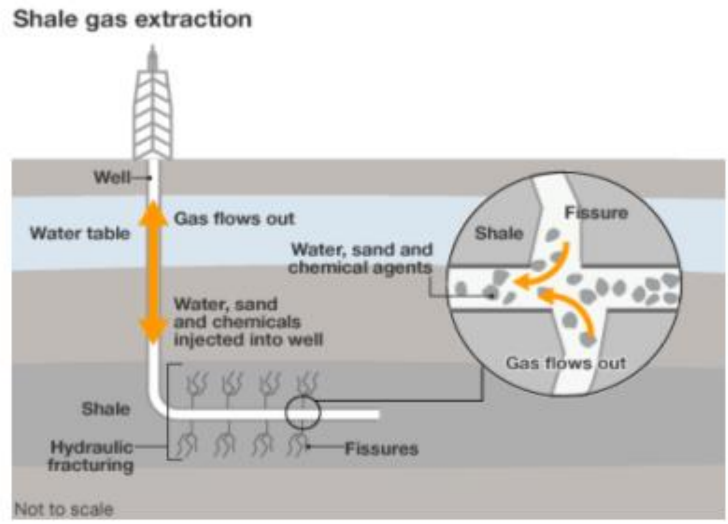

Fig. 1.6: Shale Gas Exploitation Concept (Source: Synopsis)

Shale rocks are a type of sedimentary rocks made of clay sized particles and has a laminated appearance. Shale rocks are in areas where gentle waters have deposited sediments that become compacted *(softschools.com)*. Roughly 70% of earth surface is covered by Shale.

Shale rock can form in plays, rivers, basin and oceans. Roughly 55% of all sedimentary rocks are Shale. Figure 1.7 shows Shale Play with enlarge scale.

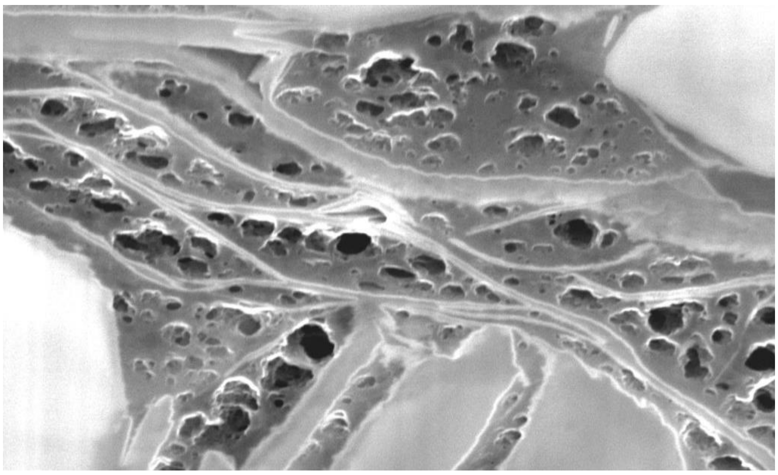

Fig. 1.7: Shale Gas Reservoir (Scale 500 nm, Pore size=70nm)
(Source: Photomicrographs and SEM images courtesy Bob Klimentidis)

1.8.1. World Shale Gas Potential

There are various estimates for the world Shale Gas Potential. Table 1.18 depicts such an estimate prepared by Society of Petroleum Engineers.

Table: 1.18: World Shale Gas Potential (Society of Petroleum Engineers, 2006)

Country/Region	Shale in Position (Tcf)
North America	3840
Latin America	2116
Western Europe	509
Central and Eastern Europe	39
Former Soviet Union	627
Middle East & North Africa	2542
Sub Sahara Africa	274
Asia (India + China)	3526
Asia Pacific	2625
Total	**16098**

1.8.2. Indian Shale Gas Plays and Potential

Study conducted so far indicates presence of various Shale Plays in India located in following basins (Figure 1.8):

1. Cambay Basin
2. Rajasthan Basin
3. Ganges Basin
4. Gondawana Basin
5. Assam Arakan Basin
6. Damodar Valley Basin
7. Cauvery Basin
8. Vindhayas Basin
9. Bengal Basin

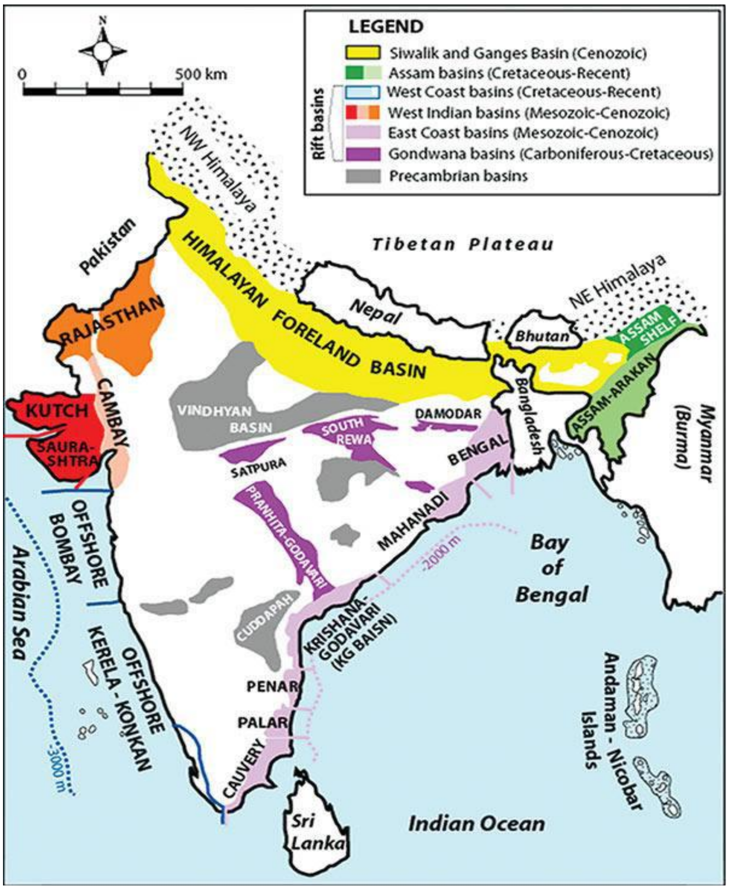

Fig. 1.8: Shale Plays in India (Source: V. K. Rao, 2011)

1.8.3 Understanding Shale and Unconventional HC Resources

In Unconventional Resources (Shale Gas, Tight Gas, and Coal Bed Methane) the hydrocarbon system elements are largely controlled by the properties of a single lithology or closely spaced groups of lithologies further:

- The ability to commercially extract natural gas from Unconventional Resources represents the primary risk in these resource types, and the commerciality of a particular play varies spatially within the region of hydrocarbon occurrence.
- It is critical to identify and evaluate the commerciality of Play Fairways (aka Sweet Spots) and differentiate these fairways from non-commercial areas.
- Although the properties of a single lithology can control Unconventional Resource commerciality, the properties of that single

lithology represent the complex interaction of sedimentation and basin/tectonic evolution.

- Unconventional Resources require artificial stimulation (generally hydraulically induced fractures) in order to produce gas at commercial rates.
- The understanding and predicting commerciality of Unconventional Resources therefore requires understanding of a complex natural system and how that system will respond to engineering intervention.

Figure 1.9 shows Tight Gas reservoir, Figure 1.10 shows Conventional Gas Reservoir, Figure 1.11 shows World un-conventional Gas Basins, Figure 1.12 shows North America's Shale plays.

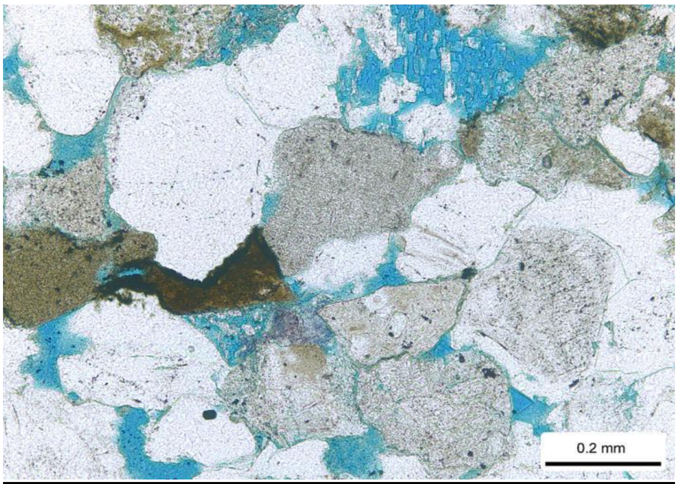

Fig. 1.9: Tight Gas Reservoir (Scale 200micro metre)
(Photomicrographs and SEM images courtesy Bob Klimentidis)

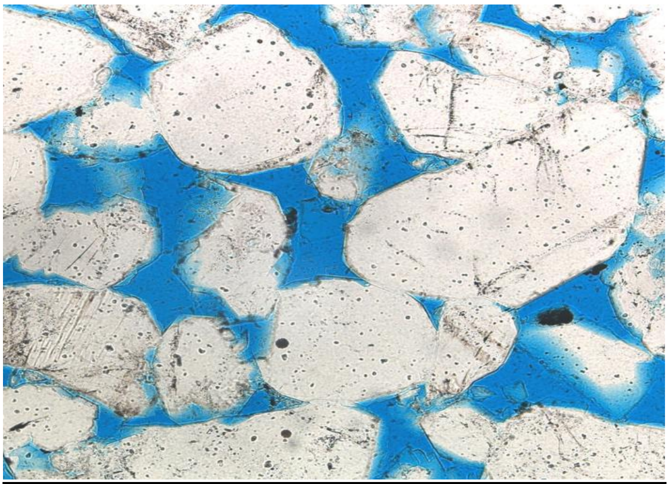

Fig. 1.10: Conventional Gas Reservoir (Scale 200micro metre)

(Source: Photomicrographs and SEM images courtesy Bob Klimentidis)

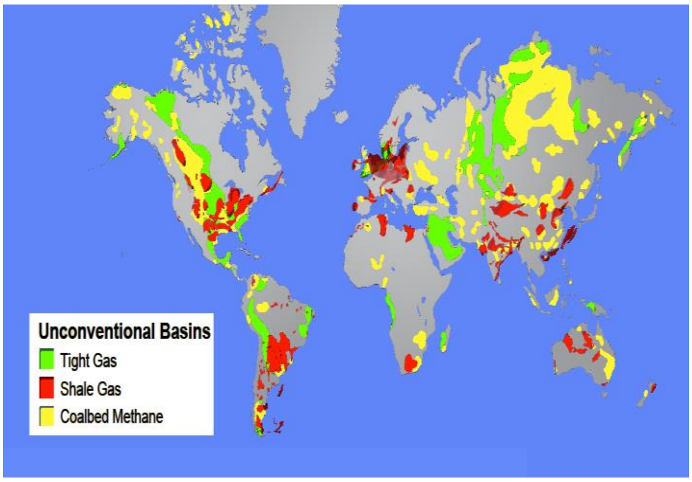

Fig. 1.11: World Un-Conventional Gas Basins
(EIA, Mar 2010, ARI, Dec 2009, EPRC, Dec 2009)

Fig 1.12: North American Shale Plays (Internet site)

1.9 Need for Research

To find the reasons as to why India has not yet taken up the E&E activities in spite of the fact that India needs huge amount of energy for its economic growth and it has reasonably good Shale Gas resources.

1.9.1 The trigger for the research

The trigger for the research has been the energy requirement for economic growth of India with due care for the environment. India's primary energy consumption has reached 563.6 Mtoe against world primary energy consumption of 12,476.6 Mtoe during 2012 (BP, 2013). India's projection of primary energy growth of 3.1% (IEA 2010) is highest in the world. As against this, India witnessed an energy consumption growth of more than this, during 2011 itself the non-commercial primary energy showed a growth of 7.4% even with world economic crises (Table 1.14). India's primary energy consumption growth is shown in Table 1.19

Table 1.19: Indian Primary Energy Consumption and its growth (Planning Commission, 2006)

Year	Primary Energy Consumption (Mtoe)	% of the World	Growth over the prev. year
2008	446.5	3.90	6.28
2009	484.1	4.38	8.40
2010	511.6	4.28	5.50
2011	534.8	4.37	4.40 (7.4*)
2012	563.5	4.52	5.40

**non-conventional energy growth (IEA Report)*

In Indian context, the consumption of primary energy in Power sector constitute a major portion (more than 60% as against a world's average of 43%) and therefore power sector energy demand needs more attention. Referring to table 1.21, the electric power generation from all resources accounts for 2, 23,343.60 MW, which translates to 893 mmscmd of natural gas and 361.7 Mtoe of energy. With a total of 563.5 Mtoe of energy consumed by India during 2012, the Power sector demand accounts for 64% of the primary energy consumed.

The projections of power requirement for the Indian economy growing at 8% and 9% per annum as given in the Table 1.20 below (Ministry of Power, 2005). Taking even a conservative growth of Indian economy at 8% per annum for the next 18 years; India needs an installed capacity of over 950,000 MW from the present 202,000 MW – a capacity addition of over 40,000 MW every year for the next 18 years or around 800 MW every week. Of course the capacity addition figures are much higher if one considers the economic growth rates of over 9% per annum. Today, for each 1% of economic growth, India needs around 0.75% of additional energy (Planning commission, 2011). The Planning Commission of India assessed that this value could fall to 0.67% between 2021 and 2031, however 0.67% is also substantial to source (Planning Commission, 2011).

Table 1.20: Projections for Electricity Requirement in India (Ministry of Power, India 2005)

Year	**Billion kWh**		**Installed Capacity (GW)**	
	8%	**9%**	**8%**	**9%**
2006-07	700	700	140	140
2011-12	1029	1077	206	215
2016-17	1511	1657	303	331
2021-22	2221	2550	445	510
2026-27	3263	3923	655	785
2031-32	4793	6036	962	1207

Table 1.21: Projection for Electricity Requirement (based on falling elasticity) (Integrated Energy Policy 2008)

Year	Billion kWh				Projected Peak Demand (GW)		Installed Capacity Required (GW)	
	Total Energy Requirement @ GDP Growth Rate		Energy Required at Bus Bar @ GDP Growth Rate		@ GDP Growth Rate		@ GDP Growth Rate	
	8%	9%	8%	9%	8%	9%	8%	9%
2003-04	633	633	592	592	89	89	131	131
2006-07	761	774	712	724	107	109	153	155
2011-12	1097	1167	1026	1091	158	168	220	233
2016-17	1524	1687	1425	1577	226	250	306	337
2021-22	2118	2438	1980	2280	323	372	425	488
2026-27	2866	3423	2680	3201	437	522	575	685
2031-32	3880	4806	3628	4493	592	733	778	960

Note: *1. Bus Bar assumes 6.5% auxiliary consumption*

2. Peak demand is estimated assuming system load factor of 76% in 2010, 74% in 2010-11 to 2015-16, 72% in 2016-17 to 2020-21 and 70% for 2021-22 and beyond.

3. Optimal utilization of resources bringing down the ratio between installed Capacities required to peak demand from 1.47 in 2003-04 to 1.31 in 2031-32

The generation capacities needed to support economic growth given by the planning commission are conservative estimates if one goes by the report of

Mckinsey and company (2009). McKinsey calculated that the peak demand will be around 350 GW by 2017 instead of 213 GW as estimated by the Central Electricity Authority (CEA) and 226 GW (assuming 8% annual GDP growth) as projected in the Integrated Energy Policy (Fig 1.13). Accordingly, by 2017, India would require a total installed capacity of 415–440 GW in order to service this demand. This means that over the next 5 years, the country would have to install twice as much capacity as it has been able to install over the last 65 years.

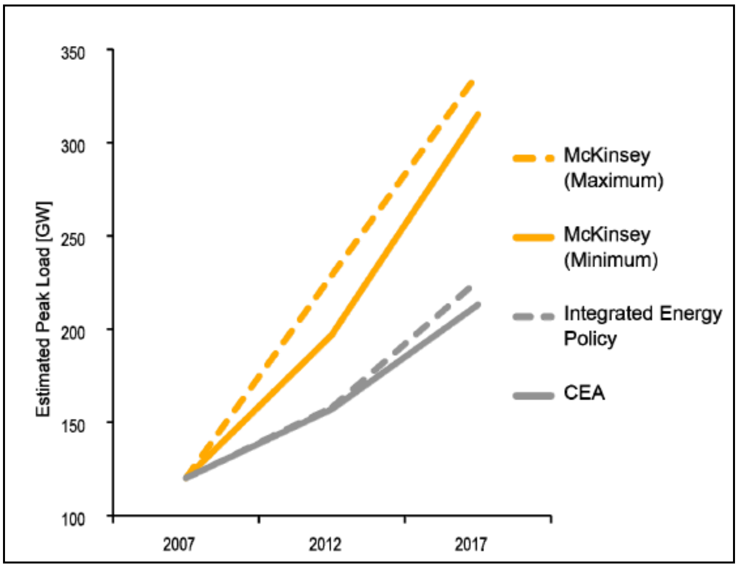

Fig. 1.13: Peak Load Capacities Scenarios for India (Mckinsey Reports, 2009)

The power-generating capacity in India, at present, is not enough to meet the demand either now or in the future (CEA, 2011) (Figure 1.14). In 2010–2011, India experienced a generation deficit of approximately 11% and a corresponding peak load deficit of 13%. India's frequent electricity shortages are estimated to have cost the Indian economy 6-8% of gross domestic product (GDP) in the recent years.

To power the economic growth currently being targeted, it is estimated that India will need to more increase its installed generating capacity to over 300 GW by 2017. The electricity undersupply in India is estimated to cost the economy as much as INR 34 to INR 112 for each missing kilowatt-hour

(NREL, 2010). Thus, the total cost of the power deficit of 100 billion units in financial year 2010–2011 amounted to at least INR 5000 billion (NREL, 2010).

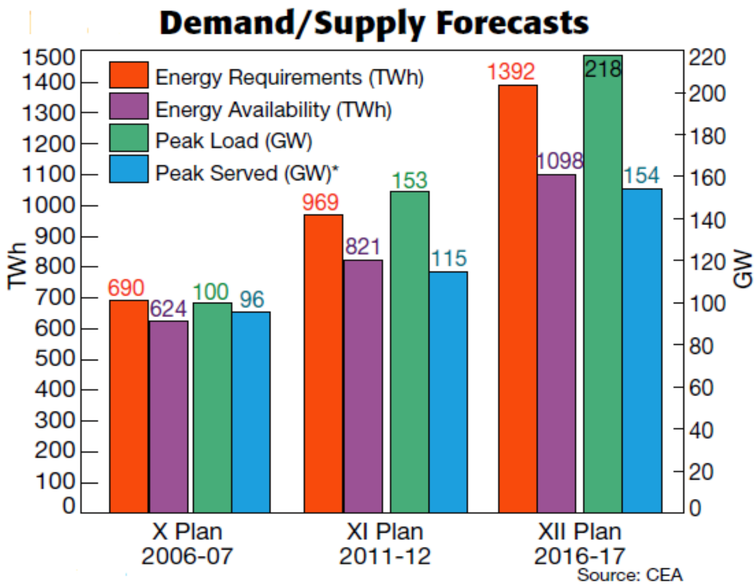

Fig. 1.14: Power Demand and Supply Forecasts in India (CEA, 2011)

While the peak power deficit averaged 4 GW during 2006-07, it worsened to 38 GW during 2011-12 and the gap in deficit is likely to grow to 64GW by 2016-17 as per CEA (Figure 1.14). With power deficit projected to increase further in the foreseeable future, and traditional fossil fuel based generations straining the exchequer, it is expected that India will need additional avenues of power generation to fulfil its energy needs. The government plans to provide universal access and to increase per capita consumption to 1,000 kWh by end of 2012 (IEA, 2009). About 100,000 villages have no access to electricity, and almost 400 million Indians (in 2009 as per IEA) are without electricity coverage. This number is likely to remain more or less the same as per projections of IEA for 2015.

India's per capita consumption (~ 750 kWh) is one of the lowest in the world. There is a critical link between energy and economic activity and low levels of energy consumption has a negative bearing on the quality of life of the people and also on other drivers of livelihood including water, agriculture, and health (Srivastava & Rehman, 2005). The relationship between energy and development is corroborated by the fact that the population living below the poverty line in developing countries reduces as we move from a low level of electrification to higher levels. (Srivastava & Rehman, 2005 – Figure 1.15).

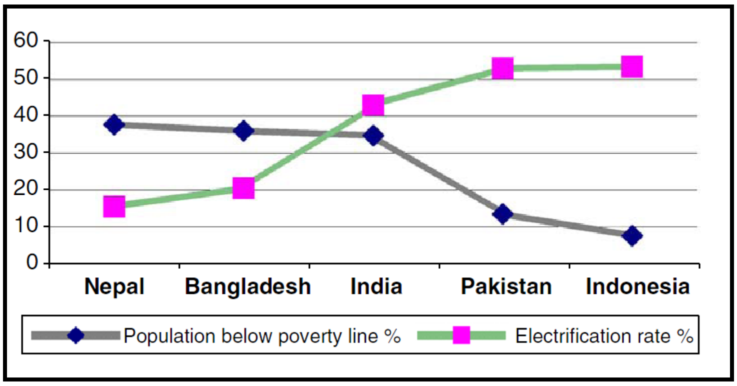

Fig. 1.15: Electrification and Reduction of Poverty in Select Countries (Srivastava & Rehman, 2005)

Also, it is well established that there is a high correlation between energy consumption and economic growth. Between 2000 and 2007 India's economy grew nearly 77 percent and this was matched by a 60 percent increase in electricity consumption (World Bank, 2010) (Figure 1.16)

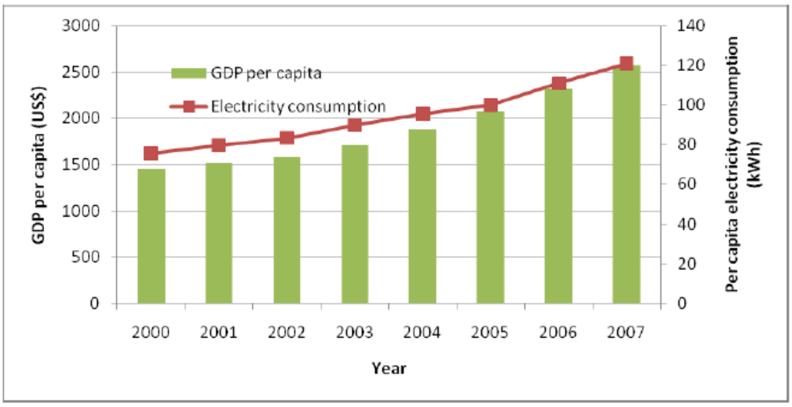

Fig. 1.16: Economic Growth and Electricity Consumption in India (World Bank Report, 2010)

However, the downside to all these spectacular growth is that the CO_2 emissions, as a consequence of energy consumption of predominantly fossil fuel based energy generation, grow along with the economy as shown in the Figure 1.17 below (Rafiq & Salim, 2009).

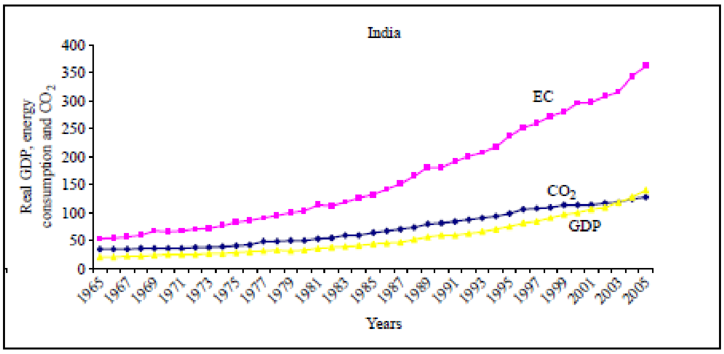

Fig. 1.17: Economy, Energy Consumption and Carbon Emission in India (Rafiq & Salim (2009). GDP, EC and CO_2 represent real output, energy consumption in million tonnes oil equivalent and carbon emission in hundred million tonnes, respectively.)

1.9.2 Limited Hydrocarbon Resources

There is a danger of the world running out of fossil fuels not in too distant future. Coal and other fossil fuels which have taken millions of years to form are likely to deplete soon. In the last two hundred years 60% of available resources have been consumed (BEE, 2003). The remaining 40% of these reserves are continually diminishing at a faster pace with increasing consumption (BEE, 2003) (Figure 1.18).

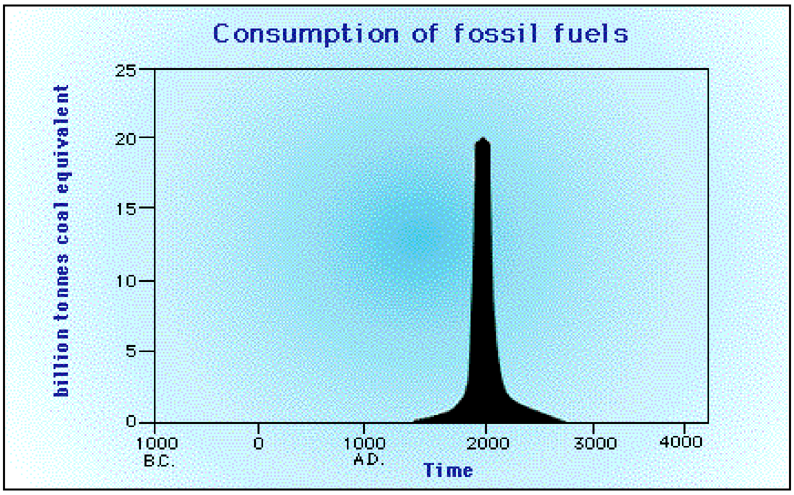

Fig. 1.18: Fossil Fuels Reserves in the World (Bureau of Energy Efficiency, India, 2003)

1.9.3 Consequences of wanton use of fossil fuels

According to the Planning Commission, coal-based thermal power plants are likely to contribute about 300 GW in 2030, up from about 113 GW in 2011

(Planning commission, 2011). With the large number of coal-based thermal power plants are likely to be commissioned; coal consumption in the power sector will be 610 MT up from 380-500 MT by 2011-12 and 1.3 Billion tonnes by 2021-22 (Chikkatur & Sagar, 2009). Meeting the growing energy demand based on the current pattern of energy supply will become increasingly difficult in view of the needs to keep Greenhouse Gases (GHG) emissions and crude oil import bill low.

Table 1.22: CO_2 Emissions by Fuel Source (Breeze P, 2008)

Carbon Dioxide Emissions (t/GWh)	
Coal	964
Oil	726
Gas	484
Nuclear	8
Wind	7
Photovoltaic	5
Large Hydro	4

There are several documents (IPCC, 2012, REN 21, 2012, WISE, 2010) that highlight havoc created by continued use of fossil fuels including air pollution, acid rains, severe storms, flooding, food shortages due to reduced rainfalls, dwindling freshwater supply, loss of biodiversity, health problems and many more. Renewable energy can be an important part of India's plan not only to add new capacity but also to increase energy security by diversifying supply, reduce import dependence, mitigate fuel price volatility and address environmental concerns. Accelerating the use of renewable energy is also essential if India has to meet its commitments of reducing emissions 25% of the 2005 levels (NAPCC, 2008) to reduce its carbon intensity. Figure 1.19 shows CO_2 emissions by fuels.

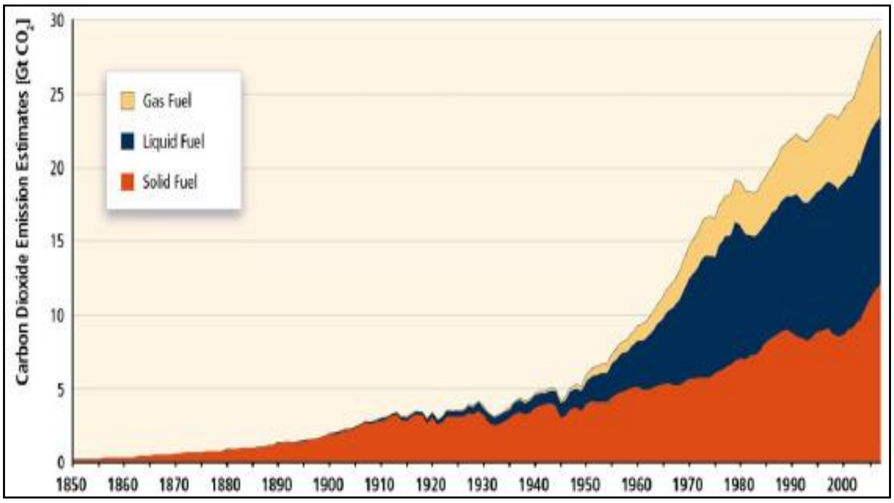

Fig. 1.19: CO_2 Emissions by Fuel Source (IPCC, 2011)

The total Greenhouse gas emissions including CO_2 are shown in Figure 1.20.

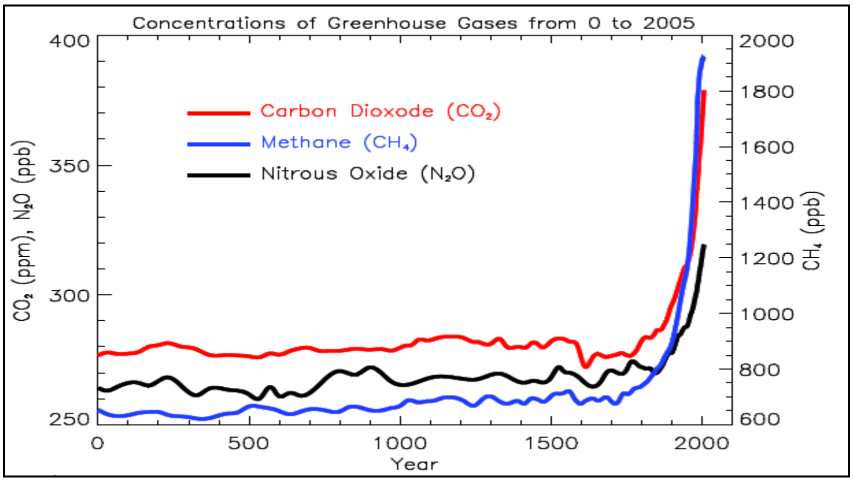

Fig. 1.20: Greenhouse Gases Concentration for the last 20 centuries (Solomon et al. 2007)

Every 1 GW of renewable energy capacity added reduces CO_2 emissions by more than 3 million tons a year. Renewable energy can provide secure electricity supply to foster domestic industrial development, attract new investments, and hence serve as an important employment growth engine, generating additional income.

1.10 Business Problem

The challenges faced by the Indian energy sector are the scarcity of energy resources vis-a-vis demand in general. However, it also has many related issues as below:-

1. The electric power consumes more than 40% of the primary energy resources and still the power generation has been much less than the demand.
2. The Indian Energy Basket has more than 84% share of high polluting energy resources like coal & oil (liquid petroleum products) which are causing environmental problem.
3. India imports more than 70% of petroleum and petroleum products, 30% of natural gas (this share is going to increase once more LNG terminal get commissioned) which puts high burden on the country's exchequers.
4. India therefore, needs to:-
   - (i) Increase power generation to meet the economic growth
   - (ii) Find newer energy resources domestically to reduce the dependency on imported fossil fuels (Coal, Oil & Oil Products and Natural Gas) as they continue to drain the country of its precious foreign exchange reserves apart from the challenges caused due to their price volatility and energy security concerns.
   - (iii) Reduce greenhouse gas emissions caused due to burning of fossil fuels as environmental and ecological concerns continue to mount.
   - (iv) Optimize renewable energy resources as they are indigenous, abundant, clean and inexpensive in the long run.
   - (v) Tap non-conventional hydrocarbon resources to meet the energy demand for economic growth and preserve the environment. Shale Gas is considered to be of high potential to meet growing energy demand with environmental friendly characteristics.

All these five challenges are inter-related as fossil fuels are in short-supply and hence needs to be imported which drains the foreign exchange reserve ($125 Billion in 2010-11, $150 Billion in 2012-13) apart from polluting the environment, which makes it appropriate to encourage eco friendly energy resources. Further since the optimized exploitation of renewable energy resources is also not able to meet growing energy need of the country, the unconventional resources like Shale Gas in the country be exploited with national thrust.

The business problem can hence be stated as how can India leverage additional resources of non conventional energy to support its economic growth, that are eco-friendly fuels and thus non-polluting and are indigenously available thus saving precious foreign exchange .

1.11 Outline of the Study

It is apparent that India needs to encourage growth of unconventional sources of energy to meet its growing energy requirement and to mitigate the risks associated with coal and other polluting fuels. Even with optimization of the share of renewables in energy, the energy demand to a large extend will remain unmet. However, a comprehensive policy is needed to start and sustain the exploitation of Shale Gas as observed in several countries in the world (the literature review section covers this in detail). What constitutes the basic elements of Shale Gas Policy, at a fundamental level, needs to be known to draw up the entire architecture of this intervention.

The main objectives of the study are to conduct a thorough analysis (covering Policy makers, technology providers, technical support providers, service providers, academia and environmentalists) for exploration and exploitation of Shale Gas in India. Study will also take reference of the policies adopted by select European countries (UK, Poland, France, Ukraine and Lithuania), China, US and Australia to find out the supporting and retarding traits in those countries.

This thesis will do exhaustive literature survey of the efforts of Policy makers, E&P players, Service providers and the law enforcing agencies (both executives and judiciary) and there after the factors influencing Shale Gas E&E in India will be identified employing appropriate research model

1.12 Significance of the study

India needs to leverage every avenue of energy resource to meet its growing energy demand side management and adopt energy efficiency measures to make available energy resource for additional requirement of the process industry, manufacturing and service sector to provide adequate energy to enhance its economy and cater to the growing aspirations of its people. While, almost all indigenously available conventional resources have been tapped, unconventional resources and the renewable resources continue to remain an untapped or un-optimized territory.

With domestic production of coal, oil and natural gas, not able to the demand and imports of these fossil fuels burdening the exchequer, India has to quickly exploit the unconventional hydrocarbon resources it has, to get additional electricity and other form of energy into the market.

Currently, there is limited amount of literature available on what could be the Shale Gas resource potential in India, but the exploratory and incidental finds suggest good potential of Shale Gas in India. This thesis will attempt to bridge that gap and will try to add to the existing body of knowledge of literature, which may be useful to policy makers, energy planners and researchers to unlock the potential of Shale Gas in India. The thesis will also analyse the reasons as to why India has not been able to harness Shale Gas in spite of the success of US

1.13 Scope of the Study

The scope of the study is limited to India conditions, covering various probable Shale Plays for understanding the possible factors or traits responsible for the present status of exploration & exploitation of Shale Gas in those plays and what are the changes required to accelerate the process of Shale Gas E&E.

Extensive literature survey of Shale Gas Exploration & Exploitation in US, UK, Ukraine, Poland, Lithuania, France, China, and Australia shall been done on policies adopted by these countries that helped or obstructed the growth of Shale Gas there.

1.14 Organization of the Research Report (Thesis)

The study consists of **six chapters**. The first chapter is the "I**ntroduction"** to the topic including the energy needs of India to sustain its current economic growth, the contribution of renewable and unconventional resources in the energy mix in the country. This chapter also mentions that India needs to tap into unconventional resources of energy.

The second chapter is "**Review of Literature"**, which studies the global Shale Gas scenario, present status of Shale Gas in US, Canada, Europe, China, Australia, and India with reference to the policies and other factors to encourage the Shale Gas growth in India. This chapter also highlights the gap in availability of literature in the area of Shale Gas Policy and Shale Gas E&E in India. Variables are identified through literature review.

The third chapter explains the "R**esearch Design"**, the rationale of the study followed by the statement of the research problem, objectives of the study, research questions, scope of the study, research model, the research methodology, sampling process, Instrument design, questionnaire format, scale formation, Instrument reliability, Instrument validity, pilot testing, data collection and operating definitions of variables found through literature survey and analytical tools used for analysis of primary data.

The fourth chapter deals with the "A**nalysis and Interpretations"**. The factor analysis reduces the 42 variables, identified through literature survey and administered as a questionnaire to 341 respondents, into 12 factors and then the logistic regression gives the log odds of E&E of Shale Gas in India. The formulated research model is empirically validated and consequent results are reported.

The fifth chapter is the "**Learning from Global Experience**" based on the Shale Gas E&E programmes pursued by select countries (US, Canada, UK, Poland, Ukraine, Lithuania, China and Australia), identify a set of Shale Gas policies, programme and procedure from these countries that can be adopted by India and identify a set of policy imperatives that need to be uniquely tailored by India with a view to pursue the Shale Gas E&E in India.

Finally the Sixth chapter gives the "C**onclusions and Recommendations"**. Bibliography is given at the end as reference.

1.15 Concluding Remarks

India is one of the fastest growing economies in the world and an emerging superpower. Increase in energy requirement to support this growth in economy is essential. However, continued reliance on conventional fossil fuels will prove unviable from the ecology, sustainability and economic point of view. India even after tapping its renewable energy potential to an optimized level will not be able to sustain its economic growth and therefore exploitation of unconventional resources is essential.

The challenges faced by Shale Gas E&E have been discussed with respect to the success story of US and constraints in Europe especially in France, Poland and UK. However, what's missing is formulation of comprehensive policy to harness Shale Gas. Extensive literature survey was conducted to identify the basic elements or fundamental building blocks that need to be addressed to accelerate the growth of Shale Gas E&E in India. Literature survey was focussed to understand the success mantras of US in promoting Shale Gas and whether these learning can be leveraged by India to encourage Shale Gas E&E in the country.

Currently there is a dearth of literature on Shale Gas E&E in India. This thesis also is an attempt to fill the gap owing to nascence of literature on factors that may drive the growth of Shale Gas for India, by identifying a set of variables that form the core components of Shale Gas E&E policy to develop and empirically test a model for it. It is hoped that this thesis may add to the existing body of knowledge as literature on the Shale Gas in India is in nascent stage.

1.16 Summarizing Introduction

To power the economic growth, India will need to increase its power generating capacity substantially in the next 5 years (Planning Commission of India, 2010). Most of the electrical energy globally (India is not exception) has been derived from fossil fuels and in the future world will face the fuel crisis as fossil fuels in the world are limited (Saidur et al., 2010).

If India fails to protect its environment, it would face a huge economic and ecological challenge and hence for its overall development India needs to adopt eco-friendly energy resources like natural gas or renewable sources for power generation (Pode, 2010). Emissions from petroleum & petroleum products, huge import bills will force India to adopt natural gas or renewable sources in the immediate future in an accelerated manner (Bhattacharya & Jana, 2009).

Globally, in terms of energy volumes, the renewables are not able to cope up with the increasing energy demand and the major thrust will therefore be on natural gas both for short term and long term energy need. Further the natural gas potential from conventional resources is limited and the hopes are therefore pegged on to the unconventional resources, of which Shale Gas in the one commercially exploited in US and Canada.

This research will study the various aspects of the Shale Gas Exploration & Exploitation globally and bring out the issues influencing Shale Gas E&E. With the help of market research, the study will identify a set of factors that form the core components of influence on Shale Gas E&E in India. The Report will examine these factors with a view to recommend the course of action for Shale Gas E&E in India including devising a framework for effecting implementation.

Chapter 2
Review of literature

2.1 Introduction

In this chapter the learning from the earlier research work carried by scholars, industry associations, policy makers and thought-leaders in the Shale Gas Exploration and Exploitation have been described to capture the essence of the existing knowledge that exist in this field. Once the current literature is studied with a view to develop an overall understanding of the scenario as it transpires today, it becomes imperative to build the foundation of existing quantum of knowledge by identifying the research gaps that exist. The research gap becomes the starting point of this research work.

The objectives of the literature survey are:

1. To understand the overall Shale Gas Exploration and Exploitation (E&E) scenario in the world
2. To study the global Shale Gas E&E scenario and highlight the supportive policies (covering exploration, exploitation, marketing, demand side and supply side policies that encompass both the Conventional and unconventional hydrocarbon) that have helped the growth of Shale Gas in the world
3. To discuss the overall Shale Gas scenario in US, Europe, Australia, China and India with a view to explore the literature that analyses the contribution of supportive policies in the growth of Shale Gas.
4. To review the existing Hydrocarbon E&P and Shale Gas E&E policies in India, those that have contributed to the growth of Shale Gas in particular (Conventional Hydrocarbon in general) in India

5. To study the existing Shale Gas E&E scenario in India and examine the body of knowledge that highlights the growth of Shale Gas in India and its supportive policies
6. To briefly discuss about the Shale Gas prospects/ feasibility in India – based on the experimental data available from various studies.
7. To identify and elaborate on the list of variables identified through literature survey that forms the master list of core building blocks of a comprehensive Shale Gas E&E policy in India.
8. To identify the research gap in the existing body of knowledge, which then becomes the basis for conducting this research work and the thesis

2.2 Global Shale Gas Status

Shale Plays are the matured basins formed as result of millions of year's geological activities. Table 2.1 gives a snap shot of such plays in time lines.

Table 2.1: Geologic Time Scale for Shale Plays (McRoberts, 1998)

Eon	Era	Period	Epoch	Million Years
Phanerozoic	Cenozoic	Quaternary	Holocene	
			Pleistocene	
		Neogene	Pliocene	1.5
			Miocene	
		Paleogene	Oligocene	23
			Eocene	
			Paleocene	
	Mesozoic	Cretaceous		65
		Jurassic		
		Triassic		
	Paleozoic	Permian		250
		Carboniferous – Pennsylvanian		
		Carboniferous – Mississippian		
		Devonian		
		Silurian		
		Ordovician		
		Cambrian		
Precambrian		Proterozoic		540
		Archean		2500
		Hadean		3800 4600

There have been many estimates of the Shale Gas Potential in the world. The first of such estimate was done by the Society of Petroleum Engineers. As shown in Table 1.18, it gave an estimate of the Shale Reserves of 16098 Tcf.

Shale Gas estimates has been revised several times as the exploration and exploitation progresses. The US Shale Gas exploration, a game changer in the world, has also undergone several revisions for the Shale Gas potential. In future the exploitation of unconventional Hydrocarbon resources is expected to get global thrust. Table 2.2 gives the growth of unconventional in comparison to conventional hydrocarbon resources.

Table 2.2: Share of Conventional and Unconventional Gas (IEA, EIA Report)

	Conventional Gas (Tcf)	Unconventional Gas (Tcf)	Total	Unconventional as % of Total
2007	96.4	12	108.4	12
2015	107.1	14.3	121.4	12
2020	112.5	17.9	130.4	14
2025	119.6	21.4	141.1	15
2030	130.4	25	155.4	16

The Shale Plays are ever changing and no two plays are similar. One needs to access the various Shale plays before concluding the potential. US Shale Plays are shown in Figure 2.1.

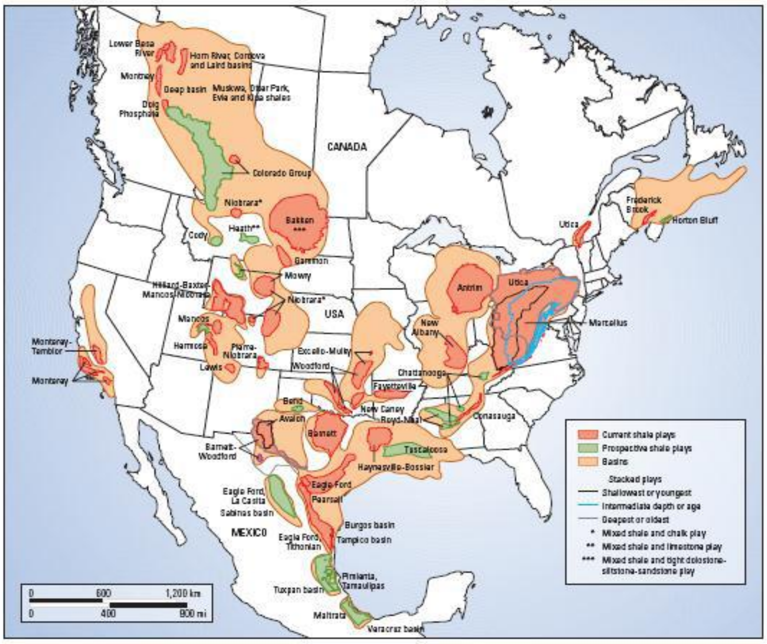

Fig. 2.1: North American Shales – Ever Changing

2.3 Literature Study Methodology

The available literature on Shale Gas was scanned through various means like professional web-sites, books, periodicals, national and international conferences and the news paper reporting. The researcher himself has presented papers on Shale Gas in various conferences like:

Indo US Shale Gas Conference, 2010 (New Delhi); Shale Gas World - Europe - 2010 (Poland); Shale Gas World – Asia, 2011 (Beijing); Shale Gas World - Asia, 2012 (Singapore); International Conference on Energy Infrastructure (ICEI), 2013 (Gandhinagar); World Shale Gas Conference, 2013 (New Delhi); World PETROCOAL Conference, 2014 (New Delhi); Conference on "India's Readiness for tapping Unconventional Hydrocarbon Resources", 2014 (New Delhi). *(Detail of paper presented/ session chaired are placed at **Appendix-A**)*

The literature survey carried out has been put under following groups;

(i) North American (US & Canadian) Experience
(ii) European Experience
(iii) Asian Experience
(iv) Australian Experience
(v) Other General Experience

2.4 North American (US & Canadian) Experience

In US the efforts for exploration of Shale Gas have been there for more than a decade and the production was increased when conventional gas price went high in 2008.

The estimates of US Shale Gas have been varying from source to source who under took such estimation. Table 2.3 below gives a compilation of such estimates.

Table 2.3: US Shale Gas Potential (Compiled from various sources)

Year	Shale Gas Resource Potential (TCF)	Estimated By
2006	3840	Society of Petroleum Engineers
2008	2247	Influential Study
2009	1836	Potential Gas Committee*

*establishes by the University of Colorado, School of Mines in June 2009. This is the highest estimate ever released by that group *(GSGI 2009*)

2.4.1 Types of Shale Plays in US and Canada

Among various kinds of Shale plays, the following types are more prevalent.

i. **Barnett Shale** - Barnett Shale is marine basinal deposit of middle to late Mississippian age (290 to 300 million years ago). This is the largest natural gas play in the United State. The location of Barnett Shale is Fort Worth Basin Texas. The Fort Worth metropolitan area above this Shale is highly populated. The spread of Barnett Shale is shown in Table 2.5. The gas production from Barnett Shale has been 10 bcf in 1985 and in 2005 it reached 360 bcf (Eric Potter, 2012). Another Barnett Shale formation in Delaware has different characteristics. Barnett and Woodford formation in the Delaware Basin (a part of Permian basin) has Barnett Shale which is deep and clay rich Shale. So at present it is not working like everyone thought it would. It is no rich in TOC as the ford worth basin Shale.

ii. **Caney and Woodford Formation** - are located in south central Oklahoma. The Shale plays are in early stage of development.

iii. **Eagle Ford Shale** - The Eagle Ford Shale was deposited millions of years ago in the Cretaceous Period when much of Texas was a shallow sea. It's 50 miles wide and extends about 400 miles across the state, from the border to East Texas. The formation generally produces more oil on its northern arc; more natural gas, or so-called "dry gas" on its southern arc; and more natural gas liquids such as propane and butane in-between. For now, the Eagle Ford is a liquids play that produces a greater percentage of crude oil or natural gas liquids. (www.mysanantonio.com). The nature of Eagle Ford Shale is very tight which has low clay content, high carbonate and is an extensional basin. This Shale is very prolific play that for the most part is bounded on top by the Austin choke formation and gives liquid and gas. The Pennsylvanian age of Shale varies from 292 to 300 million years.

iv. **Haynesville Shale/Bossier Shale -** Located in east Texas and north-western Louisiana and has relatively deep deposits ranging from 3-4 km below ground. This is the top producing US Shale

v. **Floyd Formation -** in Black warrior basin in North West Alabama

vi. **Fayetteville Shale -** This type of Shale Plays are located in Arkansas and eastern Oklahoma. These Shales have similar age and geologic character as Barnett shale. Estimated gas volume touches 17 tcf.

vii. **Marcellus Shale -** This is Devonian Shale located in six US states covering north eastern states including New York and Pennsylvania. Range Resources Corporation was the first company to drill economically producing well in Marcellus formation (Gas Strategies, 2011)

viii. **Antrim Shale –** This is located in Michigan Basin next to the Barnett Shale. The Antrim Shale has been one of the most actively developed shale gas plays. Most of the expansion took place in late 1980s. This shale has shallow depth and small stratigraphic thickness. (Gas Strategies, 2011)

ix. **New Albany Shale** – this is located in the Illinois basin covering portion of Illinois, Indiana and Kentucky (Gas Strategies, 2011)

Comparison of various types of Shale Plays is shown in Table 2.4.

Table 2.4: US Shale Plays - Comparison (Arther, 2008)

COMPARISON OF DATA FOR THE GAS SHALES IN THE UNITED STATES							
	Barnett	Fayetteville	Haynesville	Marcellus	Woodford	Antrim	New Albany
Estimated Basin Area, square miles	5,000	9,000	9,000	95,000	11,000	12,000	43,500
Depth, ft	6, 500 - 8,500	1,000 - 7,000	10,500 -13,500	4,000 - 8,500	6,000 – 11,000	600 – 2,200	500 – 2,000
Net Thickness, ft	100-600	20-200	200[11]- 300	50-200	120-220	70-12	50-100
Depth to Base of Treatable Water, ft	~1200	~500	~400	~850	~400	~300	~400
Rock Column between Pay and Base of Treatable Water	5,300– 7,300	500 – 6,500	10,100 – 13,100	2,125 – 7,650	5,600 – 10,600	300 – 1,900	100 – 1,600
Total Organic Carbon, %	4.5	4.0-9.8	0.5 – 4.0	3-12	1-14	1-20	1-25
Total Porosity, %	4-5	2-8	8-9	10	3-9	9	10-14
Gas Content, scf/ton	300-350	60-220	100-330	60-100	200-300	40-100	40-80
Water Production, Barrels water/day	0	0	0	0		5-500	5-500
Well spacing, Acres	60-160	80-160	40-560	40-160	640	40-160	80
Original Gas-In-Place, Tcf	327	52	717	1,500	52	76	160
Reserves, Tcf	44	41.6	251	262, 500	11.4	20	19.2
Est. Gas Production, mcf/day/well	338	530	625-1,800	3,100	415	125-200	

NOTE: See paper for data sources (Arthur, et. al., November 2008)

US Shale Gas production success has become a game changer. Natural gas production from unconventional gas resources has significantly increased with production from shale gas formation rising almost 65% from 2007 to 2008. The game changing nature of shale gas is due to both increased production and significant increase in the estimated natural gas resource base.(Gas Strategies, 2011). The gas production profile in US is depicted in Figure 2.2 below.

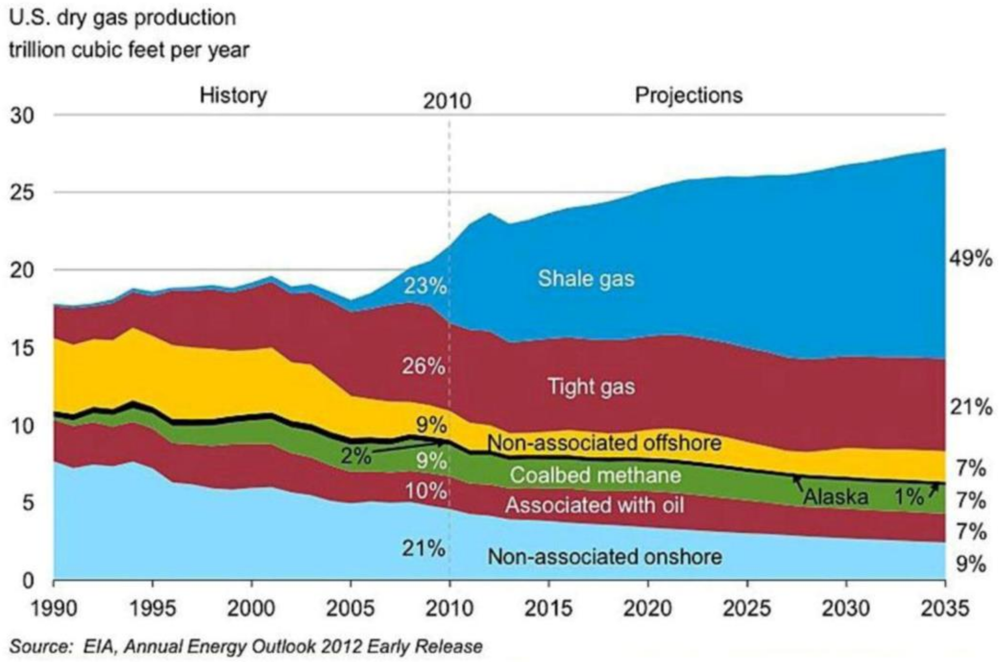

Fig. 2.2: US Gas Production Past and Future Projection (EIA,2012)

However, all is not well in US for Shale Gas E&E. Doug Norlen, Policy Director of Pacific Environment, an advocacy and research organisation that tracks federal and corporate financing of energy project, abroad says “These (Shale Gas) projects have already started causing steep inflation in **costs of local housing and services**, and except for lucky few who get temporary construction jobs, the economic condition for local communities can actually get worse”.

In South Africa and many other countries (including India), minerals under (land) property are owned by government and not by individuals. It is interesting to note that, if the revolution continues in the US and extends to the rest of the world, energy consumers can anticipate a future dominated by cheap gas. However, if it falters and the current hype about Shale Gas process an illusion, the world will face serious gas shortage in the medium term. (Prof, Paul Steven, 2010)

Shale Gas and tight gas deposits are spread over much wider area as compared to conventional hydrocarbons. Shale Gas deposits in place are around 0.2 to 3.2 bcm per km^2 of territory as compared with 2 to 5 BCM per km^2 for conventional gas (EIA, 2009).

This Shale Gas & tight gas require **many more wells to be drilled**. Furthermore, the wells deplete much faster than conventional gas wells and their depletion profile is an early peak followed by a rapid decline. Experiment on Barnett Shale Plays shows wells depleting by 39% in the year 1 & 2, 50% between years 1 & 3, and 95% between years 1 & 10. Thus, Shale wells might have a life of 8-10 years only compared with 30-40 years for conventional gas wells.

These technical characteristics give rise to two key questions about “The Shale Gas revolution in US; will it continue or frizzle out; and will it be replicated elsewhere?”

Survey of energy Resources – Focus on Shale Gas – World Energy Council 2010 observed that "Given the fact that there are still significantly producing reserves of conventional natural gas around the world, there may not be sufficient incentive on a regional basis, to identify or exploit unconventional natural gas in near term."

It may also be the case that the amount of energy needed to produce unconventional gas (UG) is considerably higher than the conventional gas.

2.4.2 Advantages of expanding use of Shale Gas

1. Adding significant quantities of Natural Gas to the global resource base.
2. Shorter time to first production compared to conventional gas.
3. Using cleaner energy source.
4. Broader use of new drilling technologies around the world.
5. Improved security of supply for gas importing countries.

2.4.3 Drawbacks of expanding use of Shale Gas

1. Uncertainty over cost and affordability.
2. Doubt about the environmental acceptability of the production technology.
3. Uncertain rate of decline which may materially impact reserve estimate
4. Local opposition to Shale Gas development

2.4.4 Other Issues

Water associated with the gas is produced at some stage of the recovery, usually at the tail end of the process, this is the water trapped in the pores of rock or near the Shale formation and is called connate water.

In some cases early production of water occurs due to infiltration of the fracture into the underlying saline water body. The Ellenberger and Onondaga are water bearing formations below the Barnett and Marcellus reservoir, respectively. By contrast, some Shale Gas plays are very dry, i.e., they do not have connate water, as for example portion of Haynesville (Louisiana) Shale.

Whether from connate water or the water layers below the water will be very saline, in part, because of the age of the rock. Disposal of water is a major issue, which may cost USD 10 per barrel or USD 500,000 per well.

The water coming out of the Shale may contain bacteria or even radioactive material. Their treatment is essential because these bacteria's can cause production of H_2S down hole which makes the gas less valuable and cause corrosion. Reverse Osmosis (RO) can remove salts and bacteria's and Ion Exchange process can remove metals.

There have also been reports on contamination of potable water by gas or hydro fracing fluid. Most recently, sensationalised by a documentary "GASLAND", the popular literature ascribes two hypotheses to the phenomenon. One is the migration of the fracturing operation cracks from the reservoirs upto the water body. The other is gas or fluid leakage from well.
The aggressive pursuit of Shale Gas is causing production losses at traditional gas fields.

Shale Gas revolution in US has also sent ripples throughout the world, and Europe is one of them. A study – "Shale Gas in EUROPE: A revolution in making" reference; "Gas Matter, published in March, 2010 by *Gasstrategies.com*" describes that Europe's most promising basins (Shale) lye offshore, particularly in the North Sea, and offshore production of Shale Gas has not been tried yet (the likely issue here is not technology but economics).
Water contamination by water mixed with chemical for hydraulic fracking is feared. Concerns have been sufficiently stayed for New York State, to

essentially impose a moratorium on Shale Gas drilling near a water shed that supplies drinking water to the New York City.

The uncertainly of Shale Gas estimates is quite certain. US alone have many varied Shale Gas estimated reserves. For example, an influential study done in 2008, estimated that North America has 2247 TCF of Natural Gas reserves. In June, 2009, the potential gas committee established by University of Colorado School of Mines established the US Natural Gas based resource base at 1836 TCF, the highest estimate ever released by that Group (Susan L. Sakmar, 2008)

Disposal of the water flowing from Shale Gas well including the return frac water is becoming a problem in US. The EPA's recent approval of the drilling of 9 new wastewater injection wells in Elk County for the disposal of Marcellus and Utica produced water is a testament to the volumes of produced water that are currently coming out of the region. The demand for innovative treatments and disposal options is rapidly on the rise as operators seek the most cost-effective strategies for handling the increasing volumes of excess produced water that cannot be re-used in operations.

Karen Johnson, Chief of EPA Region III Groundwater & Enforcement Branch, has said more are in the offing for the state, including three more new disposal wells that could receive federal permits. *"We continue to have frequent meetings with [gas well] operators and a number of additional permits are under review,"* going on to say; *"Independent companies and big operators are all saying they are going to need more capacity for disposal."*

While several E&P companies in the Marcellus and Utica are currently recycling produced water for reuse in the next frac job, the volume of water currently being produced is starting to increase beyond what can be recycled. The demand for innovative treatments and disposal options is on the rise as operators seek the most cost-effective strategies for handling the increasing volumes of excess produced water that cannot be reused in operations. To address the issues of water from Marcellus and Utica Shales, a global conference was organized on 28-29 March, 2014, Canonsburg, PA in US. *(Good input for India as the water scarcity is daunting the Shale Gas E&E Initiative)*

The Big Questions Are However:

- What **levels** will this produced water need to be treated to?
- How much extra **capacity** will these disposal wells provide?
- What **treatment** method has proved the most effective for disposal?
- Will these disposal wells be the most **cost-effective** solution in the long run?
- What are the **alternative disposal options** besides injection wells?
- What are the latest **disposal regulations**?

Water Disposal Strategy: Understanding how an operator has designed a Cost-Effective long-term strategy to dispose of excess water that cannot be recycled. In US context the following approach is a welcome decision (*info@american-business-conferences.com*)

Public Water Treatment: Establishing the pre-treatment standards for discharge into public treatment facilities to determine the minimal level of treatment required

Disposal Permitting: Detailing specifications of the latest Chapter-78 and Chapter-13 Regulations to ascertain the implications on disposal operations

Evaporation: Examining evaporation systems as a viable alternative to disposal wells.

Water Transfer collaboration: Understanding how operators can collaborate to develop a cost-effective pipeline system to minimize the overall cost of water handling.

2.4.5 Canadian Shale

The larger concentration of Shale plays lies within the western Canada sedimentary basin which extends from north east British Colombia to south west Manitoba. The other basins are located in the arctic North West territories, Yukon, Quebec, South Ontario, New Brunswick and Nova Scotia. Shale Gas estimates for Canada is 1100 tcf of which the marketable resources are 128 to 343 tcf. Various Shale basins in Canada are:

- **(i) Utica Shale** – is fine grained black colour Shale found in Quebec. Similar to Utica Shale found in South Ohio (US)
- **(ii) Horn River Basin Shale –** Found in North East British Colombia and is relatively new natural gas discovery. This is the largest known Shale Gas find in Canada. Resource Potential of 250 Tcf of which 10 to 20% is recoverable. A 36 inch pipeline is planned to connect this gas source to existing Trans Canada Pipeline system (ww.ogj,2012)
- **(iii) Alberta Bakken Shale** – As many as 15 prospective Shale Gas formations has so far been identified. A report by Alberta geological survey estimates 1291 Tcf gas in place in the five formations, namely Duvernay, Muskwa, Basal Banff/Exshaw, North Nordegg and the Wilrich.
- **(iv)Montney Shale –** Located in west Canada is just south of horn river shale and extends to east of Alberta. Estimated reserves of 50 Tcf (ww.ogi, 2012)
- **(v) Cardium Shale** – Located in west Canada covering Albreta and extend up to British Columbia and down to Montana. Currently conventional Natural Gas is being produced from these formation. (*http://www.oilshalegas.com/cardiumshale.html*)

Canadian Shale program is getting required thrust. The plan is to explore all Shale Basins and establish one LNG export terminal in West (Kitimat) and in the East (St. Jose) by converting this from regasification to liquefaction terminal (Wesfoote, 2012).

Table 2.5: Location of US Shale Plays (Compiled from various sources)

Shale Play Type	Location
Barnett	Fort Worth Dallas, Southern Texas counties-Johnson Hill, Bosque, Mc Lennan, Tarrant County
Eagle ford	South Texas
Fayetteville	Arkansas
Haynesville	East Texas , western Louisiana
Horn river	Canada
Marcellus	Delaware river Basin, Pennsylvania, Ohio and New York, west east Virginia
Montney	Canada
New Albania	Canada
Woodford	Illinois, Indiana, Kentucky

2.4.6 Challenges to developing Global Shale Gas

The IEA has recognised that there are numerous challenges to replicate the success of US Shale Gas revolution overseas. There are several issues raised by IEA that may impact the development of global unconventional gas resources. These include:

1. Limited studies on un-conventional gas potential around the world
2. Environmental concerns
3. Fiscal condition
4. Landowner acceptance: US land owners get USD 25,000/acre (INR 12,50,000/acre) and 25% of production revenue as Royalty
5. Interference from local authorities
6. Pipeline and Infrastructural issues
7. Availability of technology, equipment and skilled labour force, and
8. Gas players experience.

Zurich American Insurance Company brought out in 2011, a report which analyses the pros and cons of the Shale Gas revolution in US. As per this report, the two of the largest Shale Gas formations Barnett and Marcellus are located close to major urban population centres. The Marcellus Shale is also located next to abandoned coal mining operations where methane gas is present. In the North East, the legacy of environmental damage from coal mining operations still weighs heavy over public officials and residents.

Environmental concerns for Shale Gas drilling include:

1. Potential chemical spills causing pollution of local ponds and irrigation canals
2. Natural Gas or fracturing chemical seeping into the water table due to an inadequate casing cementing.
3. Natural Gas leaching into municipal drinking water.
4. Inadequate disposal of fracking mixture.
5. High water volume required for Shale Gas fracturing.
6. Surface disturbance
7. Radioactivity from NORM inside shale well
8. Release of Greenhouse Gases during Shale Gas Production and Processing
9. Traffic congestion problems

(karmakar GP, Pandey B, Sircar A. 2011)

The US safeguards against damage to environment and ground water and the risk cover for operators. Regulations governing hydraulic fracturing have been in existence for 50 years. Multiple, federal, state and local government rules address the environmental protection during Shale Gas operations including the protection of water resources. These rules cover:

1. Well permitting
2. Well material & construction
3. Safe disposal of unused hydraulic fracturing fluids
4. Water testing, and
5. Chemical record keeping and reporting

Although fracturing fluids are 98% water, concern has been raised about the nature of the additives in the remaining 2% of the fluids. Ten states already require some level of disclosure of substances used in Shale Gas drilling. On September 9, 2010, the Environmental Protection Agency (EPA) issued voluntary information requests to 9 leading national and regional hydraulic fracturing service providers. The EPA is seeking the information on the chemical composition of fluids used in hydraulic fracturing process, data on the impacts of the chemical on human health and environment, Standard Operating Procedure (SOP) at hydraulic fracturing sites and the locations of the sites where fracturing has been concluded. The data will be incorporated into the hydraulic fracturing study.

In the Marcellus area, Delaware River Basin commission recently published new regulations that govern a range of drilling activities, including requiring drilling companies to post a bond of USD 1,25,000 (INR 62,50,000) per well to cover the plugging and restoration of abandoned wells and any remediation necessary.

Further, with the kind of awareness being generated globally, the insurance coverage is also likely to change from present practice of a sudden accidental coverage, which has a defined reporting and discovery periods of 72 hrs for discovery and 30 days for reporting, as an example. The paper published by Zurich, describes that the Shale Gas operator, may in future be liable to take “Pollution Policy” which provides for “Gradual Accident Coverage” and don’t have defined reporting provisions. For example, in the case of a fracturing fluid leaking into water supply, general liability would not cover this incident while a pollution policy would. An Environmental Pollution Policy (EPP) can bridge the coverage gap that exists, if a Shale Gas operator is only covered by General Liability.

Hannah Wiseman in his article “Untested Waters: The rise of hydraulic fracturing in oil and gas production and need to revisit regulation” has observed that the fracturing was “first used commercially in 1949” and “is now essential to economic production of oil and gas and commonly used throughout the United States and the world”. The Pennsylvania Supreme Court observed as early as 1983.

Further the Pennsylvania Supreme Court has given two landmark verdicts in the litigation concerning Shale Gas.

1. Range Resources case *(Range Resources Appalachia, LLC versus Salem township, 2009 WL 413748, Pa. Feb. 2009) -*

   Salem Township enacted an ordinance that was aimed at regulating the land development and surface uses that accompany drilling for oil and Gas. Several oil and Gas companies brought an action asking the common court to make various declarations. The trial court held that the Pennsylvania Oil and Gas Act pre-empted the Regulations the township had enacted. The Pennsylvania Supreme Court eventually affirmed the holding of both trial court and commonwealth court. In its case opinion, the Pennsylvania supreme court discussed the importance of a uniform state level regulatory scheme for Oil and Gas drilling- a factor that both the involved Oil and Gas Companies and Pennsylvania Department of Environmental Pollution (PDEP) put forth as an important policy consideration. The PDEP pointed out, however, that the policy goal of promoting uniformity should not lead to the ousting of all forms of municipal regulations of oil and gas operations.

2. The Huntley Case (*Huntley & Huntley, Inc. versus. Borough Council of Borough of Oakmont,2009, WL413723, Pa. Feb. 2009) –*

   This case addresses the extent to which municipalities shall be allowed to set standards associated with drilling within their jurisdictions.

   According to Pennsylvania S.C decision, Zoning- ordinances should be viewed separately from regulations that the oil and gas Act would definitely pre-empt. The court held that “absent further legislative guidance, Section 602 (of oil and gas Act) reference to “features of oil and gas well operations regulated by this Act” pertains to technical aspects of the well functioning and matters ancillary thereto (such as registration, bonding and well site restoration, rather than the well’s location”. In other words, municipalities are not stripped of their ability- to dedicate where certain types of land use may occur within their jurisdiction, even if further regulation of those uses is pre-empted by State law. In addition, the court noted that the policy interest accompanying development of oil and gas resources and land use are not so similar that they serve only one function. It asserted that:

> The state interest in oil and gas development is centred primarily on the efficient production and utilization of the natural resources in the state, a county's interest in land use control is one of orderly development and use of land in a manner consistent with local demographic and environmental concerns.

Note: *The sum total of above two rulings of the Pennsylvania Supreme Court can be summarised as: The standards set at different levels of Government should not be eliminated. They should however flew into one program with enough manpower to monitor all of the laws and regulations and keep oil and gas companies both informed about the requirements that must be met and satisfied at the speed with which the relative importance of all of the competing interest are weighted and a drilling permit is either issued or drilled.*

2.4.7 Resistance in US

34 of the US states having gas production contributing 99% domestic oil and gas produced. US has in position the following Acts and regulations to ensure Water, Air and Environmental standards:

1. Clean Water Act – 1972, (Federal Act)
2. Clean Air Act – 1972, (Federal Act)
3. Safe Drinking Water Act, (Federal Act)
4. Energy and Minerals Act – 2005, (Federal Act)
5. Surface disposal of fracking waste and similar drilling wastes (Pennsylvania state Regulations)
6. Control on quantity of water used for fracking (Texas State water law)

In 2009 the huge spread of Marcellus Shale covering the states of Pennsylvania, New York and Ohio was found. To enable such discovery US 2005 Energy bill (piloted by Dick Jenny who earlier held the position of VP Halliburton) exempted Shale Gas E&E from the provisions of Clean Air Act, Clean Water Act-1972, Super Fund law and other environmental and democratic regulations. This has been the enabler of Shale Gas Exploration by companies like ENCANA, William, Cabot Oil & Gas Corporation and Chesapeake who started actively exploring Shale Gas using new Halliburton technology and as of now 34 states in US are actively pursuing Shale Gas.

The proponents of environment who have been opposing CBM and Shale Gas E&E raised various issues and even made a documentary film titled "GAS LAND". This documentary of 2010, written and directed by Josh Fox, raises the issues of:

(i) Air pollution
(ii) Water contamination

Which affect the local populates the marine and wild life in and around CBM and Shale Gas E&E areas. They supplemented their arguments stating that the existence of 596+ chemicals including Thiocynomithayl Thio-benzothiozole (TCMTB), Ethylbenezne and other proprietary chemicals which include: corrosion inhibitors, biocides, Shale control inhibitors, viscosity breaker and drilling fluid in the fracking fluids are dangerous chemicals.

Each well may require water quantity for fracking varying from 1-7 million gallon and each well can be fracked as many as 18 times, thereby putting more stress on the water resource of the locality. The fracking fluid inside well along with gases and chemicals (added to fracking fluid and the chemicals present inside the well) can seep through water table and the disposal of return frack fluid creates:

- Contamination of drinking water
- Ground water contamination with natural gas
- Seepage of oil and water

- Water coming out of tab was so contaminated that it started burning
- Chemical burns in the faces of a few local populates observed
- Health problem such as indigestion, laziness etc

The documentary even presented the test data (dated 6-5-2009) of the frack water and shows that it contains chemicals like Barilium-331count, Sodium , MBAS (Methalene Blue Action Substance), Ethyl benzene (a known carcinogen) etc which developed water conductivity of 32800 as against zero for clean water. They also claimed that the disposed water effects marine life up to 35 miles downstream of the disposal point.

The sub-committee on energy and Minerals-Bill examined various stakeholders particularly the fracking fluid chemicals providers against the specific complaints of 6 states which were exposed to Shale Gas E&E activities. As a part of deliberations, Ms. De Gette an opponent of fracking was also given opportunity to seek answer of her questions, from the fracking chemicals manufacturers. The opinion remained divided as many of the suppliers claimed that the chemicals they mix in the fracking fluid are non-harmful but did not agree to disclose the percentage composition. (*The Louisiana Supreme Court later ruled that the manufacturers of frack fluid need not disclose the composition of proprietary fluid for patent protection and commercial reasons*

2.4.8 Reason for choosing Marcellus Shale example

This is similar to Indian Shale Plays which mostly extend beyond a State boundary. The Marcellus Shale play lies in the States of Pennsylvania, west east Virginia and is unlike the more localized Barnett Shale play in northern Texas.

The Marcellus Shale formation is similar to a water resource in that it is a resource that crosses borders and is therefore difficult to regulate at a State level when it comes to ensuring profitable and environmentally sound use.

Hannah Wiseman further observes that "both Congress on EPA (in US) have made several significant and potentially harmful decision of fracking. Just as industry obtained a waiver from Federal regulations for MTBE, Congress exempted fracking with exception of fracking with diesel fuel, from the safe drinking water Act". On the toxicity data on MTBE remains woefully inadequate, information on the environmental and health effects of the substances used in fracing is limited to EPA study and several smaller reports or white papers by government agencies and environmental and industry based interest group.

EPA report 2004, lists 15 products of potential concern, whereas One Health analyst has testified that there are at least 171 products and 245 chemicals within those products used for Natural Gas development. Testimony of Theo Colborn PhD Environmental Health Analyst before house committee on oversight and Government reform (Oct. 25th, 2007). Although, her testimony focused on fracing, this analysis did not specify, however, whether these products and chemicals were components of fracing fluid.

(Costal Oil & Gas Corporation Vs. Garza Energy Trust (268 S.W. 3d 1,2)

Second and more importantly, the EPA's report is too general to provide adequate data on risk. It emphasises that "it is important to note that information presented in the material safety data sheet is for pure product. Each of the products listed in frack fluid composition, (the label of constituent of potential concern) is significantly diluted prior to injection". The concentration is indicated in the study.

(http://www.epa.gov/safewater/uic/pdfs/cbmstudy_attach_uic_ch04_hyd_frac_fluid.pdf)

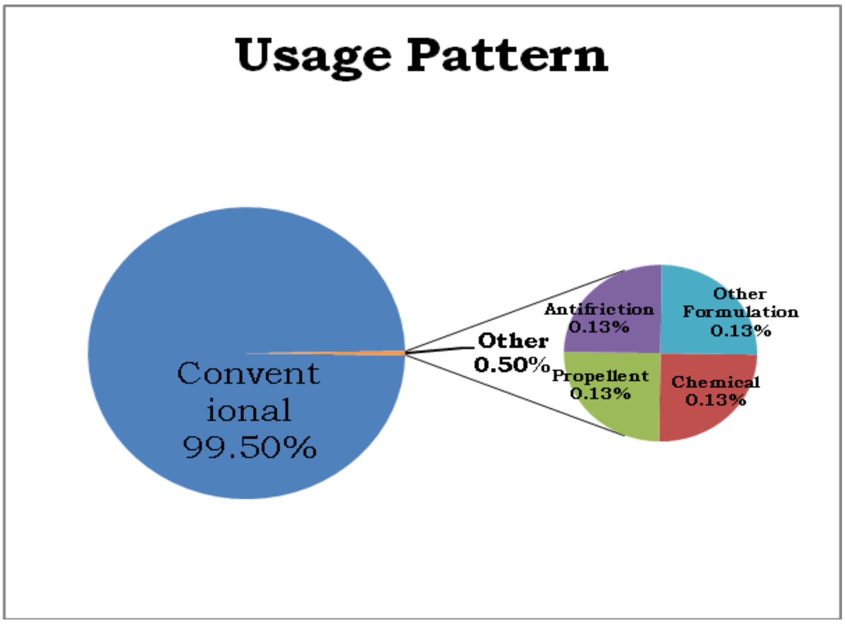

Fig. 2.3: Frac Fluid Usage Pattern (Source: EPA report)

Similar, observations are reflected in an analysis presented in an Article in Zurich Help Point where water and sand constitute 99.51% and other only 0.49%. The other include; Surfactant (0.085%), KCL(0.06%), Gelling Agent (0.056%), Scale Inhibitor(0.043%), pH Adjusting Agent (0.011%), Breaker (0.01%), Cross Linker (0.007%), Iron Control(0.004%), Corrosion Inhibitor(0.002%), Biocide (0.001%), acid (0.123%) and Friction Reducer (0.088%).

2.4.8.1 Water Management

The issue of water management is of high concern in US both due to higher quantities required for fracking, the use of chemical for fracking fluid and the return of contaminated water from the Shale well. For example, American Business Conference scheduled held on 28-29 March, 2014 in Canonsburg, PA describes the latest hot topic of debate is water chemistry. Since, the Bureau of land management's proposal stipulating the disclosure of hydraulic fracturing chemicals being used on public land, the topic of safe water quality has become hotter than ever.

Both kind of the interest group are available worldwide. First the one who just oppose the process in the name of environment or other sensitive issues and second the one who really help the industry and the society. For example, “Collaboration between GE and corporation of Midland Texas has resulted in a water distillation process that reclaims nearly 70% of the waste water from Oil gas fracking operations.” This could greatly improve fracturing operation in States like Texas, when GE estimates that there are more than 50,000 permitted disposal wells for waste water. GE wants to make first make this process available to the Barnett, Fayetteville and Appalachian Shale’s natural gas drilling operations. This interesting revolution is brought out by Society of Petroleum Engineers. New collaboration aims to recover hydraulic fracturing waste water for reuse and disposal.(J. Petroleum Tech. ,2008).

2.4.8.2 Shale Gas Impact

An article contributed by (Bill Bothe, 2011), indicated that “the rise of Shale Gas will slow the development of Renewable Energy resources, why invest in billions of dollars needed for green power, wind and bio-mass if low cost Shale Gas right in our own background?”

However, the caution is also addressed by the article explaining that the Shale Gas supplies will not last forever, which means that a renewable energy plan should still be a part of our National Energy Strategy (in US Context).

2.4.8.3 Shale Gas Evacuation System

In US 5 Lac miles (8 Lac km) of Pipeline network has helped in evacuation of Shale Gas from production field. Even then, it is widely understood that the existing network of Pipeline will prove inadequate to the challenge of bringing Marcellus gas to market as production level continue to increase. (Derek Weber, 2010)

The un-conventional resource plays across North America have one important factor in common – they are also associated with the use of massive amount of water operators in the Marcellus Shale Plays are faced with the gamut of restriction on the availability of water for use in hydraulic fracking and the lack of treatment and disposal facilities to deal with flow back water and natural gas fluids.

The issue or constraint will not only be a transportation Pipeline but the gathering pipeline network to a GGS (Gas Gathering Station). The length of network and its complexity is much higher for Shale Gas as compared to conventional E&P simply because the large numbers of wells which Shale Gas production requires. The new mid stream companies have emerged as a part of Shale Gas revolution in US (Derek Weber, 2010)

Not big companies like En Bridge or Alliance have been able to cope up with the growing requirement of small size Gas Gathering Network. For example, a new company Laurel Mountain Midstream (LMM) was formed in 2009. This is a JV between Williams and Atlas Pipeline Partners LP (51% stake by William).

Currently LMM provides gathering service for Atlas Energy's 4620 wells, delivering natural gas into its system with an average transport of about 100 mmscfd. LMM also owns and operate approximately 1000 miles of intra state gathering lines in western Pennsylvania, western New York and Eastern Ohio.

2.4.8.4 Acid Mine Drainage

When atmospheric oxygen penetrates rock and oxidises pyrites (ferric sulphides) to form sulphuric acid which then etches the rock and liberates iron salt. This phenomenon is called Acid Mine Drainage (AMD).

Frac Biologist technology uses natural soil micro-organism to prevent oxidisation of tailings and waste rock, thus preventing AMD and returning western Pennsylvania's rivers and stream to their natural state.

2.4.8.5 Shale Boom in Canada

Western Canada Sedimentary Basin, now produces about 16.2 bcfd gas of which 70% is expected to US to meet (16% of US Demand), as per the estimates of the energy consultant Ziff Energy, the total gas output in the Western Canada Sedimentary Basin will drop below 14 bcfd by 2020 from 16.2 bcfd. Canada expects their Shale Gas programme will not only compensate for this shortfall but also enable Canada to export additional gas as LNG. In order not to be held hostage to the domestic market, Apache has taken over the lead role Canada's first proposed LNG export project. US Base, Apache has acquired 51% of kitimat LNG project which is designed to ship 750,000 mcfd of LNG to Asian market by 2014 (Gary Park, 2010

Kitimat LNG will provide producers in Canada with secure access to key world market. It will also stimulate the development of gas reserves in Canada. EOG Resources have signed a memorandum of understanding to contribute 100,000 – 200,000 mcfd of Horn river gas to Kitimat. Spain's Gas Natural and Korea Gas have signed tentative deals to take volumes of LNG from Kitimat.

2.4.9 Shale Well Water related Issues

As the Shale Plays defer in nature so is the issues related to connate water. Few additional examples substantiating this argument are cited below:

(i) Gas Shale's that produce little or no water

- (a) The Lewis Shale formation found primarily in San Juan Basin in New Mexico and Colorado is set to produce very little water (US Energy Investor, 2005)
- (b) According to two sources the Fayetteville Shale in Arkansas produces little or no water along with a gas (J. A. Veil, 2007).

(ii) Gas Shale that produce water

- (a) Barnett Shale Gas wells can produce a lot of water. According to US geological survey data, some well produce about as much water as oil field well do (approx. 1638 gallon/kfc). In Delton County, gas well produces even more water (approx 2226 gallon/kcf). Devon energy reported that its Barnett Shale well, some amount of water is produced for the life of the well varying from 0 to 400-500 bbl/day (jay Ewing, 2008).

(b) One company extracting gas from the New Albany Shale in the Illinois basin has said that it achieve peak gas production following 6-10 months period of removing water from Shale well known as "Dewatering" (Oil and Gas investor,2006).

(c) The Antrim Shale in Michigan also contains water that must be removed in order to achieve maximum gas production rate. 12-18 months of dewatering may be required before peak production rate is achieved (US energy investor, 2005)

2.4.10 Green House Gas Emission by Shale Gas Exploration

Shale Gas contributes 30% more methane as compared to normal E&P. This is because of the fact that 3.6% to 7.9% of methane from Shale Gas production escapes to atmosphere in venting and leak over the life time of a well. Higher emissions from the Shale Gas occur at the time of wells are hydraulic fractured – as methane escapes from flow back return fluid - and during drill out following the fracturing.

Methane is a powerful greenhouse gas, with a global warming potential that is far greater than that of carbon dioxide, particularly over the time horizon of the first few decades following emission. The footprint for Shale Gas is greater than that for conventional gas or oil when viewed on any time horizon, but particularly so, over 20 years compared to coal, the foot print of Shale Gas is at least 20% greater and perhaps more than twice as great on the 20 year horizon and is comparable when compared over 100 years. (Howorth, Sept, 2012).

2.4.11 Hydraulic Fracturing

There were three primary "Camps" (Frack fluid) regarding what to use to fractures Marcellus Shale: (Lisa Sumi, 2008) and (Independent Oil and Gas

Association 2006). The selection of one which suits the most shall be done by the operator.

- Straight Nitrogen Gas
- Nitrogen Foam
- Slick Water

The Slick water fracturing was initially developed for Barnett Shale, early in 1997, Mitchell Energy fired a first slick water frac (also called a light sand frac). It used 800,000 gallon of water along with 200,000 lbs of sand.

Slick water frac requires much more water than a typical sand and water frac. This type of fracture has proven to be cost effective system in Barnett Shale and is being expended into Haynesville Shale.

According to Schlumberger, Slick water (a low-viscosity water based fluid and propellant) is more commonly used in deeper high pressure Shale, while nitrogen-foamed fracturing fluids are commonly pumped on shallower Shale and Shale’s with low reservoir pressure.

Fig. 2.4: World Largest Frack Location (Source: Apache 2011)

Many companies have different views depending upon their field experience, for example; Range Resource feels that Slick Water gradually increase the productivity of their Marcellus wells, but still it feels that slick water fracturing is not optimal in the Southern area because of low pressure.

Cobot Oil & Gas recently reported that it deepened several wells to the Marcellus and determined that Slick water Stimulation was more effective than Nitrogen fracture in the Higher pressure Marcellus.

The article further describes that, in the Slick water fracture used in the Barnett Shale, additive may include:

- Friction reducers
- Biocides
- Surfactants, and
- Hydraulic Acid is also used as a part of the fracturing process (Schein G., 2008)

However, there is a strong consensus against fracking with diesel fuel. The major opposition in US came from Water Protection Council. The Energy Policy Act of 2005 exempted all forms of fracking from the Safe Drinking Water Act with the exception of diesel fuel (Hannah Wisemen, 2009)

2.4.12 Radioactive Metals in Shale Plays

The Devonian-age Shale has enough radioactive material to have been considered as potential low grade resource of Uranium. The Marcellus is considered to be "Highly Radioactive Shale" (Ohio Department of Natural Resources, 1997).

It may be noted that the sub surface formation may contain low levels of radioactive materials such as Uranium, Thorium and their daughter products, Radium 226 and Radium 228. In the oil & gas industry, radioactive materials known as "Naturally Occurring Radioactive Materials" (NORM), can be brought to the surface through Oil & Gas wells, this can happen in number of ways including:

- When fluids that are present in the radioactive formation are pumped out of the well,
- The Natural Gas itself may contain “radon gas” a radium daughter.

According to Rail Road Commission of Texas, because the levels of radioactive substance are typically so low, the NORM in produced water and natural gas is not a problem, “unless it becomes concentrated in same manner”. There are number of ways this concentration can occur, for example:

- Through temperature and pressure changes that occur in the course of oil and gas production operation.
- Radium 226 and 228 in produced water may react with Barium surface to form a scale in well tubular and surface equipments.
- Radium 226 and 228 may occur in sludge that accumulates in pits and tanks, and
- During gas processing activities, NORM can occur in radon gas in the natural gas stream. Radon decays to lead-210, than to Bismuth-210, Polonium-210, and finally to stable lead-206. Radon decay elements occur as a film on the inner surface of inlet lines, treating units, pumps and valves principally associated with propylene, ethane and propane processing streams.

Because radioactive materials become concentrated on oil & gas fields equipments, the highest risk of exposure to oil & gas NORM is to workers employed to cut and ream oil field pipes, remove solids from tank and pits, and refurbish gas processing equipments.

2.4.13 Acid Producing Minerals

Marcellus Shales are known, in some region, to contain acid producing minerals such as pyrite and sulphides. Survey conducted by the Pennsylvania

Department of conservation and Natural resources, indicated that lower part of the Marcellus formation contain the acid producing minerals. (Refer website: http://www.dcnr.state.pa.us/topo geo/open file/acismaplayers.aspx#8)

When pyrite is exposed to air and water it breaks down and forms sulphuric acid and iron oxide- a phenomenon well known in mining industry. The acid producing reaction occurs as long as the pyrite continued to be exposed to air and water. If these conditions persist, acid will be produced until all of the pyrite/sulphide in the rock used up.

While the amount of acid generating rock material removed during the drilling of Marcellus Shale would be very minimal compared to the amount of material exposed during a mining operation, the drill cutting may still contain enough pyrite to cause problems. The weathering of pyrite Shale can result in acid generation, metal mobility, and salinization of ground and surface water. (Michele Tuttle, Paul Biggs, and Cyrus Berry)

Metal Mobility is caused because the acidic drainage can dissolve toxic metals (e.g. Copper, Aluminium, Cadmium, Arsenic, Lead and Mercury) that are present in the surrounding rock or soil. Black Shale like Barnett, Marcellus, Fayetteville, New Albany and others are often enriched in trace of metals. US geological survey has found high concentration of arsenic, cobalt, chromium, molybdenum, nickel, vanadium and zinc in stream sediments near outcrops of pyrite-rich Devonian Shale (Tuttle M.L.V, Goldhaber M.B and Breit GN. 2001)

To address this type of situation, Pennsylvania has provided by code:
For example, Article 78.63 (B) states that "A person may not dispose of residual waste including contaminated drill cuttings at the well site unless the concentration of contaminants in the leachate from the waste does not exceed the maximum concentration stated in Article 261.24 table (related to characterisation of toxicity)

Hydrogen Sulphide: H_2S gas occurs naturally in some geologic formations and in ground water from those formations. It is formed from decomposing underground deposits of organic matter such as decaying plant material. It may be formed both in deep or shallow wells. H_2S is flammable and poisonous, it can cause Nausea, illness and in extreme cases death.

In some areas, Devonian Shales are known to contain hydrogen sulphide. For example the ground water contains H_2S at following locations:

(i) Central Crawford County- having Devonian Shale bedrock

(ii) Clark County- New Albany Shale

(iii) Derry Township- Marcellus Shale

The use of chemicals in frack water or frack fluid is a matter of the patent with the manufacturers. Whereas, in US the disclosure of the composition of frack fluid is not mandatory, but in UK it is mandatory to disclose the formulation. The frac water uses more than 200 chemicals while they make up just a fraction of the total material in the fluid; they include recognised carcinogens like Benzene, Arsenic, and Polycyclic Aromatics (IFC International, 2011).

Other substances are associated with endocrine disruption, damage to reproductive health, immune suppression, and genetic mutations. Contamination of water, would indeed pose a continuing health threat to human & wildlife drinking or exposed to this water.

2.4.14 Regulatory & land Laws aspects (Pennsylvania State)

US have an exemplary federal system of governance. There are 40 states. Each State has its own Regulator and the Supreme Court. Here we take a reference of Pennsylvania State which is a Shale rich state.

The authorities involved in Shale Gas Exploration are:

1. **Federal Government –** Provide support and guidelines to states on the issues of Energy and Environmental Protection, such as :

(i) Federal Regulator for Energy (FERC) provide guidelines to State Regulators.

(ii) Environmental protection Agency (EPA) provides guidelines for environmental related issues.

2. **State Government –** State has passed several Acts and framed many laws control water and environmental protection, such as:

   (i) Oil &Gas Act

   (ii) The Coal & Gas Resources Co-ordination Act

   (iii) Oil & Gas conservation law

   (iv) Clean Stream law Act. This provides the PDEP (Pennsylvania Department of Environmental protection). This gives PDEP to control water pollution in the State. The law sets standards for discharge of industrial wastes and requires that permits to be obtained for any waste that will flow into Pennsylvania water system.

   (v) Bureau of oil and gas measurement (PDEP Programme)

3. **Municipalities –** there are almost 200 Civic authorities (Municipalities) in the State of Pennsylvania. As per the judgments pronounced by the Supreme Court, the municipalities have authority particularly for zoning and land use. They have power to give permit for drilling including restoration.

4. **Others –** Other interested group and effected group represent social and environmental bodies , like:

   (i) Inter-state River Basin Commission

   (ii) Inter State Oil and Gas Compact Commission (IOGCC) is a national level interest group and intends to provide beneficial policies across the country. IOGCC seeks to bring together concerned parties such as oil and gas regulators, environmentalists, industry members and governors of Member States, so that they can form committees and collaborate on finding solutions to the problem that arise in conjunction with utilizing oil and gas resources. The IOGCC also seeks to present to Congress a united front of the State Governors in order to advocate for the most beneficial use of oil and gas resources and the most effective regulation. The

Governors of all the States affected by development of Marcellus Shale Plays are Members of the IOGCC.

(iii) Susquehanna River Basin Commission- looks after the related issues.

There is no Regulation for property lease. Prices offered for lease started from $300 per lot for a signing bonus plus royalty from 12.5% to 18.5%. It eventually increased to $18,250/ acre, plus royalties of as much as 27.5% or even higher in some cases, the property owners who signed the initial base agreement are finding themselves facing similar disadvantages as those encountered by the owners in the Barnett Shale region.

Shale Gas has not only revolutionized the energy market it has started posing as threat to many business especially LNG. (Woodside Petroleum Limited, 2011 December 7)

In the SWOT analysis presented by Woodside in its Data-monitor Dated 7 December, 2011 it describes "increasing production from Shale plays" as threat to their LNG business segment. it further says that Shale Gas has already had its impact on US gas reserves and Changed the gas supply scenario of the country significantly. This has resulted in subsequent reduction in LNG demand in the US, which in turn has had significant impact on global LNG market. For instance, on pricing level, the reduced US gas demand has decreased the demand between the Atlantic and the pacific basins, thus exerting further downward pressure on LNG prices.

2.4.15 Cost of Drilling Shale Well

As the Shale Plays differ from formation to formation the cost of drilling therefore differs for Shale Plays to Shale play and further methodology adopted. A few examples of the actual cost incurred adopted various techniques cited below:

(i) A well drilled in Marcellus Shale in Pennsylvania state by Terry Engelder, cost them $0.8 million for a vertical well and $3.0 million for horizontal well

(ii) Atlas Energy drilling in Fayetteville in Fayette County spent $1.3 million for a vertical well and $4 million for a horizontal well

(iii) Dominion resources drilled well in north central and west Virginia spent $1 million for a vertical well and $3 million for a horizontal well

(iv) Range resources drilled vertical well in various locations costing approx. $0.9 million (Lisa Sumi, 2008).

Thus it is observed that a Vertical well in US has been costing somewhere between $0.82- $1.3 million (a variation of about 60%). Similarly, the horizontal well costing somewhere between $3.0-$4.0 million (with a variation of 33%)

2.4.16 Production Cost of Shale Gas

General: There is a significant debate over the production costs of Shale gas. Estimate of Shale Gas extraction cost in North-America ranges from $4-8/Mcf ($4-8/mmbtu at a CV of 9000Kcal/sm^3). The differences in estimate is significant & complex and also reflects the cost of drilling Shale well as discussed in preceding Para.

US Natural Gas price in 2008 exceeded $10/mmbtu throughout the forward gas market. With Shale gas impact, by 2010 Natural Gas price came down to $7/mmbtu (John Rowe, 2010). The EIA estimate for Henry Hub Gas Price from 2009-2035 vary from $4.4/mmbtu to $7.2/mmbtu (EIA, 2011).

Globally, the price of Shale Gas extraction will be determined by accessibility, environmental regulation and evacuation infrastructure (World Energy Council, 2010).

Indian Context: In Indian context the gas pricing mechanism is getting evolved as a market determined pricing mechanism. The other factors which impact gas pricing in India are the availability of gas, accessibility to gas (infrastructure for transportation) and the affordability by the consumer (Price). (Negi B. S., Dr. Pahwa M. S. et al, 2012).

Flexible Factory model for Cost Control: Unconventional gas plays in US and Canada suffers from swings in market condition as well as unexpected geologic complications. While the industry has made significant progress in terms of reducing development cost and compressing cycle time by standardizing process and technical design. The dramatic change of prices in 2008 and subsequent liquidity crises has forced companies to re-examine development in many assets. The industry has adopted a business process capable of handling large number of wells and application of factory-like models are now becoming the industry norms to speed up both surface and drilling activities of multi-year development programs. Companies have been able to reduce development cost by upto 40% and accelerate time to production by 30%. However there are some negative side-effects like acquiring large inventories and uneconomical leasing of land. To strike a balance between these two, a flexible approach is advisable which employees a continuous improvement capabilities to adjust when needed, the efficient but rigid factory-model to a flexible factory model capable of sustaining low unit development cost and rapid cycle time while making mid course correction such as change of well design, spacing, pace, etc., when geology or market condition change. A flexible factory model has three building blocks: (Brain Forbes, et al,)

i. Definition of trigger for course correction
ii. Deploying continuous design improvement capabilities, and
iii. Operating with rolling planning horizon.

2.4.17 Reviewing US Success Story

1. US have been quick to identify its Shale Potential.
2. Large area leased at fast pace.
3. US wildcatters have continuously experimented, and adapted their drilling techniques, reducing cost (Since no two Sale are alike).

4. There has been little resistance to the development of Shale Gas by local communities due to low population density.
5. Local entrepreneurs.
6. Factory model for Shale Gas well drilling.
7. Environmental concerns surrounding Shale Gas have not been overstated.
8. Well developed P/L network.
9. Strong political support.
10. Public awareness program including public hearing.
11. Making all stakeholders as partners in the project.

2.4.18 Creating Public Awareness

Shale Gas being a new area of hydrocarbon exploitation there are many questions in the mind of the public particularly about public safety and environmental safety. An article written by Marni Soupcoff published in National Post Canada on October 18, 2012 gives the approach which the explorer employed for public awareness related to issue an effect of oil sands Canada. The article starts with a perceive notion among the masses *"Every one has opinion on the oil sands: they are destroying the earth or saving the country or may be a bit of both. So be it. Not much can be done to change the minds on periphery of spectrum. It never can. It would be helpful for the rest of us. Though, to know exactly what the environmental impacts on oil sands really are."*

Further, "*That Alberta announced the creation of an environment monitoring system that will be controlled independently – run by neither Govt. nor industry. If, Alberta can put in place a system that provides reliable and trusted data- it's now upto a management board appointed by the province's environment minister to iron out the details – we may finally be able to have the sort of reasoned discussion about the oil sands that have been virtually impossible to date."* Such kind of public awareness program would iron out the wrinkles on thought process not based on the facts. For example the paper reports – "two years ago a study by university of Alberta environmental scientist David Schindler was instrumental to realize that the Athabasca River for becoming more polluted, thanks to the oil sands development. But the results were questioned in many circles because of Schindler clear anti oil sands agenda. Schindler had also joined a group of scientist in writing an open letter that advocated strategic booting to defeat the conservatives in 2008 federal election. This was clearly an unsuccessful venture. It is therefore essential that "Alberta needs meaningful environmental monitoring i.e. completely divorced from (independent of) the policy maker, the profit seekers and environmental lobby so that whatever results are written, will form a fair basis for criticism or praise for even better – constructive succession for the industry. An advt. from the explorer (Impairer oil) in association with CAPP (Canadian Association of Petroleum Producers), is placed as fig. 2.5). Similarly, the Public awareness program may be useful to understand the impact of Shale Gas exploitation.

Fig. 2.5: Public Awareness in Canada
(Source: Canadian Association of Petroleum Producers, scanned from News Paper)

2.5 European experience

Europe Shale Gas potential revised from 509 Tcf (2001 estimates of Kawata et al) to 559 Tcf (World Energy Council, 2010). Europe has Shale Plays spread in Franc, Germany, Netherland, Sweden, Norway, Denmark, UK, Poland, Lithuania, Ukraine and Turkey. As per EIA estimate of 2011 Shale potential in Europe was 624 Tcf. Such encouraging Shale gas potential attracted MNC like Exxon Mobil (who made German explorer Wintershall as its partner), Chevron, Conoco Philip and Marathon to Europe (Gas Strategies 2010).

Europe also wanted to quickly employ the experience learnt in US and efforts have been made in Poland, Britain, Germany, and France. After initial study, France employed moratorium on Shale Gas exploitation in 2011. Country wise, European experience is studied as below:

2.5.1 Poland Experience

Poland shale gas reserves were estimated to 5.3 tcm (187.6 tcf) (EIA 2011) which was largest in Europe. This volume can meet Poland’s energy need for 300 years: however the recent polish estimate shows gas volume of 346 to 768 bcm only, thereby slashing the estimate by about 80%. “Poland is not Texas” said Kash Barchett a European energy analyst at the consulting firm IHS London

MND Drilling services have been the first foreign drilling operator in Poland (Schmidt, Jun. 2012). Following two disappointing test wells in Jan. 2012, Exxon Mobil made the decision to call off further exploration. International energy giant like Exxon Mobil (US) and Talisman Energy (Canada) have scaled back their investment after disappointing early attempts at extraction. Further, competition from other fossil fuels like coal has made it unprofitable to tap many of the country’s new energy fields including shale gas E&E.

Hydrocarbon potential in Poland as given by Geo data ltd is shown in fig 2.6

Fig. 2.6: Sedimentary Basins in Poland (Geo Data Ltd)

Poland, whose hopes for Shale Gas faded after three international firms quit for disappointing drilling results, has been looking for signs of bigger quantities of the unconventional gas, which could help to reduce its reliance on Russia.

Lane Energy started production testing at its well in the northern city of Lebork in July 2013. The daily amount of gas being produced there still does not qualify as commercial production, but is the largest amount of gas obtained in any Shale Gas well so far in Europe, the newspaper said.

"This is very good news for Poland and European oil geology," Piotr Wozniak, deputy environment minister and Poland's chief geologist, was quoted as saying. He said the results should encourage other companies to speed up work on Shale Gas Exploration.

Polish refiner PKN Orlen is expected to announce the results of production tests at its Shale Gas well in Syczyn in eastern Poland, which Wozniak has described as one of the most promising in the country. Poland, which consumes 15 billion cubic metres of gas a year, mostly imported from Russia, has estimated its recoverable Shale Gas reserves at up to 768 billion cubic metres.

It has issued more than 100 Shale Gas Exploration licences to local and international firms which have drilled 48 wells to date. Some companies, however, have complained that the commercial output of Shale Gas is being delayed by red tape and difficult geology. This year, Marathon Oil and Talisman Energy followed Exxon Mobil in pulling out of Poland

As reported on Aug 28, 2013 (Reuters) - Lane Energy Poland, an oil and gas exploration company controlled by ConocoPhillips, is extracting some 8,000 cubic metres of Shale Gas per day at a test well in northern Poland, an amount unseen in Europe to date, the *Rzeczpospolita* daily newspaper reported on Wednesday.

Fig. 2.7: Shale Plays in Poland (Internet)

2.5.1.1 Policy and Regulationsns in Poland

POLISH dreams that Shale Gas would transform the country into a second Norway have been tempered in recent months. The geology is more difficult than anticipated and the proposed regulation has been repeatedly delayed. After great initial enthusiasm companies such as Exxon Mobil, Talisman and Marathon Oil threw in the towel and quit the country.

In a recent report investors complained that the legislation currently being drawn-up ignores many of their demands. The Organization of Polish Exploration and Production Industry (OPEPI), the industry's main lobby group, is concerned whether the government will get "excessive controls and rights" in Shale Gas exploration. They say the ministry of environment handed out five-year exploration licences to companies and they can be extended only once, for two years. (The first ones will expire in 2013-2014.) Since, Shale Gas fields take longer time to develop than conventional fields, says the OPEPI, they will have insufficient time to make discoveries before the deadline, at which point they either have to apply for a production license or hand it back to the ministry. The lobby also criticizes the proposed laws for imposing disproportionate penalties on them if they fall behind in their work schedules even due to circumstances beyond their control.

The Polish government used to be gung-ho on Shale Gas. Unlike many of their contemporaries in Western Europe, Poland’s politicians brushed aside environmental concerns, impressed by estimates that the country was sitting on the largest Shale Gas Reserves on the continent. Extracting oil and gas from Shale offered solutions to two particularly thorny problems, namely how to reduce the country’s dependence on costly Russian gas imports and cut greenhouse gas emissions from its heavily-polluting coal-fired power plants.

The former Soviet-bloc country inherited gas infrastructure built to transmit gas in one direction only, from the east. Since 1989 Polish politicians have been trying, spectacularly unsuccessfully until recently, to diversify the country’s energy supplies. As a result they have been forced to accept gas import prices higher than those paid by their richer western neighbors.

Burning gas emits fewer CO_2 emissions than coal or oil but Poland sits on the largest coal reserves in the European Union and it has built more than two decades of economic growth on coal-fuelled power. Currently Poland produces more than 90% of its electricity from coal or lignite-fired power plants. In recent years, Warsaw has found itself alone in resisting demands from Brussels to adopt more stringent emissions targets. Commercial Shale-Gas Production would allow Poland to shut down older polluting coal plants and replace them with gas-fired plants, thereby reducing the country's emissions.

So it's easy to see why, in April 2010, before a single exploration well had been drilled, the Polish foreign minister, Radoslaw Sikorski, said Shale Gas offered Poland the chance to replicate Norway's success. By then, both foreign and Polish oil and gas companies had rushed to grab exploration acreage, attracted by a combination of gas prices four to five times higher than in America, fields close to the market and a government that was actively promoting the industry.

The first exploration well was drilled in June 2010. To date around 40 wells have been drilled, more than anywhere else in Europe. Not one has flowed gas at a commercial rate.

Exxon Mobil quit Poland in June last year after drilling just two wells. In May of this year Canada's Talisman and Marathon Oil, an American firm, also withdrew from Polish exploration citing unsatisfactory results. Operators admit the technology of extracting gas from Polish Shale has proved harder to crack than they anticipated.

Even so, Pawel Poprawa, a Geologist from the Energy Studies Institute, who authored the Polish Geological Institute's estimate of the country's Shale Gas reserves, observed that only a few wells have been drilled to draw conclusions about the rocks. Only four horizontal wells have undergone multi-stage hydraulic fracturing, the best indicator of a field's reserves. The government's proposed fiscal and regulatory framework is the main reason why companies slowed the pace of their exploration in recent months.

2.5.1.2 The current regulations are inadequate.

It can take over a year for companies to obtain the permits to change their work program and drill a well deeper for example. The government wants to increase its “take” from a commercial Shale Gas industry. It has proposed new taxation capping the government take at 40% of an operator’s profits. Companies acknowledge new taxes will be introduced but argue that talk of figures is premature given no one knows yet if Shale Gas will prove to be commercially viable in Poland. The ministry of finance has eased matters by saying it will postpone the collection of any new taxes from 2015 to 2020.

More controversial are the draft regulations proposed by the environment ministry that will create the state-owned company, NOKE, to take stakes in all future production concessions as a way of guaranteeing the state’s interest in future production. Operators are concerned they are being forced to take on a partner in NOKE that, unlike the Norwegian state company it is based on, will be staffed by public administrators with no experience of unconventional hydrocarbons.

Companies that have already invested millions of dollars drilling wells are also worried the proposals do not give them a legal guarantee to transfer their existing exploration licenses into production licenses without taking part in a competitive tender. “If there is a change in the government’s approach then it is not too late for this industry to patiently work its way through the problems with some realistic prospect of success. If we continue on the road we’re on at the moment, this industry will be very modest and will not fulfil its potential,” said Tomasz Maj, until recently Talisman’s Poland Manager. (Jul 10th 2013, 17:00 by A.E. | WARSAW)

“Shale Gas in Europe is unlikely to revolutionize the energy industry like it has done in US. Across the continent policy makers and public remain wary of the potential environmental impact of technologies like hydraulic fracking used to extract Shale gas. In addition, Europe is much more densely populated than the US, making it difficult to win the government approval to tap the new energy deposits, often near, major cities. Complicating matters, technical expertise and drilling rigs are in short supply and regulations differ among countries.

“The opportunity is there, but the early exploration efforts have been disappointing”, said Stephen O’Rourke, a senior gas supply analyst at the energy consultancy Wood Mackenzie in Edinburg, Scotland, who estimates that European Shale Gas might meet a mere 5% of demand within the European Union by 2030

“There is a lot of uncertainty. A slowdown in Europe’s efforts to exploits its Shale Gas reserves, roughly 10% of the world’s deposits could not come at a worse time for Europe’s companies, which are already suffering from a continued debt crises and anaemic growth.

In US, energy intensive industries like manufacturing and chemical production have benefited from a drastic fall in fuel costs because of a domestic energy boom in Shale Oil and Gas. Natural gas prices, for example, have fallen by almost 67% over five years, and US is on track to become the world’s largest oil producer by 2017, according to EIA.

Fuel cost for European companies, by contrast, remain roughly double those of their US competitors, while many countries, particularly in Eastern Europe, are dependent on natural gas from Russia. Also, the continent’s fossil fuel production has fallen steadily over the past 10 years, even as global demand has risen

Although it has some of the largest deposits of unconventional gas in Europe, France banned fracking in 2011, and Bulgaria and the Netherlands have taken similar measures. Political leaders remain concerned over the potential environmental harm from the technology, while campaigners also have questioned efforts to promote fossil fuels over green technologies like wind and solar power.

“Shale Gas isn’t long - term solution to Europe’s energy security issues” said Antoine Simon, a campaigner at the environmental group Friends of the Earth in Brussels. We should be looking to develop our renewable sector.

European Shale Gas experts say more environmental studies are needed to address public concern about the security of extraction of the fossil fuel. Rene Peters, chairman of the EU Shale Gas Expert Group, told a conference in Warsaw on Tuesday that data gathered from extensive exploration in the United States does not apply to Europe, where geological and environmental conditions are different. The conference, on the sidelines of U.N. climate talks, concerned Shale gas's potential as a bridge between coal and renewable energy *(Reference; Economic Times dated 26-04-2013)*.

Concerns about the environment are among the key reasons holding back the development of the Shale Gas industry in Europe, where some countries have moratoriums on drilling. Only Britain and Poland are exploring their deposits, though a local protest halted exploration in southern Britain in August. (*Associated Press, Posted on November 12, 2013 at 12:33 PM, Updated Tuesday, Nov 12 at 4:47 PM)*

Fig. 2.8: Shale Gas Fracking facility- by Poland's PKN Orlen Company (Source: Reuters / Peter Andrews June 15, 2013, Published time: August 29, 2013 14:43 Edited time: September 04, 2013 09:49)

Poland has begun a test extraction of Shale Gas in amounts not seen in Europe before. Eager to reduce energy dependency on Russia, Poland has succeeded even after three international firms quit drilling in the country.

Lane Energy Poland, controlled by ConocoPhillips, is now extracting some 8,000 cubic metres of Shale Gas per day at a test well in the northern city of Lebork in Poland, Reuters quotes a polish newspaper. Although the productivity of the site is lower than at gas fields in the US or Canada, it is still a breakthrough and marks the first positive result for Shale Gas extraction in Europe, according to the Poland's Chief Geologist Piotr Wozniak.

Another Polish refiner PKN Orlen is also expected to announce the production results of tests at its well in Syczyn in eastern Poland, one of the most promising in the country.

Three international majors, Exxon Mobil, Marathon Oil, and Talisman Energy, dropped out of the program after they failed to hit their targets.

According to a June report by US Energy Information Administration (EIA), the estimates for Poland's Shale Gas resources have fallen from 187 trillion to 148 trillion cubic feet.

Poland imports up to 70 percent of its gas from Russia and is eager to reduce its energy reliance on its neighbor. The country issued more than 100 Shale Gas Exploration licenses to local and international firms which have drilled 48 wells so far.

Poland’s Shale Gas breakthrough sparked talks on Warsaw’s gets rid of “gas dependence” on Russia in the near future, foreign media reports. However, the senior analyst at Investcafe consultancy Grigory Birg told Business RT, Polish Shale Gas may lead to minor reduction of gas price for Poland, but won’t have an impact on the amounts in acquires from Gazprom.

“On the one hand, growth in the supply of gas through the active development of Shale deposits may lead to some reduction in prices , however, given that the cost of Shale Gas extraction never exceeds the cost of traditional gas production, the potential for lower prices - is limited”, Birg told RT.

Environmental concerns over the technology of fracking have divided European politicians and society. France and Bulgaria have completely abandoned the use of fracking. However, at the moment 12 European countries are running Shale Gas extraction tests, Reuter’s reports (Commodities, EU, Gas, Innovation, Natural resources, Resources)

Due to Policy changes and regulatory Constraints, Marathon Oil Corp. and Talisman Energy Inc withdrew from Poland. Also because the Shale playas geology being much more unfavourable than had been earlier thought, EnI has also retracting from Poland. Thus leaving only San Leon (Dublin based) company having 3 permits in Northern Poland.

On 13th January 2014, san Leon informed (as reported by Bloomberg on 23rd January 2014) that they have successfully produced 60,000 cfd of gas from a vertically fracked Shale well in the Baltic Basin in North Poland. San Leon Energy is backed by George Soros and Black rock. This gas flow is without clearing the well of the frack fluid. On removing the frack fluid, it is expected to reach flow rate of 200,000 to 400,000 scfd from Shale Play. This is approx 4 mmscmd / year or 0.03% of the annual energy (during 2013 16 bcm) consumed by Poland.

2.5.2 Ukraine Experience

Ukraine will sign a $10 billion Shale Gas production-sharing agreement with U.S. energy major Chevron next week - its second such deal this year, after an earlier agreement with Royal Dutch Shell. The production-sharing agreement foresees an initial investment of $350 million by Chevron in exploratory work aimed at establishing how commercially viable Shale reserves are at Olesska, which covers 5,260 km^2. The two Shale Gas projects could provide Ukraine with an additional 11 to 16 billion cubic metres (bcm) of gas in five years' time, according to government projections. (Rigzone, Edelweiss Report October, 2013)

The above report took a practical turn when the Ukrainian government on Tuesday signed a Shale Gas production-sharing agreement with the Chevron, as the country strives for energy independence from neighbouring Russia. Energy Minister Eduard Stavitsky said Tuesday that under the deal, Chevron will initially invest $350 million into exploratory and drilling work in the Oleska field in western Ukraine. Total investment could surpass $10 billion over 50 years.

The Ukrainian state will receive 30 percent or more of the extracted gas, depending on the field's capacity. The deal follows a similar agreement signed with Shell this year. Ukraine has been trying to reduce its dependence on natural gas from Russia because Moscow has been applying pressure, including sanctions, on Ukraine to prevent it from signing a free-trade agreement with the European Union this month. *(KIEV, Ukraine (AP) November 5, 2013).* Also in January 2013, Royal Dutch Shell signed a similar deal covering the nearly 8,000 sq km Yuzivska field in the east of the country.

Ukraine is still reckoned to have Europe's third-largest reserves: the US Energy Information Administration estimates recoverable reserves at 1.18tn cubic metres. Ukraine's gas consumption last year was about 50bn cubic metres, with domestic production of about 20bcm. According to government estimates, on a base scenario, Chevron's Oleska field could produce 8-10bcm a year.

Eduard Stavytsky, the country's energy minister, has said that if the two Shale projects and offshore ExxonMobil project worked out as hoped, they could together produce 20bcm annually within 10 years. That would double current production and potentially enable Ukrainian production to completely meet its gradually falling domestic demand.

Some experts suggest, such projections may be optimistic – even wildly so. But if Shell, Chevron and Exxon demonstrate that international majors can operate successfully in Ukraine, even more modest production could have big implications.

Edward Chow, a senior fellow at the Center for Strategic and International Studies, said the PSAs could "trigger sound energy policy", including protection of investor rights, and rule of law. If Shell, Chevron and Exxon demonstrate that international majors can operate successfully in Ukraine, even more modest production could have big implications

Success by the majors and expansion of Ukraine's domestic energy industry could also lure-in foreign oil services groups and smaller independents.

Cheaper energy, meanwhile, could help efforts to develop new sectors of the economy.

Some of that scenario may be threatened if Ukraine, as now looks possible, fails to sign an EU free trade deal this month, and turns instead to Russia. A big cut in Russian gas prices – say, to levels paid by neighboring Belarus – could make new domestic production in Ukraine less competitive.

A price cut of that size, however, seems unlikely unless Kiev takes the extra step of joining a Russian-led customs union – to which Mr. Yanukovich still seems resolutely opposed. As long as that remains true, Ukraine will hold increasing allure for western oil groups.

Recently, Russia annexed Crimea from Ukraine and the two countries are still not at peace. NATO has threatened Russia of the Sanctions. As a pressure tactic, Russian has now purposed to increase its gas price to Ukraine from \$268.50/1000m^3 (\$7.5/mmbtu) to \$485.5/1000sm^3 (\$13.6/mmbtu, taken CV as 9000kcal/sm^3). (*Times of India 06 April, 2014*)

2.5.3 Lithuania Shale Experience

Baltic Basin (Silurian - Lower Paleozoic) of Lithuania has good Shale Potential. Lithuania called the Shale Gas Exploration tender hoping to become less reliant on gas from its former Soviet Union, Russia.

U.S. energy major Chevron has pulled out after winning a tender to explore for Shale Gas in Lithuania, blaming changes to laws which have made it less attractive that came in after it placed the bid for exploration rights. (VILNIUS, October 8, 2013 (Reuters)

Chevron was the only bidder to explore for unconventional hydrocarbons in the 1,800 square km Silute-Taurage prospect. The government picked it as a winner a month ago on the basis of its bid submitted in January, 2013.

Lithuania's Prime Minister Algirdas Butkevicius said in a statement he regretted Chevron's decision, but admitted there was a lack of regulatory clarity.

"The parliament still debates various amendments, which could affect the use of hydrocarbons in our country. That means that first of all we need to have a legal framework in place," he said in a statement. The proposals debated by the parliament include taxing exploration of Shale Gas and Shale oil at 40 percent, up from the current 16 percent on conventional hydrocarbons. "The government will discuss whether to call a new tender for exploration of Shale Gas and oil," a government spokeswoman said.

Chevron said it will stay in Lithuania, focusing on exploration of conventional hydrocarbons at its existing Rietavas block. The company also said it remained "committed to exploring and evaluating investment opportunities in Central and Eastern Europe”. Chevron, which has four concessions for Shale Gas Exploration in neighboring Poland, said earlier it wanted more consultation with the Polish government on proposed draft amendments before they are adopted.

Exxon Mobil, Talisman and Marathon have pulled out of Polish Shale gas, citing difficult geology and short-comings in the regulatory environment.

Polish Energy Company Lotos said it might be willing to explore for Shale Gas in Lithuania, provided the conditions on offer are improved, after Chevron pulled out as the sole bidder in a tender for a license. Lotos Chief Executive Pawel Olechnowicz told Reuters, when asked whether Lotos would be interested in taking part in a new tender.

Lotos controls most of Lithuania's oil production through full ownership of two small oil companies and a 50 percent stake in a third, all of which hold conventional oil licenses. Chevron said when it withdrew that changes to law had made the license less attractive.

The Baltic Basin, which extends from northern Poland to southwestern Lithuania through Russia's Kaliningrad exclave, is seen as one of the most promising regions for Shale Gas Exploration in Europe.

Lithuania's environment ministry formally cancelled the Shale Gas Exploration tender last week but said another one could be called after revising the legal framework.

Lithuania media speculated that one reason Chevron withdrew could have been proposals in parliament to double a tax on Shale Gas production to 40 percent.

2.5.4 United Kingdom Experience

The British Ecological Survey estimates Shale Gas reserves at 1300 tcf (sufficient to meet 6 year gas requirement of UK). UK Shale Plays are shown in Figure 2.9. Bow land Basin, NE England (Carboniferous) has promising Shale Potential.

UK has licensed I.Gas to explore Shale Gas in Northern England. I.Gas started exploration in the licensed area (Figure 2.10) and it has estimated in a part of Northern England alone about 170 Tcf of gas exist. This company initiated Shale Gas exportations in Manchester where local Govt. associations have asked for 10% of revenue sharing from Shale Gas production *(Telegraphs 28 December, 2013)*. UK Energy Minister who had the Shale Gas programme apprehends that this demand could make Shale Gas program is unviable.

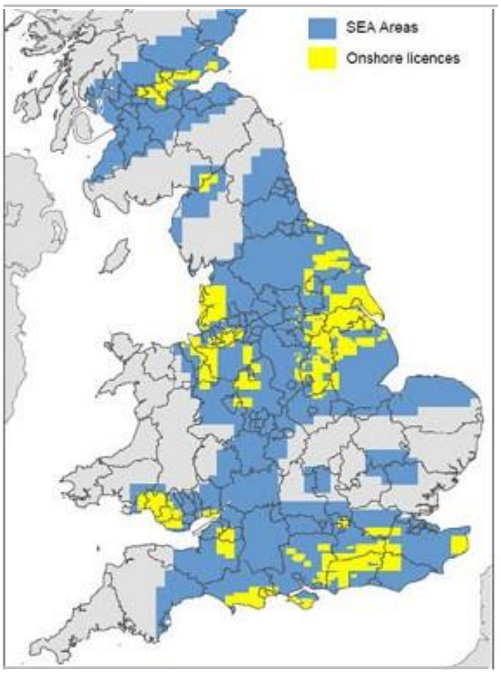

Fig. 2.9: UK Shale Plays *Fig. 2.10: Drilling in North England*

The explores have offered to make GBP 1,00,000 down payment and 1% of the revenue from the Shale Gas (when produced). Still the demonstrator are obstructed the exploration Figure 2.11.

Fig. 2.11: Protesters slow down machinery being transported to drilling site in Barton Moss, Salford Manchester (The Telegraph can reveal that the leading campaigners against "fracking" in the North West have no connection to the area)

In UK, over the past 30 years, more than 2,000 onshore wells have been drilled of which approximately 200 have used techniques similar to fracing to enhance the recovery of oil or gas. One of these onshore block is Wytch Farm in Dorset located in one of England's most famous regions of outstanding natural beauty and special scientific interest, and therefore an area where the aesthetic and environmental impact of drilling are highly sensitive issues. (Prof. Robert Mair, 2013). To address the environmental issues royal societies and royal academy of engineering set up a joint committee. The committee report suggested that the environmental risk could be managed effectively as long as operational best practices were implemented and enforced through regulations. Britain has a good track record of upholding rule of law and Regulations. For example, every company must disclose the contents of the fracturing fluid they use, which is not mandatory in America.

The government has accepted all recommendations. Most of the Shale Plays in Britain have been at a depth of 1.7 to 3.1 Km. if the wells are properly cemented the ground water or the frac water is not likely to contaminate the ground water or the natural reservoir. Further in Britain there is a scheme to ensure that the design construction and abandonment of wells is reviewed by independent expert. Such a recommendation of the joint committee have been submitted to the government and suggested that the judgment should be evidence-based on science and engineering, which will help to ensure that the best decisions are made, un-swayed by preconceived notions of risk or benefit. Prof. Robert Mair, 2013 chaired the joint committee). Committee also recommended monitoring methane emissions and groundwater composition at potential sites now, before any fracking takes place (as well as during and after such operations). This baseline monitoring is vital, since methane can be present in groundwater naturally. Such data will be the only way of keeping close track of the environmental impacts of fracking in situ, and should be submitted to regulators to inform local planning processes and address wider concerns.

Shale Gas companies must also play their part in building public confidence. It should be mandatory for operators to conduct Environmental Risk Assessments. Local communities should be involved and informed from the very start. People need have a say in the planning process and to feel their concerns are being addressed.

In recent weeks, the Sussex village of Balcombe has found itself at the centre of the argument around hydraulic fracturing, or "fracking". This debate has become heavily polarized, and there has been much speculation around the environmental risks of Shale-Gas extraction, concerning water contamination and earth tremors.

Such resistance continues in UK even though the Government has come in support of the Shale Gas E&E. A news item "Cameron faces battle to enlist communities in fracking drive. Even though the UK Prime Minister has promised that the communities would be able to keep 100 percent of business rate from Shale Gas sites, rather than the usual 50%. That is on top of receiving GBP 100,000 per well and 1% of turnover from fracking sites" still the conservative MPs warned that government stating that the incentives were not generous enough and environmentalists accused ministers of trying to buy off councils".(Jim Pickard and Elizabeth 2014).

However the Public opinion is slowly moving in favour. According to research by the University of Nottingham, 54% of the respondents have been supporting fracking".

2.5.5 European Concern in replicating US

The success story of US has created a wave of expectation especially among the net energy importing countries. Some of the issues which EU countries feel for consideration are;

1. Concrete geological data on and experience with Shale Gas is still in its infancy. However to tackle this knowledge gap, the first European

Shale Gas research initiative launched in 2009 (GASH-Gas Shale in Europe) sponsored by European Oil & Gas companies.

2. Difficult to get local residents support.
3. Densely populated than US.
4. Mineral rights are owned by the State, leaving the residents with all trouble and only few benefits.
5. Environmental awareness being higher than in US.
6. In Sweden local residents filed a complaint with the administration in Court in Dalarna, demanding Shell to stop drilling for Shale (the complaint was however rejected).
7. France has already banned hydro fracturing.
8. Equipment shortage as compared to US (US has now 2000 onshore drilling rigs but Europe has only 50, only 7 of these are located in Poland) (Europe the new frontier of Shale rush" Financial times 7 march, 2010).
9. Water sourcing problems more acute in EU.
10. Local Infrastructure inadequacy.
11. Higher labour cost than US.
12. Shale Plays are deeper (the breakeven point of Shale Gas in US as per Bentek energy & wood Mackenzie) is $3 to $7/ mmbtu as against this European Union breakeven price would $10/ mmbtu.
13. Lack of political dynamic inside Europe to promote Shale gas. So far the only indirect mention of Shale Gas reserves can be found in the second energy review, which states that the European commission will commence discussion in Berlin fossil fuel forum, on which additional measure would be taken at community and national level, and in particular in partnership with Norway to further promotes the increased cost effectiveness and environmentally compatible access to indigenous Europe fossil fuel".
14. The drawn out discussion making process and risk-average mindset of the major oil and gas group in Europe, could also slow down efficiencies and development the commercialization of Shale.

Common ground lobby talk (WPSU-2008) (*http://www.wpsu.org/lobbytalks/archives.html*) of Pennsylvania submits that, "Although the potential for fracking fluid to pollute nearby groundwater sources may seem like the most intuitive concern associated with hydraulic fracking, the main environmental concern arising from the extraction of natural gas from the Marcellus Shale formation is connected to the amount of wastewater that is generated by the fracturing. This waste water is, a salty fluid known as brine, can contain hydrocarbons and metals, and may even contain a small amount of radioactive materials. The brine is ten times saltier than ocean water when it flows out of the well bore *Ref. {Susquehanna River basin commission, commission meeting, Gas well drilling and Development: Marcellus Shale (June 12, 2008)}.*

After the fracking process is completed, the waste water remains to be disposed of in some manner. In places like Texas, this waste water can be injected back into ground because there are natural, deep saltwater depositories with limestone caps in the region. In the Marcellus Shale States however, this solution may not be feasible option.

The wastewater could be transported to other states but such transportation would be very costly. The best readily available option, at least for this state of Pennsylvania would be to treat this waste water at in-station facilities. There are currently five facilities in Pennsylvania that are equipped to treat waste water.

The other Marcellus Shale states, must also confronts the problem of how to dispose of wastewater accompanying hydraulic fracturing. Indeed the ways in which one state deals with the problem will affect surrounding states as well. For example, West Virginia has also been addressing the excess volume of wastewater that is created by the fracking process. According to an article in the Stats Journal, West Virginia waste water treatment plants dilute the brine and discharge it into nearby rivers. This practical is becoming problematic as the quantities of brine that need treatment increases.

In one region of West Virginia the increased amount of diluted brine flowing into the Monongahela River caused the river to exceed the standard set out for the permissible amount of total dissolved solids present in the water.

Dilution causes, the management of brine, at high volumes a watershed level issue. The nature of the wastewater is such that the place at which it is disposed will not be the only location affected. Even the diluted brine dumping into rivers, the effect of that dumping will accumulates and spread.

If the volume of the brine increases as extraction from Marcellus Shale formation becomes an increasingly feasible endeavour, a problem that is currently levelised and relatively harmless could become a major environmental concern.

2.6 Asian Experience

China, India and Indonesia have been studied in Asian context.

2.6.1 Chinese Experience

China has hundreds (505) of Sedimentary basins, of which 53 are Cenozoic micro blocks and 3 big blocks. 424 blocks are non-marine basin (Mesozoic), 12 Marine Basin (Palaeozoic) and 69 Marine covered by non marine materials. Geological formation is very complex with time scale of Cambrian, Permian and Mesozoic period (Li Yuxi, 2011).

EIA estimates 2009 put China Shale Gas reserve at 1275 tcf against that of US 862 tcf. The Shale play basins potential reserves are as under:

Table 2.6: Shale Gas Estimates China (Source: EIA, 2009)

S. No.	Shale Basin	Shale Gas Estimates (Tcf)
1	Longmaxi	270
2	Permian	220
3	Qiongzhushi	125
4	L. Silurian	100
5	L. Ordovicn	90
6	M. Ordovicn	60
7	L. Cambrian	40
8	Others	370
	Total	**1275**

However, the estimate of Shale is not yet firmed up, as has been said earlier the Shale Plays are ever changing. The resource potential of Shale (as of 2011) is about 31 tcf as recoverable resources. These resources are spread are in South (46.8%), North (8.9%), Northwest (43%) and Qinghai – Tibet (1.3%) (Prof. Li Yuxi april 2011). These recovewrable Shale resources are of Paleozoic (66.7%), Mesozoiuc (26.7%) and Cenozoic (6.6%). Types of Shale Plays in China are shown in Table 2.7.

Table 2.7: Types of Shale Plays in China (Li Yuxi, 2011)

Type	Distribution	Advantage	Characters
Marine Shale	South of China (mainly in the Yangtze region	Thick, TOC and RO high, distribute stably	Cracking Gas
Shales forms in paretic facies	North of China (north, northwest and northeast)	Not thick, TOC high, RO<3.0%	Coal-related gas
Shale formed in lake facies	North of China, mainly in big sedimentary basin	Middle to thick, TOC high, RO<1.5% distribute stably	Wet gas, light oil or condensate oil
Shale formed in paludal facies	Mainly in the basin with coal	TOC is high, Ro, 3.0%	Coal-related gas

CNPC and Royal Dutch Shell joined hands to explore Shale Gas in China. Both companies signed Production Sharing Contract in 1999. The JV formed $1.3 billion. Natural Gas to the tune of 3bcm is being produced from Changbei field. This field gas is tight as it is trapped in rock that doesn't easily give up their treasure. Shell solved this problem with horizontal wells that level off when they reach the gas, which is deposited in layers about 10,000 feet below the surface. A two pronged pipeline is then drilled from the bottom of the well horizontally for about 6,000 feet so that the well can suck gas from a huge exposed part of rock. So much gas flows into these pipes that Changbei's fields are highly prolific.

Prior to JV with Shell, PetroChina used to take 250 days to drill a well costing them $17 million. Now it takes about 130 days, slashing cost to $10 million per well. Both Shell and CNPC intend to jointly invest in Qatar, Australia, and elsewhere. Shell has allowed entry to CNPC in Syria which CNPC thinks as entry into Arab world.

Note: *China explorable Shale Gas reserves 25.1 TCM sufficient to meet china's gas demand for 200 years.*

The above explorable reserves of 25.1 TCM (about 888.54 Tcf) have now been revised to 1,115 Tcf as of June 2013(Gobal Energy 2013/ EIA 2013). These reserves are the largest of any country in the world. Thus in 2013, China becomes the one of the only three countries (with US and Canada) to produce Shale Gas in commercial quantities (EIA Report 23-10-2013). Sinopec Corp has started pumping Shale Gas from test well in commercial quantity. Sinopec feels that it will be a breakthrough in the development of Shale gas. This definitive result will boost prospects of more competition in upcoming third round of bidding.

During round-II in 2012, Government awarded 19 exploration blocks to 16 local companies who pledged $2 billion over following 3 years. Amongst these 16 were the 6 state run companies mostly affiliated with big utilities and Coal miners including Huadian Group, Shenhua Group and China Coal Group, 8 other were energy investment firms freshly formed under the auspices of local government and 2 were little known private firms.

None of these awardees from 16 firms under bidding round II has drilled any well so far (November, 2013). Also the corruption scandal at Petro china where four senior executive are arrested has retarded Shale movement in

China. The good news is that in November, 2011, china has raised domestic natural gas price to $8/mmbtu (*Ref. Craige Stephen*)

With continued efforts China has now been preparing itself for third round of Shale Blocks bidding. “Shanghai Securities News” reported on November 8, 2013, quoting Reuters that China’s third bidding round includes Shale Plays in South west city of Chongqing and Sichuan & Hubei.

China has also tried to frac its Shale Plays with propane as fracking fluid thereby, overcoming the requirement of water (Tom Martl, 2012)

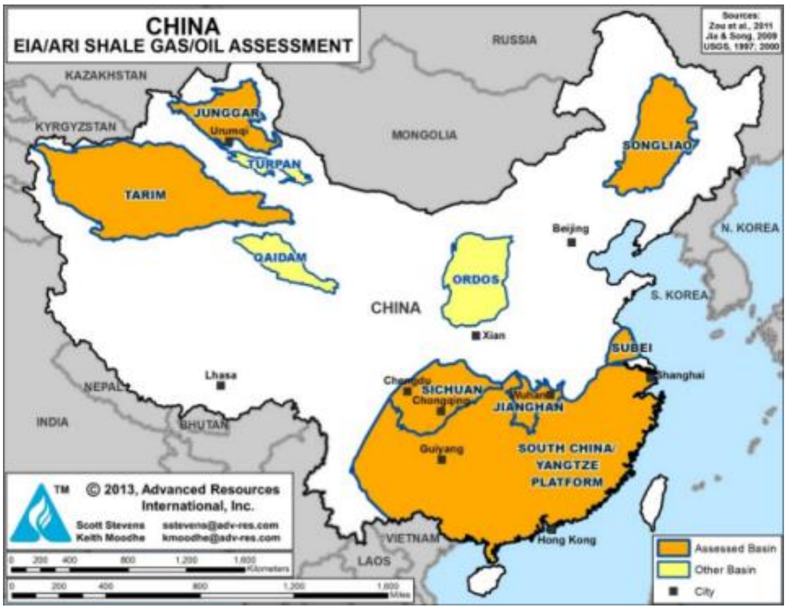

Fig. 2.12: China’s third round of Shale Blocks Bidding (EIA/Today in energy)

China was ranked as the largest holder of Shale Gas resources among the 41 countries assessed for technically recoverable Shale resources in the study released by EIA/ARI this past June. The Chinese government has not officially reported on Shale Gas production, but some independent Chinese energy analysts have claimed commercial production of at least 0.003 Bcf/d of Shale gas, mainly from the Sichuan Basin.

Extracting Shale Gas consumes vast quantities of water, and water is scarce in much of the mainland regions rich in gas resources, particularly in northern and northwest China. Environmentalists and some mainland residents worry that the water and chemicals used to fracture rock will drain water supplies and cause sandstorms.

Unlike the US, where Shale layers are simple and uniform, China's Shale layers, like those in Europe, are heavily faulted, according to a Daiwa Securities research report. This means rock formations are deformed as a result of underground movements. Only short horizontal sections can be drilled, incurring higher drilling costs. Many of these faults are tectonically active, Daiwa reports, quoting Advanced Resources International, an American unconventional gas industry consultant.

2.6.2 Indonesian Experience

In 2006, drilling in Java, an island of Indonesia, led to eruption of a mud volcano that killed at least 13 people and displaced more than 30,000 people, thereafter, Indonesian government did not allow drilling for Shale gas.

Fig. 2.13 Indonesian Shale Plays

As per the study by Bandung institute of technology Indonesia holds 1000 TCF of Shale Gas reserves.. They expect to tender the Shale blocks by end of 2011. During 2011, Indonesia produced 905 thousand BPT of oil and 247

MMSCMD of gas from its 15 producing basins, out of total from 56 basins. Indonesia expected to tender for development of onshore Shale Gas field in eastern Indonesia. (Eddy A. Subroto , 2011) The highlight of Shale Gas plays are:-

(i) Average depth around 600 m
(ii) Structurally complicated
(iii) Policy on Shale Gas development under preparation
(iv) Expected cost of Shale Gas well 8 million dollar

2.6.3 Shale Gas in India

Shale Gas reserves in India are expected in following basins: *(B. Kumar, 2011)*

i. **Cambay Basin**: comprising of Cambay Shale (Early Eocene), Olpad (Eocene-Paleocene).
ii. **KG Basin**: comprising of Vadapurru Shale (Eocene Paleocene), Palakollu Shale (cretaceous), Raghavapuram and kommugudem formation Shale (Permo-Carboniferous).
iii. **Cauvery Basin:** comprising of Komarakshi formation (Santonian Campanian), kudavasal Shale Sattapadi Formation (Albian-Cenomanian).
iv. **Assam Arakan Belt:** comprising of Shale within sylhet formation (oil) (Early Eocene), kopili Formation (Fm) (oil) (Mid Eocene), upper Disang Fm (oil) (Eocene), lower to middle barail Fm (oil) (Oligicene), Bhuban Fm (gas) (early Miocene).
v. **Gondawana Region:** covering the areas of Satpura, South Rewa, Damodar and Pranhita Godawari. The Shale Plays comprise of Baraker Shale (Lower Permian), Bijori/raniganj (Upper Permian).
vi. **Rajasthan Region:** comprising of Bilara Formation (permo-Carboniferous), Pariwar-Baisakhi-Badeswar (Uppere Jurassic).

vii. **Vindhyas Region:** this region covers Vindhyan and Cuddapan and comprises of Sirbu Shale, Ganugrah Shale, jhiri Shale, Panna Shale and Bijaigarh Shale (all belong to Meso-neo-proterozoic age).

viii. **Ganges Valley:** comprising of Middle and Lower Siwalik (Upper-Mid Miocene), Karanpura (Upper Silurian-lower Devonian, Tihar /Jhani (Proterozoic).

ix. **Bengal Region:** covers the areas of Bengal and Mahanadi and comprises of Jalangi Formation (Late cretaceous-Paleocene).

However the assessment of reserves has not yet been carried out for enabling any Commercial exploration for Shale gas. The available information is tabulated below:

Table 2.8 Shale Gas Potential Assessment for India (Compiled from various sources)

S. No.	Resource Potential(tcf)	Remarks
1	3526	Compiled by Society of Petroleum Engineers, combined for India and China.
2	63	EIA Independent Statistics & Analysis Report April, 2011, Report shows China Reserves at 1235 tcf. Thus combined reserves for India and China are 1385 tcf.
3	500	Report from Hardy Oil presented during Shale Gas India 2011 Conference (for KG basin, Cauvery and Cambay basin only).
4	55-100	McKinsey & Co.

The table above shows that it is too preliminary information to be relied upon for any commercial exploration. Government of India has signed an MOU with US in November, 2010, which has following four important provisions:

i. Resource assessment (in association with US Geological Survey).
ii. Co-operation on Technical issues.
iii. Developing a policy frame work.
iv. Exchange of experience.

Thus the intentions are clear but speed is important. As of now no significant progress is reported.

Table 2.9 Experimental Data from Indian Shale Plays (EIA report 2012)

Basin Parameters	Cambay Basin	K-G Basic	Cauvery Basin	Assam-Arakan Belt	Gondwana	Vindhyan
Formation	Older Cambay Shale and Younger Cambay Shale	Raghavapuram Shale (Kommugudem formation)	Settapadi formation and Andimedam formation	Disang Shale and Bhuban Shale	Borren measures and baraker formation	Chokaria olive Shale, ghanurgarh Shales
Geologic Age	Paleocene-Lr. ecocene	Late cretaceous , Permian-carboniferous	Late cretaceous, Early cretaceous	Paleocene, Eocene and Miocene	Early to late Permian	Proterozoic
Depth (m) Average	1200-2000	>2000	2000-3000	>2500	>2000	>1800
Thickness (m)	500-1200	300-1500	300-750	400-1000	500-100	>350
TOC (%)	1.5-4.0	1.4-5.3	0.31-4.76	0.64-1.00	4.0-10	0.40-6.04
VRo (%)	0.75-1.20	0.90-1.30	0.65-1.20	0.57-1.94	.40-1.20	No data
Kerogen type *	II & III	II & III	II & III	II & III	III	II & III
Gas concentration (Bcf/sq. Mile)	231	143	143	120	123	No data
Prognosticated Resources (tcf)	217	280	80	55	85	Not Estimated

**Kerogen Type II is both oil and gas prone and Kerogen type III is is only gas prone*

2.6.3.1 The major opportunities identified for India are

i. Significant number of geologic basins across the country.
ii. The technology which was developed in US over the past three to four decades is available for application around the world.
iii. New technology is becoming a worldwide commodity through efforts of major service companies operating in many countries.
iv. Increased Global demand for energy will continue to be an incentive for worldwide unconventional energy sources, India being no exception.

2.6.3.2 Indian Field Experimentation

I. Reliance Industries Ltd. (RIL) has done experimental drilling for Shale Gas in Cambay Basins covering Tectonic blocks of:

- Patan block
- Ahmedabad -Mehsana Block
- Tarapur Block

- Broach Block
- Narmada Block

The Stratigraphy of Cambay basin is given in Table 2.9. The observations based on the core analysis are given below.

(i) Cambay Shale TOC (1.2-5.7) & HI (75-200): Good Source Potential

(ii) At the penetrated sections maturity (VRo): 0.7 to 1

(iii) Basin model: Good calibration with measured data

(iv) Significantly matured (wet gas window) section with good thickness demarcated

(v) Average Clay - 38%

(vi) Average Quartz - 36%

(vii) Organic Richness & Maturity: Satisfactory at the drilled locations

(viii) Maturity map derived from basin modeling suggests suitable zones of future interest: Well calibration boosts confidence

(ix) Thickness of Cambay Shale: significant

(x) Genetic gas characterization: Gas found in the sections drilled are of thermogenic origin

(xi) Hence, gas generation potential is proven in the study area

(xii) Integrated approach is useful for evaluating gas Shale potential in areas with few wells drilled

*Table 2.10 Generalized Stratigraphy - Cambay Basin (RIL experimental Data***)**

Sub- Surface Strata	Age
Gujarat Alluvium	Recent to Pleistocene
Jamusar Formation	Recent to Pleiatocene
Broach Formation	Pliocene
Jhagadia Formation	UP Miocene + Mid Miocene
Kand Formation	Mid Miocene
Babaguru Formation	LR Miocene
Tarkeswara Formation	LR Miocene
Dadhar Formation	Oligocene
Vaso Formation	UP Eocene
Younger Cambay Shale	LR Eocene
Older Cambay Shale	LR Eocene
Olpad Formation	Paleocene
Daccen Trap Group	Upper Cretaceous
Somonla Formation	Lower cretaceous to Jurassic

II. GSPC Shale Gas Project;

In 2004, GSPC collected experimental data from Tarapur, Ahmedabad, Ankleswer, Sanand and Mirali. Data collected have been encouraging (Table 2.10). Depth of well (average) 2500m. (*Result: Shale Gas potential established)*

III. ONGC Damodar Valley project

Damodar valley basin Project (Costing INR 1.28bn) launched with engagement of Schlemburger as the contractor. The selection of site based on ONGC's experience for conventional fields. Following are the salient features of the project details and the findings.

(i) Sites selected: Karanpur and Raniganj
(ii) Experimental well drilled for core analysis: Core data analyzed for TOC, Gas contents, Gas stratigraphic data. From core analysis, Type-III Kerogen noticed

(iii) Data compared with US Shale Gas plays from 12 Gas producing and 50 prospective plays. It is noted that Damodar Shale has:

a. High TOC

b. Maturity 0.9 to 1.0 at 700 to 800 meter

c. Indian Shale is thickness ranges from 800 to 1500M (which is thicker as compared to US Shale)

(iv) DV Shale has high maturity at shallow depth is good for Hydro Fracking

(v) Schlumberger drilled vertical well and the Shale Gas was produced on 24th Jan. 2011 from a depth of 900m

IV. Joshi Technology Shale Gas finds

These finds relate to the observations during carrying out normal E&P activities in the conventional E&P blocks. There was an accidental find of Shale Gas from:-

(a) Dholka Field –Cambay basin, Finds (1989 and 2009) reported by Joshi Technology. Depth of Shale from 1307 to 1317 meter. Incidence of gas finds reported in the conference on 20-22 Jan 2010 (Techonology, 2009)

(b) Kanwara field Cambay basin(Tarapur Tectonic Block), thickness of Shale play more than 1000meter. TOC value of 1.5 to 4% and VRo value of 0.8 to 1.2, showing dry gas, (Techonology, 2009)

A concept of finding sweet spots goes every well with Shale Gas E&E. First, the regional or basin sweet spots are identified in the manner where Shale is encountered while drilling conventional well as in above case within the basin. There after the local or operating area sweet spot are confirmed by drilling pilot well and core & logging measurement from pilot wells provide data to update whether pilot well has intersected a sweet spot (Karen Salivan Glaser et. al. 2014). Sweet spots are the most prospective area and aligning the well bore for maximum bore hole exposure to this zone (*www.halliburton.com*)

V. Shale Gas initiative of OIL

OIL has been doing Shale Gas experiment in North East. Data generated from field exploration have not yet been made public. The experimental and exploratory data collected by various companies who took Initiative for exploration of Shale Gas in India. These data are placed in table 2.6. The data indicate that Indian Shale Plays have good TOC and the thickness of Shale Plays varies from 500 meter to 1500 meter. The depth of Shale structure varies from 300 meter to 1200 meter. We can conclude that India will have reasonably good Shale prospects.

Table 2.11 Indian Exploratory Initiative (Presentation BS Negi at Shale Gas - World Asia - 2012 Singapore, 9-12 July 2012 "Shale Gas Exploration – Preparation & Regulation in India; What Asia has to learn)

S. No.	Characteristics	RIL	GSPC	JTI	ONGC
1	Location	Ahmedabad, Patan, Bharooch etc	Tarapur, Ahmedabad, Sanand etc	Dholka, kanwara	Damodar(Karanpur, Raniganj
2	Organic richness TOC %	1.2 - 5.7	High	1.5-4.0	High
3	Vitrinile Reflection VRo	0.7 – 1.0	Not Reported	0.8 – 1.2	0.9 – 1.0 (700-800 M)
4	HI	75 - 100	Not Reported	N/R	N/R
5	Thickness	significant	Above 800 M	900-1200 M	800 - 1500M
6	Clay	38%	Not Reported	Accidental Shale Find	Not reported
7	Quartz	36%	Not Reported		Not reported
8	Well depth	N/A	2500 M	1310 M	2400 M
9	Shale Gas Potential	Established (Year-2009)	Established (Year-2004)	Established (Jan 2010)	Production (Jan.2011)

As can be seen above, the Indian Shale Gas initiative is in a nascent stage. The PSU's have been undertaking E&P activities for almost a century now and have reasonably good idea about the sedimentary basins of India. They would therefore need to attempt wild cat drilling as it is said that the oil & gas is first found in the mind of the explorer and thereafter in the field. The wild cat drilling is defined as the process adopted by the companies that look for oil & gas where other don't believe it is located (Beckley 2011).

2.6.3.3 Shale Gas Policy in India

Director General of Hydrocarbons (DGH) the upstream Regulator in India was established in 1993 by an administrative order of the government. DGH operates under the administrative control of the Ministry of Petroleum & Natural Gas (MoPNG). Government had issued guidelines for New Exploration & Licensing Policy (NELP) in 1998. Under this policy the first round of bidding for exploration blocks started in 1999. Till now nine round of bidding have been completed and 254 blocks have so far been awarded to various E&P contractors. Preparations for 10th round of bidding are on and it is expected i.e. fiscal year 2013-14 approx. 86 blocks would be offered for bidding (source briefing by Oil Minister of India, M.Veerappa Molly to parliamentary consultative committee in Mussoorie on 04th June, 2013, TOI dated 05th June, 2013).

There have been certain changes in the NELP bidding to be incorporated from 10th round. Significant among them are the abolition of Cost recovery and allowing production sharing as the major criterion for weightage in the bidding. However, there is no policy for Shale Gas E&E in India. The Government announced a policy in April, 2012 for public consultation. The comments offered by the researcher are as under:-

2.6.3.4 Suggestions on the Draft Shale Gas Policy of India

Government of India notified Draft Shale Gas Policy in April 2012 seeking public comments. The researcher made certain suggestion to the government of India on the draft Shale Gas Policy, which are placed at Appendix-B and briefed below:

1. **Shale Gas Plays Exploratory Data**

   The exploratory data from various Shale Plays are required for a competitive bidding. As of now we do not have enough data on most of our Shale plays. Shale oil/gas Policy therefore needs to define the time bound acquisition of field exploratory data indicating the " Sweet

Spots" and the responsibility for such data acquisition as a project. The role of DGH shall have to be defined in the Policy frame work.

2. **Shale Gas Price**

   Whereas the draft policy suggests that the Shale oil can be sold as oil produced from conventional E&P blocks with import parity. The policy does not bring clarity in respect to marketing of Shale gas. It only states that the Shale Gas can be marketed as per Gas Pricing and Gas allocation policy of the Government. This is a negative factor because it neither gives the freedom to market nor it assures market driven price

   Suggestion: *To begin with, producers should have freedom to market gas at arm's length at a price not less than the weighted average cost of domestic gas and LNG import price (other than spot cargos)*

3. While addressing Fiscal issue, the Shale Gas Policy needs to provide 7 year tax holiday as provided in CBM policy.

4. The water management in Shale Gas E&E is very cost intensive and has high environmental impact. As mentioned in the Dft. Shale Gas Policy, the applicable provisions are the Water (prevention and control of pollution) Act 1974 but the same does not answer all these questions. It is therefore suggested that based on global experience, we carve out the process and parameters.

5. India has very high population density with highly fractured land holding pattern. This would make land acquisition a difficult task for Shale Gas E&E. A profit sharing provision for individual land owner in proportion to the area of their land acquired may provide a solution.

   Suggestion: *Production sharing from Shale Plays may either be made as bidding condition with flat rate of production sharing mentioned in the bid document or it could be a biddable parameter (having the* *weightage of say 10% marks carved out 5% each from work programme and production sharing with the government or alternatively 10% marks carved out of production sharing provision alone)*

6. I have studied various issues/ aspects/ factors that influence Shale Gas Exploration and exploitation in India based on extensive literature review, deliberations in the conferences and discussions with the pears. A many as 42 of such aspects have been tabulated for further analysis in the form a questionnaire as a part of research study. This same is attached herewith with the suggestion that these aspects may be considered while framing Model Contract.

7. Since the natural gas transmission pipeline network in India is quite inadequate to meet the requirement of collecting gas from large numbers of Shale Gas production wells, it therefore suggested to allow growth of unregulated gas gathering pipelines (on US pattern). Policy should therefore mention that the PMP Act shall be applicable to such entrepreneurs.

*(Further Observations on various sections of the draft policy placed **Appendix-B**)*

2.6.3.5 Shale Gas Policy statement by the Central Government

The Central Government in its recent (October, 2013) policy statement has authorized the PSUs to explore and exploit Shale Gas from the acreage awarded to them on nomination basis before start of NELP. This interim policy lacks on two counts namely;

(i) It does not give equal opportunity to private and the PSU players

(ii) There is no independent regulator to work as the referee

(iii) In view of the above there will be a constant (very often subjective) intervention from the administrative ministry.

Initiative by PSUs subsequent to interim Shale Gas Policy

DGH indicated that total pre-NELP blocks with ONGC and OIL are 356, out of which 176 could be Shale bearing. However the figure indicated by ONGC and OIL are different. ONGC indicated to do drilling in 175 blocks and OIL in 15 blocks.(Business Line , Nov. 2013, *richa.mishra@thehindu.co.in*)

ONGC signed MOU with CONOCO Phillip US to study Shale in 4 basins-Cambay, KG basin, Cauvery basin and Damodar basin. Broach depression in Cambay basin was selected for pilot drilling. On No. 24th 2013, drilling completed up to 1735m depth and further drilling is in progress.

Further, ONGC on 25 Feb. 2014 to start drilling operation in Jambusar (Cambay basin) (Business Standard 23rd Feb.2014)

Coal India Ltd. (CIL) allowed to Monetize CBM

The report publishes in The Business Standard dated 31 Dec 2013 is a good reference.
Quote, " (Report by Sudheerpal Singh) : State-owned Coal India Ltd (CIL) may not get a free hand in selecting a private partner for tapping into the newly-opened Coal Bed Methane (CBM) opportunity.

The petroleum ministry may impose restrictions on private partnership for development of 4 trillion cubic feet (TCF) CBM reserves in CIL's existing blocks allocated on nomination basis.

The oil ministry's restrictions could lend uncertainty to the models being worked out for joint development of the reserves.
"The oil ministry has been mulling these restrictions. So, there is no clarity on the models of partnership until we receive a final communication from the government on the matter," a senior CIL executive told Business Standard.

He added that by restricting joint ventures with private companies, the ministry wants to discourage back-door entry by private entities in CBM exploration as the blocks have been allocated on nomination basis and not through competitive bidding.

Earlier this month, the Cabinet Committee on Economic Affairs (CCEA) headed by Prime Minister had allowed the world's largest coal miner to explore and produce CBM in its existing mines. The government plans to extract CBM lying buried in blocks and use the compressed gas to fire power plants stranded for want of fuel.

The possibility of restrictions comes close on the heels of speculations on various options for exploiting CBM reserves -- Public Private Partnership (PPP) route similar to the Mine Development and Operator (MDO) model used in conventional coal mining; floating a Special Purpose vehicle (SPV) or even through creation of a separate subsidiary.

Coal India has already identified five coal blocks in Jharkhand with combined CBM reserves of an estimated 1 TCF for exploration in the first stage.

In addition to methane, exploration and extraction from CBM coal seams would expose huge coking coal reserves for CIL. "As far as exploration is concerned, we have decided not to go through the PPP route and work it out alone. We can take that risk in the exploration stage," the CIL executive said.

The uncertainty over the CBM venture is owed also to the lack of credible data on the estimate of reserves lying untapped in the blocks, apart from the government's final decision on the issue of conditions for partnership. The CIL executive the company would float a global tender within four months of receiving the government's final communication on the issue of partnership.

"The tender would invite companies for exploration in all the five blocks together. The partner would bring in technology and would be responsible for routine work while we will spend the money," the executive said. The blocks would require investment of around Rs 25-30 Crores for the first round of initial exploration.

The government has awarded 33 CBM blocks in four auction rounds over the past 13 years. In addition, two CBM blocks to state-owned explorer Oil and Natural Gas Corp (ONGC) and one to Great Eastern Energy Co have been awarded on nomination basis.

2.7 Australian Experience

Estimated Shale reserves of Australia are 396 Tcf (EIA) and the tight gas and Shale Gas un-risked resource potential is 230 Tcf (RISC, 2010). There are four basins as most prospective and commercially viable Shalr basins, namely:

(i) **Cooper Basin:** Permian, Cambrian formation (age- 250 to 500 million years) Risked resourceof 85 Tcf (EIA 2011). Beach energy (BPT) has been the first company operating in this basin. (Potter Bell, 2011).

(ii) **Perth Basin:** North South Australia, belongs to Permian and triassic formation (age250 to 400 million years), the risked resource potential 60 Tcf (EIA 2011).

(iii) **Canning Basin:** Cretarius, Sulerian, Ordovician formation(age120 to 480 million year). Risked resources 230 Tcf (EIA 2011).

(iv) **Otwag Basin:** Cretaceous formation (age 65 years), reskes resource potential 15 Tcf (EIA 2011).

There are more basins which have Shale potential, under estimation, e.g.;

(a) Becaloo Basin
(b) Anadous Basin
(c) Sydney Basin
(d) Ceoreina Basin (PotterBell, 2011)

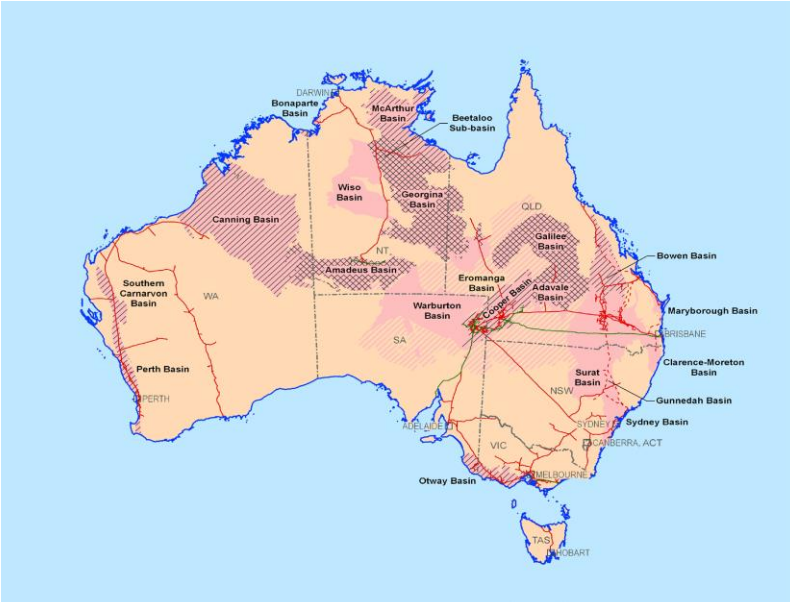

Fig. 2.14: Shale Plays – Australia (Source: Internet Site)

There are many companies operating now in Australia such as; Beach Energy (BPT), ICON Energy (ICN), Drill Search Energy (DLS), Senex Energy (SXY), Santos (STO), New Standard Energy (NSE), Bune Energy (BRU) has also inducted Mitsubishi, AWE Ltd. (AWE), North West Energy (NWE), Cooper Energy (COE). (Potter Bell, 2011)

Central Australia’s Shale Gas potential is drawing fast growing international interest and could led US energy giants to sharpen their focus on the country after presiding over an extraordinary gas boom in North America.

A leading energy investment bank in Houston, Texas, this week branded the Cooper Basin one of the best Shale prospects outside North America.

Tudor Pickering Holt released its report following healthy initial flow rates from most hydraulically fractured, or fracked, wells in the Cooper Basin, which crosses the South Australia-Queensland Border. And Tudor Pickering Holt lists strong gas prices and existing infrastructure as extra reasons for investors to sit up and take notice.

“The Cooper Basin has promising geology, with organic-rich mature Shale, strong gas pricing, favourable fiscal terms, existing infrastructure in place, and already-present service industry, low population density, few environmental hurdles and generally industry-friendly government.”

Santos and Beach Energy are the best-positioned companies to capture the growth, that early results had excited North American industry experts. Australian Shale Plays are as good as the best of the North American vertical wells,” (Professor Peter Hartley 2013)

In what would be music to big gas consumers’ ears, TPH said a key risk would be how the economics of Shale Gas compared with coal-seam gas in Queensland, and whether there was enough LNG capacity to support full-scale development, given limited local demand.

“This may be an issue similar to that seen in the US, where prolific productive capacity caused the gas price to crater.” This would be pretty funny if it came to pass. It would put the plans of the Gladstone gas majors in a spin, with their coal seam gas expansions at the expensive end of the cost curve in part owing to coal seam gas that is more expensive than these Shale figures suggest. There is currently no pipeline from Cooper to the QLD network (though there is one going the other way). Santos is a part of the Gladstone boom so it would surely seek to channel any cheap major new resource in the Cooper basin to Gladstone via a new pipeline.

But there are already pipelines from Cooper to NSW and SA. The cheap gas could be captured by the domestic market or even trigger new LNG plants in Newcastle that operate more cheaply than their Queensland (QLD) counterparts. Policy is going to determine the outcome so watch the rent-seekers swarm over this honey pot!

2.8 Others

Under this, South Africa and North West Africa are discussed.

2.8.1 South Africa

Water related issues are the most important issue in South African context. The Article describes the initiation for Shale from drilling well in the area covering 1200 Km between Jonesburg and Cape Town. This area is called "Thirsty Land", since it hardly sees any rainfall.

A Shale Gas well may need 3.7 million litres of water or more, this is an aspect of the Shale Gas exploration. The companies intending to explore and exploit Shale Gas in South Africa have to find the ways to dispose of all the toxic waste water since the closet land fill or industrial waste activity is hundreds of kilometres away. Europe and some of the countries (including South Africa) with Shale Gas potential have significantly less renewable water resources than US" (Ina Urbina, 2012).

Fracking involves injecting large amount of water mixed with chemicals and sand at very high pressure deep underground to crack rock and release gas. After fracking, much of the water returns to the surface mixed with toxic chemicals.

2.8.2 North West Africa;

North West Africa also holds good amount of Shale Gas. Air pollution from Methane escape, water contamination from spills or underground seepage, truck traffic that comes with drilling are the issues to be addressed. (Jabour Haddou, 2012). Table 2.12 depicts such potential.

Table 2.12: Shale Gas Potential in North West Africa (Jabour Haddou, 2012)

Age Ma	Shale Age		Location	Shale Gas Potential?	Comment
66	Cenozoic	Paleogene	Libya, Tunisia	No	Offshore and immature
146	Mesozoic	Cretaceous	Libya, Egypt, Morocco	Unlikely	Likely to be oil prone
199	Mesozoic	Jurassic	Egypt, Morocco USA	Unlikely	Likely to be oil prone
299	Palaeozoic	Permo-Triassic	Libya	Negligible	
359	Palaeozoic	Carboniferous	Morocco, USA	Possibly	
416	Palaeozoic	Devonian	Algeria, Libya, USA	Yes (local)	
444	Palaeozoic	**Silurian**	**Morocco, Algeria, Tunisia, Libya, Jordan, Saudi Arabia, Syria, Iraq,**	**Yes (Regional)**	**Widespread, organic rich, and with suitable burial history.**
488	Palaeozoic	Ordovician	Jordan, Algeria, USA	Yes (local)	

"In depth Energy- Horizontal Option" an article (Anilish S Mahajan Oct.2010) highlights amongst other issues the location of Shale Plays happens to be in sensitive areas including Naxal prone area. The operators may not be willing to work at such location. In the same newspaper Ajay Arora, partner E&Y writes "The Shale opportunity" and observes that the typically a Shale Gas project have Field Development costs of $1.3/mcf (thousand cubic feet) compared to $1.0/mcf for conventional gas. Production costs are also higher: &1.2/mcf compared to $0.5/mcf for conventional gas. He further observes that a comprehensive policy furnishes that provide clarity regarding average licensing, taxes, royalties and gas pricing mechanism will help the Shale Gas Exploration in India.

Addressing environmental concerns different countries have taken different stand. In an article titled "out of gas" (India Shale Gas Policy moving at a glacial pace, and the delay could prove costly). (Anilish S. Mahajan , 2012)

The world's estimated Shale reserves are indicated below:

Table 2.13 World Shale Potential

Country	Reserves (Tcf)	Remark
US	862	18 % of gas from Shale Hydro fracking on hold into stales. Impact being reviewed.
Canada	396	Exploration on hold in Quebec. Impact being studied.
France	180	Ban on Hydraulic fracking
Poland*	187	Exploration underway. Threat to veto EU proposal to ban or curtail Shale activity
China#	1275	Target to produce 30 tcf a year. Companies must treat water before releasing.
Australia	396	Exploration underway. Protests against hydraulic fracking.

(Source:-Estimated by US Energy Information Administration (EIA) made available by BT Research)

**On further fine tuning, these reserves have been put to 105.6 tcf and till 2012, 40 licenses have been awarded (study commissioned by Poland). The same study also estimated west Europe reserves at 528.0 tcf.*

 # On further fine tuning of the study commissioned by China, the explorable Shale Gas reserves have been estimated to 878.5 tcf which are sufficient to meet China's gas demand for 200 years.

About gas pricing in India the views expressed by the Dy. Chairman, Planning Commission are very relevant. He said (reported by PBP Bureau/PTI) on 8th Feb, 2012. "We should decide now ab-initio what should be the price of natural gas, what should be the principle, which should be applied. On the other hand we (advocate) freedom to price gas on an arm's length basis, but on the other hand we also say that (Companies) must allocate gas according to government priorities."

Citing example of Fertilizer sector which can bid for whatever price because their input cost is pass-through. The country must internalise real cost of energy while subsidy be determined separately. He further said, "I am not aware that any of the existing models (for pricing of gas) meets the test of economic rationality. The Planning Commission has also advocated the market determined energy prices, in its Integrated Energy Policy, which was approved by the Union Cabinet.

From literature survey it is brought out that:

1. The local energy mix in India is dominated by coal.
2. Hydropower, biomass, geothermal, wind solar and sometime nuclear is considered much cleaner than Shale gas, but quantity wise their contribution is limited to less than 10% of the primary energy basket globally.
3. A lot of water is needed for Shale Gas production. After it is used the water has to be treated and disposed properly adding pollution issues to the surrounding.
4. Shale Gas is not confined to one location rather spread widely which raises the issue of land acquisition.
5. The emission of gas during operation, could add an additional environmental burden to the Shale Gas sector since the emission of methane for the moment are not well monitored.
6. The operations to extract Shale Gas are very labour and cost intensive. Thousands of drilling and fracking of the rock have to the performed. The Regulation covering these operations are not very clear and might create unregulated and undesired disturbances including induced seismicity in the concerned neighborhood.
7. Chinese Government had stated that they will be holding auctions for third round of Shale Gas Blocks in China, as the country aims to produce 6.5 bcm of Shale Gas by 2015.
8. Shale Plays are unique and specify study needed for each Play/Basin.

2.9 Absorption of Innovation

The information gathered from the literature review which needs be applied in India will have to be percolated to the implementation level for which the theory needs be seen. Any information available for public consumption can be accessed by individual or from media to some peers and through them to individuals. The later version is more prevalent as all individuals will not have full opportunities to access the information and this concept is known as Two Step Flow Theory (also known as the **Multistep Flow Model** as shown in figure 2.15) is a theory based on a 1940s study on social influence that states that media effects are indirectly established through the personal influence of opinion leaders. The majority of people receives much of their information and is influenced by the media secondhand, through the personal influence of opinion leaders. They then begin to infiltrate these opinions through the general public who become "opinion followers". These "opinion leaders" gain their influence through more elite media as opposed to mainstream mass media. (Paul, 1944) and their book Personal Influence (1955) is considered to be the handbook to the theory.

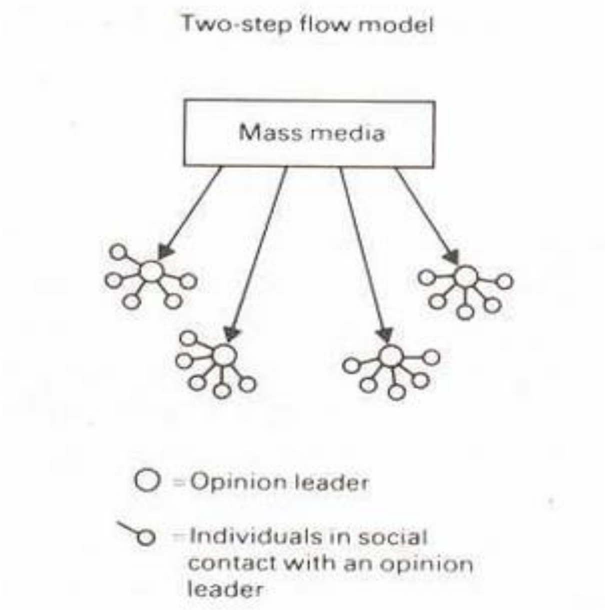

Fig. 2.15: Two Step Flow Model (Katz & Lazarsfeld, 1955)

However Deutschmann and Danielson found substantial evidence that initial mass media information flows directly to people on the whole and is not relayed by opinion leaders. Furthermore, the two-step hypothesis does not adequately describe the flow of learning. Everett Rogers' "Diffusion of Innovations" cites one study in which two-thirds of respondents accredited their awareness to the mass media rather than face-to-face communication. Similarly, critics argue that most of Lazarsfeld's findings pertain to learning factors involved with general media habits rather than the learning of particular information. Both findings suggest a greater prevalence of a one-step flow of communication.

2.9.1 Diffusion of Innovation Theory

Diffusion research goes one step further than two-step flow theory. The original diffusion research was done as early as 1903 by the French sociologist Gabriel Tarde who plotted the original S-shaped diffusion curve. Tardes' 1903 S-shaped curve is of current importance because "most innovations have an S-shaped rate of adoption" (Rogers, 1995).

Core Assumptions and Statements

Core: Diffusion research centres on the conditions which increase or decrease the likelihood that a new idea, product, or practice will be adopted by members of a given culture. Diffusion of innovation theory predicts that media as well as interpersonal contacts provide information and influence opinion and judgment. Studying how innovation occurs, E.M. Rogers (1995) argued that it consists of four stages: invention, diffusion (or communication) through the social system, time and consequences. The information flows through networks. The nature of networks and the roles opinion leaders play in them determine the likelihood that the innovation will be adopted. Innovation diffusion research has attempted to explain the variables that influence how and why users adopt a new information medium, such as the Internet. Opinion leaders exert influence on audience behaviour via their personal contact, but additional intermediaries called change agents and gatekeepers are also included in the process of diffusion. Five adopter categories are: (1) innovators, (2) early adopters, (3) early majority, (4) late majority, and (5) laggards. These categories follow a standard deviation-curve, very little innovators adopt the innovation in the beginning (2,5%), early adopters making up for 13,5% a short time later, the early majority 34%, the late majority 34% and after some time finally the laggards make up for 16%.

Statements: Diffusion is the “process by which an innovation is communicated through certain channels over a period of time among the members of a social system”. An innovation is “an idea, practice, or object that is perceived to be new by an individual or other unit of adoption". "Communication is a process in which participants create and share information with one another to reach a mutual understanding" (Rogers, 1995). Conceptual Model shown below:

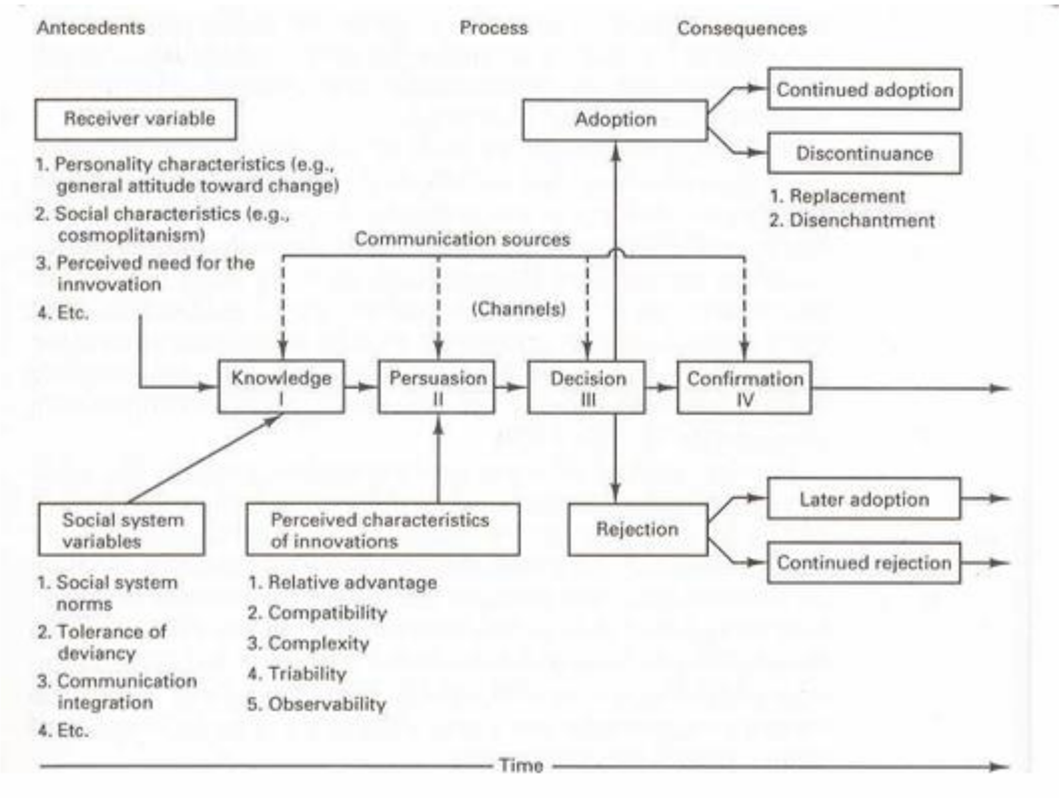

Fig. 2.16: Diffusion of Innovation Model (Rogers, 1995)

Favourite Methods

Some of the methods are network analysis, surveys, field experiments and ECCO analysis. ECCO, Episodic Communication Channels in Organization, analysis is a form of a data collection log-sheet. This method is specially designed to analyze and map communication networks and measure rates of flow, distortion of messages, and redundancy. The ECCO is used to monitor the progress of a specific piece of information through the organization.

Scope and Application

Diffusion research has focused on five elements: (1) the characteristics of an innovation which may influence its adoption; (2) the decision-making process that occurs when individuals consider adopting a new idea, product or practice; (3) the characteristics of individuals that make them likely to adopt an innovation; (4) the consequences for individuals and society of adopting an innovation; and (5) communication channels used in the adoption process.

2.9.2 Example of present study, Applicable to India for Shale Gas E&E

For the present study, the diffusion of the information / innovation available for employing in India can be summarized as under:

(1) The characteristics of an innovation which may influence its adoption- The innovations which are to be absorbed/ adopted relate to Shale Gas E&E which have been proven for success except for minor variation in Indian context. Most of the innovations will have positive influence for their adoption

(2) The decision-making process that occurs when individuals consider adopting a new idea, product or practice- It is the economics which will drive the decision making process. The comparison with alternatives will also play an important role.

(3) The characteristics of individuals that make them likely to adopt an innovation- Shale Gas E&E in India being at nascent stage, the individuals and companies will show a high adoptability for the innovations to keep them ahead of the competitors. A long term visionary approach will further enhance such probability.

(4) The consequences for individuals and society of adopting an innovation- The individuals or the companies will get economic benefits by adopting innovations. It is anticipated that most of the adoptions will be between early majority and late majority stage of the Gaussian curve of innovation absorption (Figure 2.17).

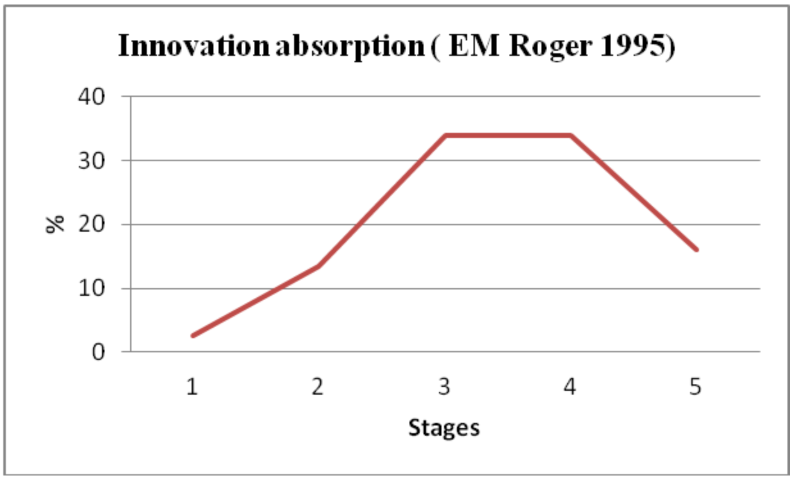

Fig. 2.17 Innovation Absorption
(Source: Drawn by the researcher based on E. M. Rogers, 1995)

(5) Communication channels used in the adoption process- Although Two-Step- Flow Model and Multi-Step-Flow Model for communication dissipation have been criticized but the diffusion of innovation theory (Roger, 1995) suggests that the information flow can be one- is to- one from various communication sources and at various stages than the adaptor takes a decision for its adoption or rejection. The adoption could be continued or discontinued in future and also the rejection could be continued or discontinued (adoption in future)

2.10 Shale Gas Acreages Acquisition

Foreign buyers accounted for 76% of the total value of US Oil & Gas M&As in the third quarter of 2011. With 22 deals valued at $37.3 billion, according to PwC US. The total value of US oil and gas deals in the quarter, rose by 135% from the same period a year earlier, with 46 deals totalling $48.8 billion. (Corporate Finance Focus, December, 2011)

Despite a number of headwinds in the third quarter, with volatile global equity markets and commodity prices, deals in energy sector continued, as companies sought to take advantage of opportunities in Shale Gas to gain technology know-how and diversify services offerings

BHP Billiton acquired Chesapeake energy acreage in Fayetteville Shale (Arkansas, by Helman Christobher -Shale Games published Forbs Feb. 27, 2012) $ 4.75 billion. BHP had not fracked a single Shale well until took over the operation of Chesapeake. The natural gas domestic price was at $4.25 per thousand cubic feet.

i. BHP Billiton acquired petro hawk energy in Louisiana and Texas in July, (Helmen, Feb. 27, 2012)
(With this BHP Headquarter in Melbourne, Australia became 15 large producers in America.)

ii. Shale Gas boom has even made transportation pipeline business as an interest of acquisition. Houston based Kinder Gap Morgan, acquired El. Paso, creating North America's largest natural gas pipeline operator. Earlier Exxon Mobil purchased XTO Energy in December, 2009. There have been 13 deals related to Shale Gas in US. In the third quarter of 2011. (Global Finance December, 2011)

iii. Reliance acquired three Shale Gas acreages in US namely:
    a. Eagle Ford Shale Play from Pioneer in 2010 for $1.32bm.
    b. Marcellus Shale Play Atlas Energy in 2010 for $1.70bm.
    c. Marcellus Shale from Carrizo in 2010 for $0.39bm.

iv. Acquisition of 20% Shale Gas acreages by GAIL from Carrizo's (Eagle Ford Acreages) and sourcing of 3.5mmpta by Gail from Chenier energy. The Shale Gas is a production field for liquid and gas. [Interview of CMD GAIL, *http://www.resourcedigest*.in p.74 (2011)]

v. BG joint venture with Texas based EXCO acquired Marcellus Shale in 2010 for $0.95bm and Haynes Ville Shale in 2009 for $1.30bm.

vi. Mitsui & Co. acquired a stake in Marcellus Shale through a deal with Anadarko Petroleum in 2010 for $1.40bm.

vii. BP with Lewis Energy JV in Eagle Ford Shale

viii. Exxon Mobil has Stuck a deal for $ 41 billion to takeover XTO energy

ix. Statoil has increase their acreage through deal with Chesapeake energy (the biggest NG producer in US)

x. Conoco Philips joining hands with Lane energy Poland (a subsidiary of U.K based 3 legs resources).

xi. GDF Suez has forged an alliance with a smaller explorer Schulpbach Energy,

xii. ONGC (India) is in discussion with several Shale Gas Companies in US for acquiring Stakes (DNA Mumbai 3.3.2012)

xiii. OIL acquired 20% stake in liquid rich Shale Gas asset in Carrizo Oil & Gas, at Denver-Jubelburg basin Colorado, US The contract is effective from 1st October 2012

xiv. Indianoil acquired 10% stake in liquid rich Shale Gas asset in Carrizo Oil & Gas, at . Denver-Jubelburg basin Colorado, US The contract is effective from 1st October 2012

xv. IOCL contemplating to buy 10% share of PETRONAS in a Shale Gas asset and LNG project in British Columbia (Canada) for $900 million. PETRONAS had earlier in 2011 acquired Canada's Progress Energy Resources in C$5.2 billion to get the Altares, Lily and Kahta Shale Gas assets in north-eastern British Columbia. In March it sold10% stakes to Japan Petroleum Exploration and another 3% to Petroleum Brunei.

2.11 Shale Gas based LNG Deals

(i) GAIL (India) contracted 3.5 mmtpa LNG from Cheniere Energy in 2011. The delivery expected to commence in 2017,

(ii) GAIL has booked 2.3 mmtpa LNG from US based Dominion Energy's Cove Point liquefaction plant. Delivery of LNG to commence by 2017. (*Source: Gail India)*

(iii) Petronet LNG has signed an initial pact with Houston based United LNG to buy 4 mmtpa for 20 years from United's Main Pass Energy Hub in the gulf of Mexico. Deliveries are expected to begin from 2018. The final agreement would be signed after United LNG obtains US Department of Energy's waiver for exporting LNG to non-FTA country such as India. Main Pass LNG Terminal has a capacity of 24 mmtpa. This terminal is developed jointly by United and McMoRan Energy Llc. (*TOI dated 26-04-2013)*

2.12 Issues emerging from Literature Survey

Various issues relating to Shale Gas world over are summarized in a table below briefing the issue (theme), select authority, context and the inference.

Table 2 .14 Summary of Literature Review

S. No.	Themes	Select Author(s)	Context	Inferences
1	Shale Gas scenario in the world	Society of Petroleum Engineers (2006)	World	World Shale Gas potential of 16098 tcf.
2	US Shale Gas Potential	Society of Petroleum Engineers (2006) University of Colorado	US	US Shale Gas Potential varying from 1836 to 3840 tcf.
3	Shale Gas Project cause steep inflation cost of local housing and services	Doug Norlen	US	Shale Gas Project cause steep inflation cost of local housing and servicing
4	Extension of US Shale Gas revolution	Paul Steven (2010)	World	Success or failure of Shale Gas Revolution E&E.
5	Comparing Shale Gas concentration with conventional E&P.	EIA Report 2009	World	Shale Gas deposit in place are around 0.2 to 3.2 BCM/km^2 Conventional gas 2 to 5 BCM/ km^2
6	Cost of production of Shale Gas	World Energy Council (2010)	World	Amount of energy needed to produce unconventional gas is considerably higher than the conventional gas.
7	Migration of well Fluid	GASLAND Video by Josh Fox	US	Migration of well/fracking fuel to water body.
8	Shale Gas Onland Vs. Offshore	Gasstrategies.com in Gas Matter (2010)	Europe	The promising Shale basin lies offshore particularly in North Sea.
9	Regulation Governing Drilling Activities	Delaware River Basin Commission	US	Drilling companies to furnish bond for $ 1,25,000 per Well towards plugging and restoration of abundant well.
10	Insurance Policy for Pollution	Zurich,2011	US	Insurance coverage for environmental production in addition to general liability insurance.
11	Land Use	Pennsylvania Supreme Court (2009)	US-Range Sources Case	The State Oil & Gas Act pre-empted the regulations that the township has enacted.
12	Land Use	Pennsylvania Supreme Court (2009)	US- The Huntley Case	The State interest in Oil & Gas development is for efficient production and utilisation of Natural Gas Resources and the county’s interest is orderly development and use of land.
13	Exemption for Shale Gas E&E.	US 2005 Energy Bill	US	Shale Gas E&E exempted from the provisions of Clean Air Act, Clean Water Act 1972, Super Fund Law and other Environmental Regulation.
14	Fracking Fluid	GASLAND Video by Josh	US	Fracking Fuel contains 596 +

		Fox		chemicals including Thiocynomithayl, Thio-benzothiozole and other corrosion inhibiters and biocides etc.
15	Declaring the composition of Fracking Fluid	Louisiana Supreme Court	US	Manufacture of Frack fluid need not disclose the composition of proprietary frack fluid for patent protection.
16	Recovery of Hydraulic Fracking Waste Water	J Petroleum Tech 2008 Society Petroleum Engineer and GE	US	The frack water could be reclaimed upto 70% for recycling.
17	Shale Gas Cheaper than Renewal Energy	Bill Bothe CEO of Energy Services published by Pipeline & Gas Journal (2011)	US	Shale Gas being cheaper than renewal energy may result in retardation of Investment in Renewal Energy.
18	Pipeline Network	Derek Weber (Pipeline Journal -2010)	US	5 lac miles of gas pipelines in US have been instrumental to deliver Shale Gas to market but it is felt that this network will be inadequate to bring entire Marcellus Shale to market. The context also includes the gathering pipeline networks to GGS.
19	Evolution of Mid Stream companies	Derek Weber	US	As a part of Shale Gas evolution new mid stream companies have emerged. Big companies like En Bridge or Alliance have not been able to cope up with the growing requirement of small size gas gathering network.
20	Canadian Shale Gas	Ziff Energy	Canada	Canada Shale will not only compensate for the falling conventional gas production but will also export LNG from its West Coast (Kitimate LNG) and East Coast (Upcoming Project –St. Jones).
21	Shale Gas E&E has more Green House gas emission than Conventional E&P	Robert W Howarth, Renee Sentaro, Anthony Ingraffea	Canada	Shale Gas contribute 30% more Methane as compared to normal E&P.
22	Option for fracking	Schlumberger	US	Out of straight Nitrogen gas, Nitrogen foam and Slick water option, Slick water preferred for deeper Shale and Nitrogen foam for shallower Shale with low pressure resources.
23	Option for fracking	Cobot Oil & Gas	US	Slick water frack was more efficient than Nitrogen frack in high pressure Marcellus. For Barnett Shale additives for friction reduction, Biocides and surfactants
24	Radioactive Shale	Ohio Department of Natural resources/ 1997	US	Devonian age Shale, Marcellus are considered highly radioactive Shale
25	Acid providing Minerals	Pennsylvania Dept. Of conservation & Natural resources	US	Marcellus Shale in some region contain acid producing minerals (specially the lower/ deeper part)

26	Metal Mobility	USGS (Michele Tuttle, Paul Biggs & Cyrus Berry)	US	Weathering of Pyrite Shale can result in acid growth and Metal mobility
27	Shale Gas threat to many business & LNG	Woodside Petroleum/ 2011	US	Increasing Shale Gas production threat to LNG
28	Public Awareness	Marni Soupco (2012)	Canada	Public awareness program would iron out the wrinkles on threat perception not based on the fact.
29	Shale Resource Assessment	Economics Times, Berchett (IHS-London)	Poland	The downword revision of Shale reserves in Poland led to scaling down the investment of Exxon Mobile (US) and Talisman Energy (Canada) in Poland.
30	E&P companies participation in Shale Policy	Polish Exploration and Production Industry Organization (OPEPI)	Poland	The Government made changes in the policy after hearing OPEPI
31	More well need to assess Shale Reserve	Pawel Poparwa (2010)	Poland	Assessing the reserve based only on a few well drilled gave incorrect result.
32	Policy Framework	Environmental Ministry (Poland)	Poland	Making state owned company NOKI as partner in all future production concessions, was not well taken by the operators on the pretext to force a partner on them.
33	Policy	Tomas Maj (2013), Talisman's Poland Manager	Poland	On the existing policy, the industry will not fulfil its potential.
34	Shale Plays are unique	Stephen O'Roureke (Wood McKinsey) "Renepeters"	Europe	Replicating US in Europe may not be possible.
35	Optimizing Renewables	Antony Simon	Europe	Renewable sector to be developed.
36	Reducing dependence on Gas import	Warsaw Talk; Gregory Birg	Poland	Poland to reduce dependence on Russia.
37	Reducing dependence on Gas import	Eduard Stavitsky , Energy Minister	Ukraine	Ukraine strives for energy dependence on neighbouring country Russia.
38	Environmental Concerns	Reuters	France and Bulgaria	For environmental concerns France and Bulgaria have completely abundon fracking.
39	Shale Potential in Ukraine	Rigwone (Edelweiss)	Ukraine	The Shale reserves expected are 390 to 560 tcf.
40	Cheap import affect Shale E&E	Yanukovich, PM Ukraine	Ukraine	Russia cut Gas price to Ukraine to the level of Belarus makes Shale E&E less lucrative.
41	Policy	Algirds Butkevicious Prime Minister Lithuania	Lithuania	Changes in the laws made Chevron to pull out of Lithuania.
42	UK Shale Reserve	IGas/Telegraphs December, 2013	UK	UK Shale reserves at 1300 tcf sufficient to meet 6 year gas demand in UK.
43	Land owner asked higher compensation	Telegraphs (December, 2013), UK Energy Minister	UK	Land owners demand 10% of revenue sharing from Shale Gas.
44	Demonstrator of obstructing Shale E&E are professional	The Telegraph UK	UK	Leading campaigners against fracking in North West England have no connection to the area.
45	Shale Gas in China	Global Energy/EIA (June 2013)	China	The revised explorable Shale reserves of China stand to

				1,115 Tcf. The highest in the World
46	Shale Gas in China	Bloomberg (November, 2011)	China	CNPC and Royal Dutch Shell joined hands for Shale E&E in China.
47	Shale Gas in China	EIA Report (October, 2013)	China	China started producing Shale Gas on commercial scale and became one of the three such countries (US, Canada and China)
48	China prepares for third round of bidding	Shanghai Security News (November, 2013)	China	China third round include Shale Plays in South West city of Chong Qing and Sichuan & Hubei
49	Alliance with Global Giant	Bloomberg	China	Shell and CNPC intent to jointly invest in Qatar, Australia and elsewhere. Shell has given entry to CNPC in Syria.
50	Indonesia Shale Reserves	Bandung Institute of Technology	Indonesia	Indonesia hold 1000 Tcf Shale Gas
51	Safety Issue	Indonesia Govt.	Indonesia	In 2006 drilling in Java let to eruption of mud- Volcano killing at least 13 people and displacing more the 3000 people.
52	Indian Shale Gas Reserves	EIA	India	EIA 2011 indicates 63 tcf reserves.
53	Shale Gas Policy	Govt. of India	India	The draft policy brought out in August, 2012. By the end 2013, as in interim measure, PSUs are allowed to explore Shale Gas in the E&P blocks awarded to them.
54	Policy Issue	Anilish S Mahajan (Feb., 2012)	India	Policy delay could proof costly.
55	Gas Pricing	Rangarajan, 2013	India	The Govt. has accepted the recommendation of Rangarajan committee thereby doubling the price of domestic gas.
56	Market determined Price	Dy. Chairman Planning Commission (February, 2012)	India	Integrated energy policy allows market determined price.
57	Shale Reserves in Australia	EIA	Australia	Australian Shale reserves estimated to 396 tcf
58	Shale Gas in Australia	Energy Investment Bank Houston	Australia	Cooper basin of Australia one of the best Shale prospect outside North America.
59	Large Water Requirement	Urbina (January, 2012)	South Africa	Shale well may need 3.7 million litre of water. Well drilled in between Jonesburg and Cap town (Hungry Land) has water scarcity and far away landfill area to dump frack water.
60	Locating Sweet Spot	Karen Sulivan et. al. (2014)	US	To minimize the risk it is better spent on analysis and interpretation of surface seismic data before deciding where to drill.
61	Wild Cat Drilling	Beckley (2011)	US	The concept of “oil & gas is first found in the mind”. Based on which companies look for oil & gas where other don’t believe it is located.
62	Flexible Factory	Brain Forbes, Joreg Ehlert,	US,	Controlling Cost of drilling and

	Model	Harve Wilczynski	Canada	time to drill by flexible Factory model for Shale Gas Exploitation
63	Shale based LNG Deal	TOI (April, 2013)	Global	Shale gas based LNG deal have brought down the global LNG price
64	Diffusion of Innovation Theory	Gabriel Tarde, 1903 Rogers, 1995	Global	Most inn ovation have S-shaped rate of adoption. Four stages of innovation absorption are : Invention, diffusion (Communication) through social system, time and consequences
65	Two-Step-Flow Theory	Paul Lazarsfeld, Barnald Berelson & Hazzel Gaudted, 1944	Global	Information from media moves in two distinct stages.First it reaches to opinion leaders who play close attention to mass media then they pass on their own interpretation in addition to tje actual media contents, thus have a personal influence on information dissipation
66	Contradicting Two-Step-Flow model	Deutsehmann & Danielson	Global	Mass media information flows directly to people and is not relayed by opinion leaders.
67	Contradicting Two-Step-Flow model	Everett Rogers 1995	Global	Study revealed that 2/3 of respondents accredited their awareness to the mass media rather than through opinion leaders, thus greater prevalence of One-Step flow of communication
68	Adoption of Innovation	Rogers, 1995	Global	Five kind of adopters for adoption of innovations making a normal distribution curve i.e. innovators (2.5%), early adopters (13.5%), early majority (34%). Late majority (34%) and Laggards (16%)

2.13 Variables found from literature survey

From literature survey a large number of variables, traits or issues which have been contributing to Shale gas program positively or negatively, were noted down. Any linkage amongst such variables was used as a tool to combine them in a group. Such exercise took the form of manual regression and has been successful in finding the set of such variables seemingly independent from each other. This exercise reduced these traits in 42 variables forming the building blocks of research questionnaire. Table 2.6 contains these variables.

Table 2.15: List of Variables identified through literature survey (Literature Survey)

S. No.	Components/Building Blocks/Variables/ Aspects
1	Shale Gas Policy
2	Availability of Shale Plays data in public domain.
3	Availability of technology for Shale Gas Exploration & Exploitation.
4	Availability of equipments for Shale Gas E&E
5	Availability of skilled labour
6	Experience of Indian E&P Companies.
7	Requirement of huge quantity of water for fracking
8	Disposal of Return Frac Water
9	Unexplored Large acreages under conventional E&P
10	Shale Plays location around insurgency prone area
11	Cost of production of Shale Gas
12	Dense Population over Shale plays
13	Land Acquisition
14	Land Owners rights limited to Land Surface
15	Smaller Pipeline Players outside regulatory provision
16	Natural Gas Transmission Pipeline
17	Preparation and Application of Fracking Fluids
18	Exposure to work force and local populate
19	Indian Gas demand supply Scenario
20	Inflation of cost of local housing and services around drilling services
21	Diversification of resources for Shale Gas exploitation
22	Support from local authorities
23	Investments in US Shale acreages by Indian companies
24	Interference by Political or NGOs
25	Public awareness about Shale Gas & its exploration & exploitation
26	Lease for government land
27	Environmental & Forest Clearance
28	Inclusion of "deposits before drilling" clause in upcoming Shale Gas Policy
29	Market driven Gas pricing with transparency
30	Introduction of moratorium on Shale Gas E&E
31	Number of wells drilling for Shale Gas E&E
32	Rate of depletion of Shale Gas wells
33	Uncertain rate of depletion of gas from Shale wells
34	Cost of Offshore Shale Gas production
35	Metal mobility
36	Cost of return Frack water treatment
37	Return Frack Water treatment
38	Problems in casing, cementing and sealing
39	Possibility of Volcanic eruption
40	Heavy traffic movement near Shale plays
41	Impact on Ozone layer
42	Judicial Activism and PILs

2.14 Research Gaps

- Global Context: Shale Gas E&E is still in the developing stage globally (except in US) and hence, only limited in depth study available.
- Indian Context: Except for the experimental data by the pioneers, there is no literature available in public domain on the factor affecting Shale Gas E&E in India

2.15 Concluding Remarks

Several literatures reviewed, and highlighted in this chapter, have supported the need for policies to explore unconventional energy resources in general and Shale Gas in particular. Many researchers have stressed the need to have policies in place to meet the requirements for exploration and exploitation of Shale Gas.

India has reasonable Shale Gas resources in place. The lesson learned from the experience of US, Canada, Europe, China and Australia needs be comprehended to start harnessing the potential of Shale Gas in India.

The information/innovation absorption model suggest that the information available from global experience can be adopted by India both trough Two-Step model and one- to –one model of information flow.

Chapter 3
Research Design

3.1 Introduction

A research design is a basic plan that guides the data collection and analysis phases of the research project. It provides the framework that specifies the type of information to be collected, its sources and collection procedure (Kinnear & Taylor, 1996; Churchill & Iacobucci 2005) define research design: "it is the blueprint that is followed to complete the study" and it "ensures that the study is relevant to the problem and will use economical procedure". While conducting the present study, care has been taken to incorporate these concepts in the research deign. There are many frameworks of research design which can be classified into two major categories: Exploratory and Conclusive. The conclusive research can be further divided into descriptive and casual research (*Seth Ginsburg, 2011*). Figure 3.1 gives the flow diagram of research design.

Exploratory research is more to do with qualitative study while conclusive research is associated with quantitative study. The qualitative research provide insight and understanding of the problem setting, while quantitative research seeks to quantify the data and typically applies some form of statistical analysis. Whenever a new research problem is being addressed, quantitative research must be preceded by appropriate qualitative research. (Mery Klupp, 2011) In this thesis, both these research designs have been employed in different degrees.

For research objective-1, exploratory research has been employed with non-probabilistic and judgmental sampling as the knowledge about Shale Gas is still limited globally. For research objective-2, descriptive research has been used with non-probabilistic and judgemental sampling. For research objective-3, a qualitative research has been employed.

The research questions were framed keeping the objectives of the research in consideration. The research questions are followed by formulation of research methodology, identification of sampling procedures (sampling frame, sample size), scale formation, followed by validity and reliability tests of the instrument (pilot testing), data collection and analysis of the data collected.

Hence, the research design used for this research work is exploratory research for identification of variables followed by descriptive research design – single cross sectional design for sampling and data collection. Figure 3.1 gives the path followed in this research work.

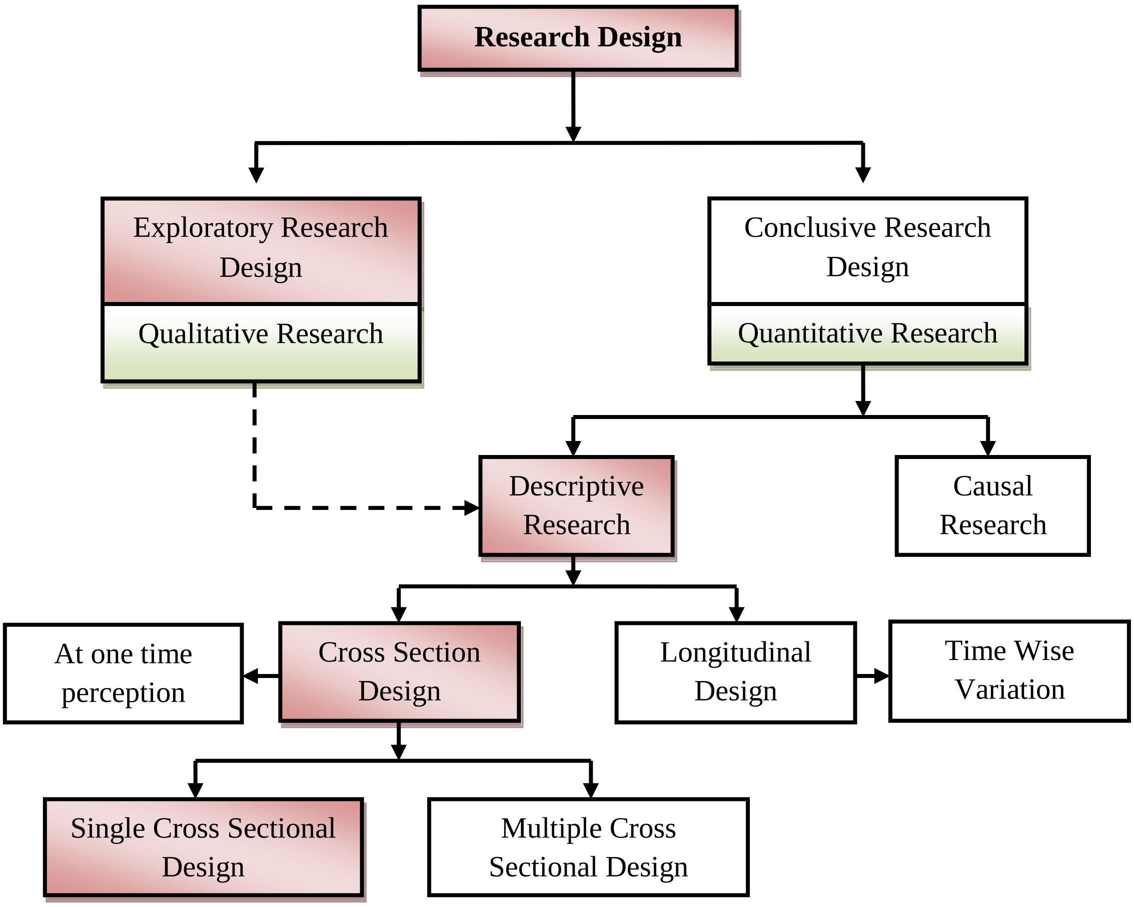

Fig. 3.1: Research Design Concept

(Source: Seth Ginsburg (2011) and additions by researcher)

3.2. Need for the study

India's growing economy is expected to continue its increasing momentum into the foreseeable future. The economic growth has a close link with the energy requirement or to say the energy growth. To sustain this growth, the energy sector needs to prepare itself for making available required energy resources for sustainable growth.

The content of various energy resources in the overall energy basket is shown in Figure 3. 2 and Table 3.1 (BP, 2013):

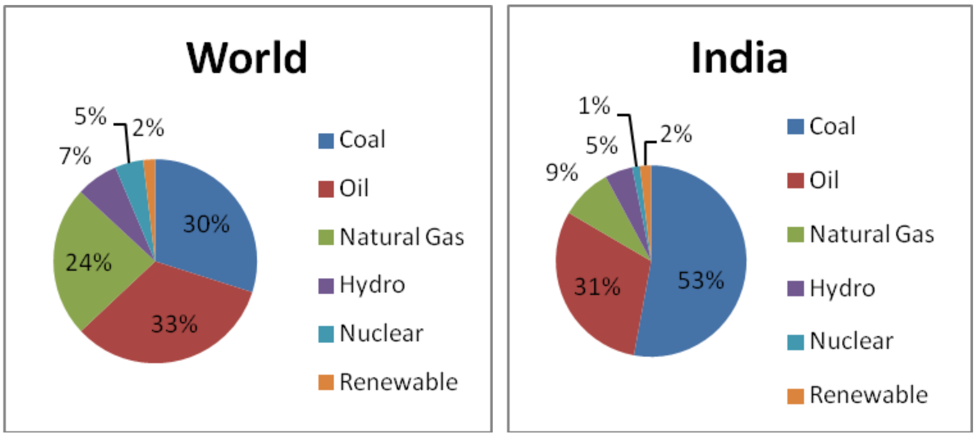

Fig. 3.2: Energy Basket Global v/s Indian - 2012

Table 3.1: Energy Basket Global v/s. Indian (BP 2013)

Energy Resource	Global (in %)	India (in %)
Coal	29.9	52.9
Oil	33.1	30.5
Natural Gas	23.9	8.7
Hydro	6.7	4.7
Nuclear	4.5	1.3
Renewable	1.9	1.9
Total	**100% (12476.6 MTOE)**	**100% (563.6 MTOE)**

The environmental concern for polluting fuel is on increase in India as in the global arena. More than 70% of the oil consumption and 30% of gas are imported, putting heavy burden on the country's economy.

The environmental awareness coupled with economy and efficiency in natural gas application, it’s demand is huge and the assessment of the demand supply gap projection indicates that on an average two third of the demand remains unmet (Integrated Energy Policy 2006). The US success story of Shale Gas Exploration is not only a game changer but an eye opener for the professional associated with gas sector or energy sector. It is in this context that a need is urgently felt to analyze as to why India has not yet embarked on Shale Gas Exploration in the country, and therefore, this research.

3.3. Statement of Problem

India has a huge gap in the demand and supply of natural gas, its domestic gas reserves are limited and various E&P operators have found Shale Gas reserves (By accident - Joshi Technology, Cambay Basin), by experimentation (RIL in Cambay and ONGC in Damodar Basin). With the proven success of US Shale Gas program, it is not understood as to why India has not undertaken Shale Gas E&E even though India has sizable Shale Gas reserves. It is therefore felt necessary to study the various issues by leveraging the experiences of select countries like US, Canada, China, and Poland etc in this sector; which could analyse the state of Shale Gas E&E in India. Such issues when addressed will encourage Shale Gas E&E in India which then becomes a motivation to identify the factors that prevent the implementation of Shale Gas E&E in India, thereby providing solutions to the identified barriers and to encourage the exploration & exploitation in this sector in India.

3.4 Research Questions

During the literature review, the following research questions have been identified that need to be answered through this research work.

Central Research Question (RQ): What are the factors that influence the Shale Gas E&E in India? Which of such factors are the barriers that prevent Shale Gas E&E in India?

Additional RQ1: What practices can be adopted by Indian Shale Gas E&E industry from the experience of other countries?

Additional RQ2: What frame work India should develop for effective implementation of Shale Gas E&E in India?

3.5 Objectives of the Study

The following are the objectives of the research work:

1. To identify the factors those influence Shale Gas E&E in India. Also to identify the barriers from such factors those prevent Shale Gas E&E in India.
2. To identify the practices that could be adopted by Indian E&E from global experience. (by studying the growth of Shale Gas E&E in USA, Canada, Europe, China and Australia)
3. To formulate a suggestive framework for effective Shale Gas E&E in India.

3.6 Scope of the study

The scope of the study is restricted to Indian geographical boundary with focus on the sedimentary basins expected to contain Shale Plays.

3.7 Research Model

To find the solution of the research questions, an appropriate research model is framed. As the nature of the study is such that the target population from which information can be obtained is limited both with respect to extent and quality of information, therefore an experimental research design (quantitative research) model is used in this study (Creswell, 2009).

The questionnaire has been developed with the input from literature survey and modulated with the inputs from peers. Each variable of the questionnaire is assessed with 7-point likert scale to get data for processing through statistical tool. The data collection is based on single cross sectional design (Figure 3.1). The research model is explained in the flow diagram Figure 3.3.

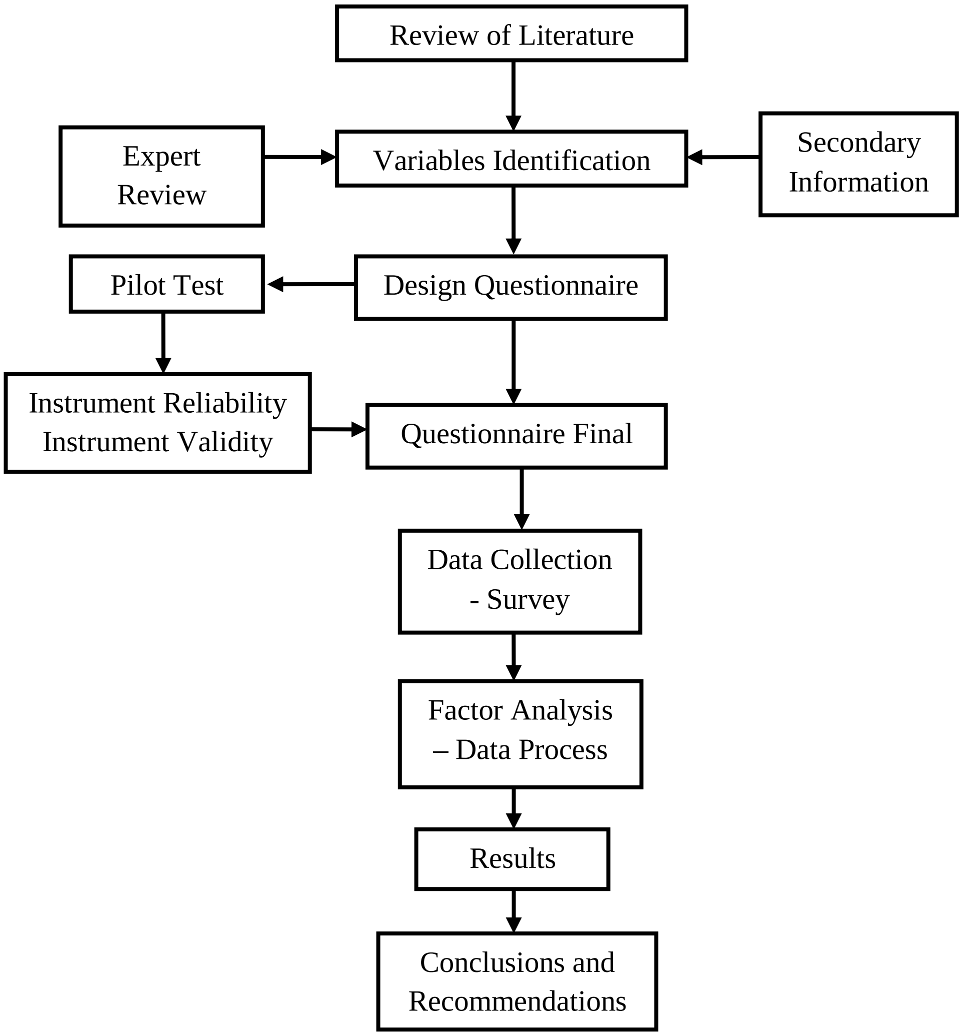

Fig. 3.3: Research Model

3.8 The philosophical world view proposed in the study

The present research work has characteristics of post-positivist worldview. The research work adopts a scientific way of doing research, holds a deterministic philosophy of cause and effect (causal effect of policy - growth of exploitation of Shale Gas, etc.), and identifies the causes that influence outcomes. It is reductionist in the intent to reduce ideas into a small, discrete set of variables that encompass business problem, research problem and research questions. Collection of data on the instrument (questionnaire) based on measures (Likert Scale) completed by participants to develop relevant understanding of causal relationship of interest, adhering to the standards of reliability and validity, use of deductive logic are some of the hall marks of this worldview (Creswell, 2009).

Similar process has been adopted in this research work making it closely aligned with the post-positivist worldview. Compared to that, the pragmatic worldview emphasizes the research problem and uses all the approaches available to understand the problem (both qualitative and quantitative methods are adopted) (Creswell, 2009). In this research work, in a limited way qualitative approaches (expert views) have been incorporated with a predominantly quantitative method of data analysis giving it a mixed method flavor of research. However, the research work is more closely linked to the concepts of post-positivist worldview – although these worldviews are not as mutually exclusive as they appear initially (Creswell, 2009).

3.9 Strategies of Inquiry

The strategies of inquiry are the types of qualitative, quantitative and mixed methods designs or models that provide specific direction for procedures in research design (Creswell, 2009). In this research work, exploratory research design (qualitative research) has been used for identifying the variables. The questionnaire containing the variables has been given to target population and the data collected using descriptive research is analyzed though statistical tool (SPSS 16.0) to identify the factors that influence Shale Gas E&E in India. Further discussion on the factors so emerged has been done to find the factors which work as the barriers to Shale Gas E&E in India.

The lesson learnt from global experience and the additional input received through the questionnaire have been utilized for implementation by Shale Gas Industry in India. How this information will be absorbed in the Indian Shale

Gas E&E has also been described. Finally, a frame- work is created taking into consideration the factors emerged from the research study and the global experience.

3.10 Research Methodology

There being three objectives of this research study appropriate research methodology has been applied to each of the objective. The methodology applied for research Objective -1 is:

3.10.1 Exploratory Research

Exploratory research (qualitative research) is employed to develop initial ideas and insights and to provide direction for any further research needed (Churchill & Iacobucci, 2005 ; Aakeret. Al. 2007). An exploratory study is essential when a researcher needs to identify problems, defines the problem more precisely and identifies any specific objectives or data requirements to be addressed through additional research (Kinnear & Taylor, 1996).

The exploratory research is highly flexible, unstructured and qualitative (Aaker et. al. 2007). Exploratory research was carried out by a study of literature survey and input from the peers.

3.10.2 Descriptive Research

Having obtained some primary knowledge of the subject matter by an exploratory study, descriptive research was conducted next. Descriptive Research renders itself to analysis using statistical tools. Contrary to an exploratory research, a descriptive study is systematic, fixed format and structured (Churchill & Iacobucci, 2005). According to Kinnear & Taylor (1996), "descriptive research is appropriate when the research objectives include (1) portraying the characteristics of marketing phenomena and determine the frequency of occurrence, (2) determining the degree to which marketing variables are associated and (3) making predictions regarding occurrence of marketing phenomena". The research objectives of the study match the two types of objective. Further the descriptive research (Figure 3.1) can employ cross sectional or longitudinal design for survey. In the cross sectional design information is collected from a given sample of the population at only one point of time while in longitudinal design the sample units of population are contacted over different period of time (Kinnear & Taylor, 1996, Churchill & Iacobucci, 2005 & Seth Geinsburg, 2011). For the purpose of this research a single cross sectional design was adopted as longitudinal study would not only have taken considerable time but the possibility of the same population being contacted again would have practical constrains. The sampling used has been non-probabilistic design using judgmental sampling (Figure 3.4).

For objective number two, descriptive research methodology has been used with non-probabilistic deign and judgmental sampling the experience gathered from the literature has also been utilized (Figure 3.5).

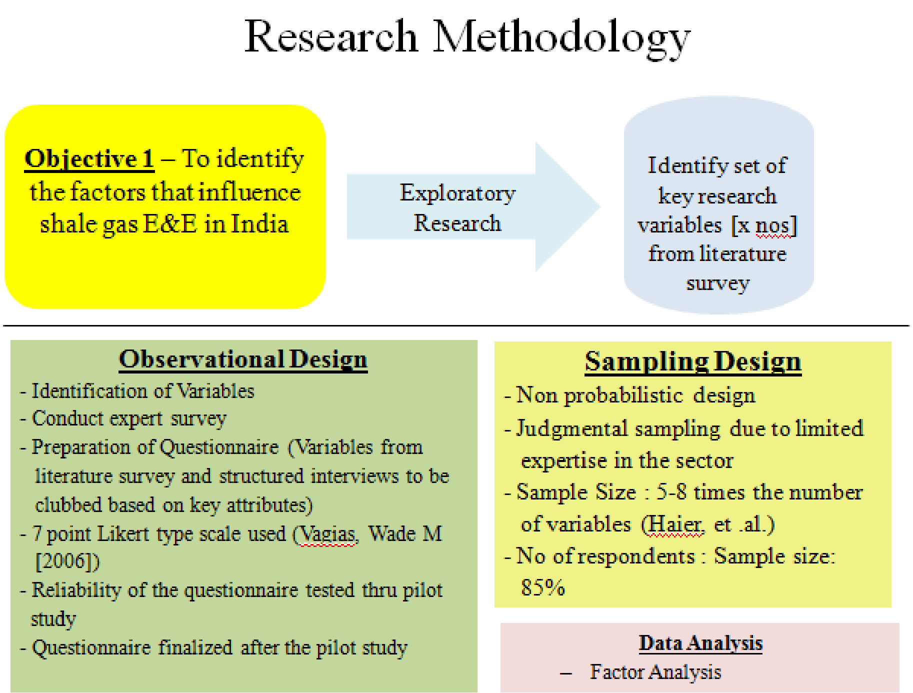

Fig. 3.4: Research Methodology for Objective -1

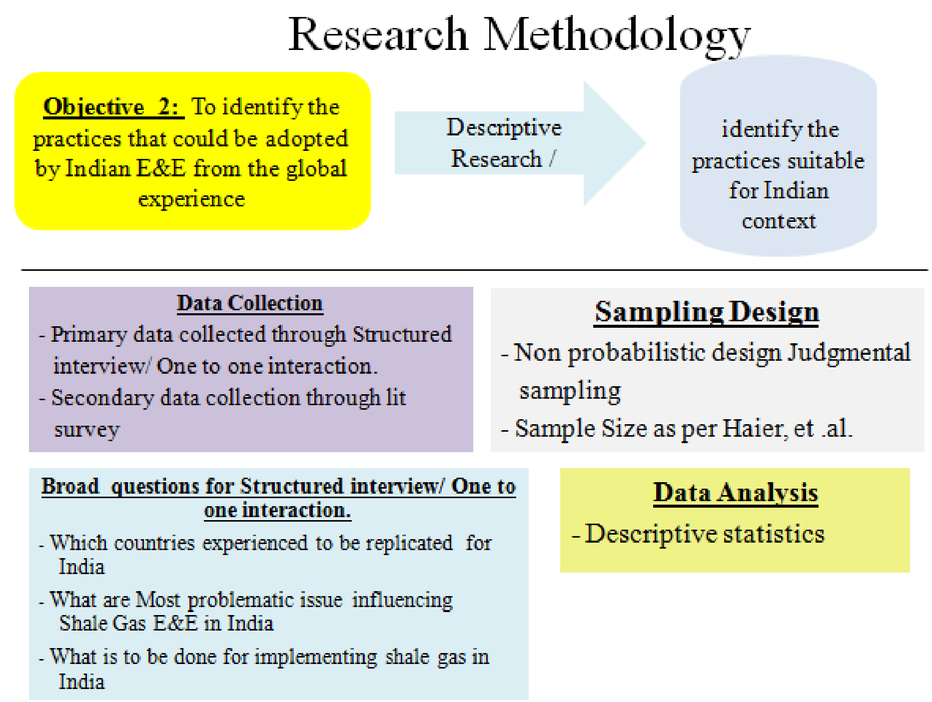

Fig. 3.5: Research methodology for Objective -2

Further the qualitative research has been used for addressing objective number three where tabulated data and text from literature survey and primary surveys from peers has been used to develop a suggestive theoretical frame work for implementing Shale Gas E&N in India (Figure 3.6).

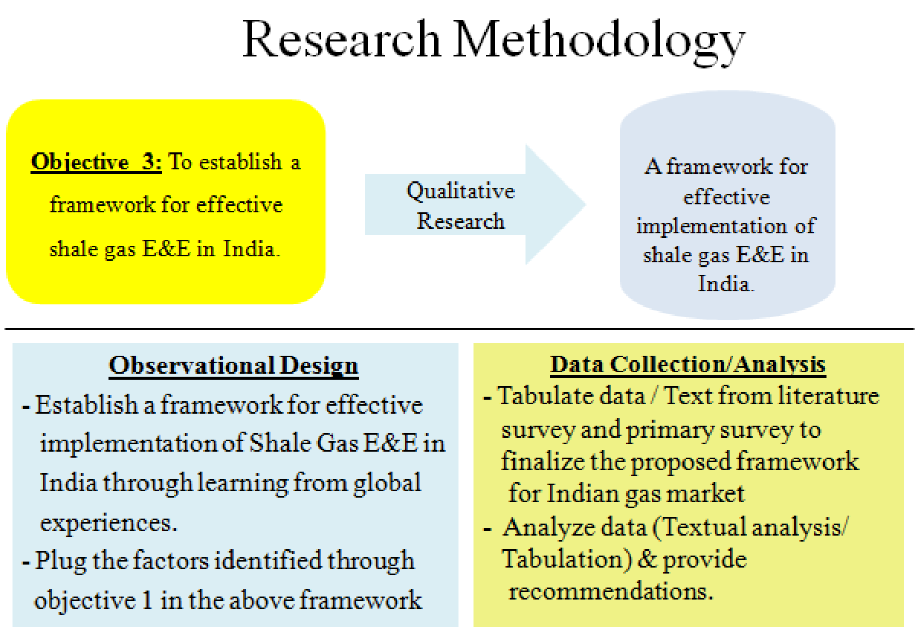

Fig. 3.6: Research Methodology for Objective -3

3.11. Sampling Procedure

The sampling procedure adopted is described below elaborating the target population, sampling elements, sampling unit, sampling frame, sampling techniques and sample size

3.11.1 Target Population

Population is the aggregate of all *elements* that show some common set of characteristics and that comprise the universe for the purpose of the research. The population parameters are typically numbers (unit) (*Chuck Chakrapani, 2011*).

Target population is the collection of elements or objects that possess the information sought by the researcher and about which inference are to be made. The target population must be defined in terms of elements, sampling unit, extent & time.

In the present research, the target population for the survey is any organization or individual having interest in the Shale Gas in India and world over. This includes companies that have an active presence in India and all those who are keen to set up base in India to exploit the Shale Gas potential offered by the country. Such population would comprise of the Policy makers, Regulators, Consultants, Service Providers, Equipment Suppliers, Companies in E&P activities both from Public Sector and Private Sector, and Academia. In addition, the global experts with experience in Shale Gas were also added to the list of respondents which included EPC contractors, Shale acreage owners in US, thought leaders in Shale Gas E&E, developers of new techniques and chemical formulation for directional drilling, fracking fluid and propellants etc. Organizations and individuals who do not have any idea about Indian sedimentary basins and are only in the exploratory mode with no immediate timeframe to set up base in India were excluded from the analysis though their opinion was sought on the specific areas of their specialization and such response have not been included in the compilation.

3.11.2 Sampling Elements

A sampling element is the object about which or from which the information is desired in survey research. The element is usually a respondent. In the present study, the survey is designed to elicit perspectives on various traits or aspects which have been or likely to influence the Shale Gas E&E in India, the sampling elements encompass officials holding or who have held the position of decision making in the sector, or have the knowledge of the Shale Gas revolution and its likely impact/influence Indian Shale Gas program. The sampling element is thus defined as people those who are (were) in the executive decision making authority in their respective companies/organization, middle management and junior management professionals who are associated in decision making, contractors, service providers and academia from Petroleum and Energy constitute the sampling elements.

3.11.3 Sampling Unit

A sampling unit is an element or a unit containing element(s) that is available for selection as a respondent at some stage of the sampling process. To better understand *sampling elements* and *sampling unit*, an example is cited: *Suppose Revlon wanted to assess consumer response to a new line of lipsticks and wanted to sample female over 18years of age. It may be possible to sample females over 18 years directly, in which case sampling unit would be same as sampling element. Alternatively the sampling unit could be the household. In the later case all household (female over 18years) would be sampled. Here element is a female but unit is household.*

For the present research, sampling unit is an individual in executive leadership roles in Government (policy making) Ministry of Petroleum and Natural Gas, Planning commission, Regulatory bodies like DGH and PNGRB, Public and Private organizations (Both Indian and Multinational) with interest in Shale Gas E&E in India, officials who actively participates in large industry conferences as speakers or panel discussions experts, moderator or as session chair in national and international conferences, the academia pursuing Shale Gas at B. Tech (Petroleum Engineering) and MBA (Oil & Gas) and the faculties teaching Hydrocarbon Exploration and Production including conventional and non-conventional resources.

Since thought leaders from hydrocarbon industry are usually invited to various conferences and the researcher had the opportunity to teach in few of the Petroleum and Energy Universities and participated in Shale Gas World Conference in Poland (Dec. 2010), in China (June 2011), in Singapore (2012) and in India (Nov.2010, 2011, 2012 and 2013), access to these leaders and the professionals became possible for the response collection exercise. Thus the sampling unit became robust and exhaustive with target population really global

Thus in the present research study sampling element and the sampling unit are one and the same.

3.11.4 Sampling Frame

Sampling Frame is the representation of the elements of the target population. It consist of a list or set of direction for identifying the target population such as telephone directory, published list of the stakeholder, etc. (Chuck Chakrapani, 2011). The respondents selected have a stake in Shale Gas in India and who have an active presence or business interest in India was identified as part of the sampling frame.

In the present case, the sampling frame consist of DGH document containing all E&P Organizations, Service provider, Consultants, Policy Makers, Regulators and Academia, (globally) through express knowledge or through directory of the association (FICCI, CII, ICC, PETROFED, SCOPE, etc), newspaper or periodicals.

3.11.5 Extent

The extent refers to the geographical boundaries of the target population. In the present survey, the extent of data collection exercise was unrestricted as the Shale Gas movement is rather new area of opportunity and global awareness of all possible Shale Gas plays is being keenly observed by all concerned. More over the multinational players are actively involved in global Shale Gas exploration. The only consideration for data collection in the form of response to the questionnaire was the knowledge about Shale Gas Exploration in general and Indian E&P scenario in particular. *Therefore the questionnaire has the response from all nationals from across the globe.*

3.11.6 Time Period

The data collection exercise was spread over later part of 2011 to March, 2013. However, data updating has been a continuous process.

3.11.7 Sampling Technique

Stratified sampling was used during the data collection process. The population was divided into different strata (Policymakers and Regulators, Public Sector Organizations, Consultants and Service Providers, Academia, and Private Sector Organizations engaged in hydrocarbon E&P business) and number of elements from each stratum in selected based on the available units (elements) in that strata. The exact percentage of these stakeholders in the sample size is given below in table 3.2.

3.11.8 Sample Size

To calculate the sample size needed for the research, Yamane's (Yamane, 1967) formula is used. Overall 2500 people were identified as the target population for the survey, those who had interest in Shale Gas exploration. Incorporating N = 2500 and e= 0.05 in the above equation, sample size was arrived at 340. Originally the questionnaire was administered to 400 respondents but some of the responses received were incomplete. So, those who submitted incomplete questionnaire were removed from the list. Finally, 341 respondents were found to have submitted their responses that were complete in all respects - a response rate of 85%. Response rates of, in person administering of questionnaire is around 60% to 80% as per (Shosteck and Fairweather 1979); Baim (1991); Shaver & Brennan (1992) and Goyder (1985). Also to conduct factor analysis, it is the norm (Malhotra, 2010) to have 8 respondents for each variable. In this survey there are 42 variables which would need 336 respondents to participate in the survey. 341 respondents are higher than the number needed to do factor analysis and therefore satisfy that condition. The breakup of the respondents is shown in table 3.2.

Table 3.2: Break-up of the Respondents to the Questionnaire

Type of Respondents	Number of Respondents	% of the Total
Policy Makers & Regulators	39	11
PSU companies	51	15
Consultants and service providers	55	16
Academia(faculties, Students and Researchers)	127	38
Private Sector Companies including multinationals	69	20
Total	**341**	**100**

In the pictorial form, the strata of the respondents are shown in Figure 3.7.

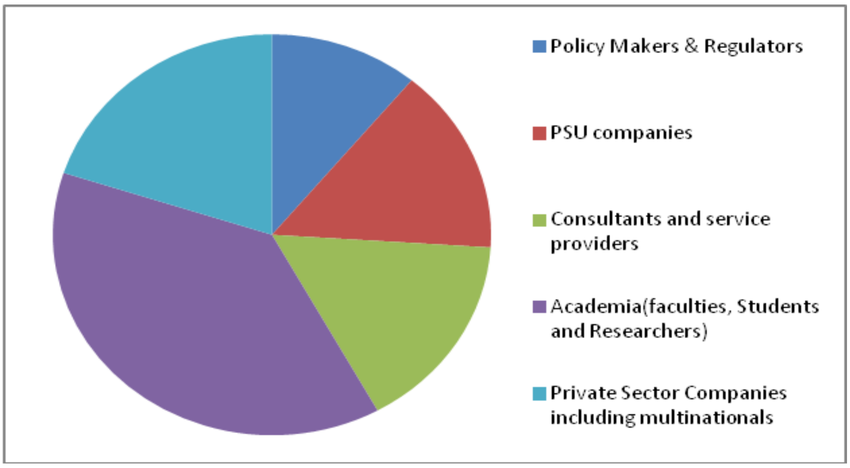

Fig. 3.7: Break-up of the Respondents to the Questionnaire

3.12 Instrument design

The instrument that was used in the data collection exercise for the research was a questionnaire which contained 42 questions with pre-defined choices on seven point likert scale and few (3 questions) open ended questions (Questionnaire is shown in **Appendix-C**). The details of the instrument development, scale formation, questionnaire format, data collection, validity and reliability test are mentioned in the subsequent sections.

3.12.1 Questionnaire development

Structured – undisguised questionnaire was used in the survey - as they are reliable, standardized, simple to administer, easy to tabulate and analyze - where the responses permitted to the respondents were predetermined on a 1-7 likert scale (Vagias, Wade M 2006). There were 3 open questions to let the respondent answer in their own words.

3.12.2 Information sought

The list of variables found from literature survey (variables and their operating definitions is explained in Appendix-D) was presented to the respondents in the form of questions and they were asked to choose an option (in the 7 point likert scale), how a particular variable would influence the E&E of Shale Gas in India (Strongly disagree to strongly agree rating).

Towards the end of the questionnaire (attached as Appendix-C in this thesis) the respondents were asked to give their qualitative observation on three questions, namely;

(i) To the best of your knowledge which of the countries experience in Shale Gas Exploration & Exploitation can be replicated in Indian context (USA, Europe, China, Australia, None, Can't Say)

(ii) In your opinion which is (are) the most problematic issue(s) influencing Shale Gas Exploration in India?

(iii) Please give your kind suggestion(s) for implementing Shale Gas Exploration & Exploitation in India.

3.12.3 Method of administration

The questionnaire was handed over predominantly in person at Shale Gas conferences in India and abroad, so that access to the right stakeholders and their response rates could be better compared to mail interview. The respondents completed answering the questionnaire at their convenience. Questionnaire were also handed over during one is to one meeting with senior officials of the Government, Planning Commission, Regulatory Board, Oil PSU's, Chief Executives, Private Sector Oil Companies Senior Executive and HOD in Academic Institutions. Questionnaires were given to the student pursuing Petroleum Engineering, MBA Oil & Gas in their class room and were also sent by email to various other stake holders.

3.12.4 Instrument reliability

Reliability is concerned with the consistency of the measurement, which means whether the questions in the survey get same type of response when the conditions remain the same. Reliability is also associated with internal consistency, which means whether the same characteristic is measured by different persons. There are four ways to estimate the reliability of the instrument (questionnaire). They are Inter-rater (assessor) or Inter-observer reliability, Test-retest reliability, Parallel-forms reliability and internal consistency reliability. Each of these estimates evaluates the reliability of the questionnaire differently. Among these, the internal consistency is the most frequently used method to validate the reliability of the instrument and the same has been used in the present case.

3.12.5 Instrument validity

Validity deals with how accurate the measurements are per se, and also a reflection of sample representativeness. Validity is impacted by robustness of survey design and whether right questions are asked to, and understood by, the respondents. 'Whether the instrument is measuring what it supposed to measure' is the core of validity estimation. The instrument has qualified the discriminant validity criterion, convergent validity criterion and concurrent validity criterion (Construct Validity – Criterion).

3.13 Pilot Testing

The questionnaire was pre-tested with 30 Shale Gas Exploration stakeholders (respondent) in the country during an International conference. The responses were added in a dummy table to make sure the questions were understood correctly and the answers were in line with the questions asked. A couple of ambiguous questions were re-worded, order of the questions were changed as per the feedback received before the questionnaire was administered again.

3.14 Quantitative Analytical Tool Used

In this research two prime objectives of statistical analysis were to reduce the set of variables into fewer numbers of manageable factors. As stated earlier, there are 42 variables in this study whose interdependence was examined to reduce them to a set of 12 factors. SPSS 16 software was used for analysis.

3.15 Operating definition of the variables found from literature survey

The operating definition of the variables found from literature survey is placed at **Annexure-D**, with a view to give a common understanding and better clarity on what they mean. All these variables are independent variables which load on 12 factors (as shown in factor analysis chapter-4).

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Chapter 4
Analysis and Interpretation

4.1 Internal Consistency Reliability

The reliability of the instrument is estimated when similar results are obtained by the items that measure similar constructs. Hence a group of people are administered a single measurement instrument, with different items, to check whether the results are consistent, as they measure the same construct. There are several internal consistency measures that are used. One of the most frequently used estimates of internal consistency is Cronbach Alpha. In this thesis, Cronbach alpha is used to estimate the reliability of the survey instrument. As the survey instrument used in the research work adopts a 7-point Likert-type scale, it is Cronbach's alpha coefficient which is calculated to check the internal consistency and reliability of the instrument. Cronbach's alpha measures the inter-relatedness of the items within the test. In other words, Cronbach alpha measures how closely a set of variables are related as a group and the extent to which all the items in a test measure the same concept or construct. Cronbach's alpha reliability coefficient normally ranges between 0 and 1. The closer Cronbach's alpha coefficient is to 1.0 the greater the internal consistency of the items in the scale. The alpha scores obtained for the questionnaire for this study is given in Table 4.1 (For factor Analysis refer **Appendix-E**).

Table 4.1: Cronbach Alpha Scores for the Questionnaire

Reliability Statistics	
Cronbach's Alpha	No. of Items
0.822	42

The alpha coefficient for all the sections in the questionnaire administered as part of the research work carried out was found to be more than 0.82 with no negative correlations seen among any of the items, thus suggesting that the items have relatively high internal consistency (George & Mallery, 2003; Nunnally,1978; Cortina, 1993; Peterson, 1994). The Cronbach alpha scores conclusively prove the reliability of the instrument used for the research purpose of this thesis.

The response of the 341 stakeholders of Shale Gas Exploration & Exploitation were taken in a 7-point likert scale and were subjected to factor analysis to reduce and logically align these 42 variables into smaller set of related factors. The Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy was worked out and the output of 0.723, as shown in Table 4.2 ensures sampling adequacy (Appendix-E) and Bartlett Test of Sphericity score was significant at 0.05 level; thereby rejecting the possibility of the variables being independent of each other. This means that the variables are correlated, which is a necessary condition to proceed with factor analysis.

Table 4.2: KMO and Bartlett's Test

KMO and Bartlett's Test*a		
Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		0.7227644
Bartlett's Test of Sphericity	Approx. Chi-Square	4973.7859
	df	861
	Sig.	0
*Based on correlations		
a SPSS 16		

The Principal Component Analysis [PCA] method is used to analyze the identified 42 variables. In this PCA Eigen Value Method is used to determine and justify the factors. Using PCA, 12 factors were determined (table 4.3 as shown below) whose cumulative percentage of variances is explained by 62.02%.

Table 4.3: Total Variance Explained

Component (Variable)	Initial Eigen values			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	6.667	15.873	15.873	4.619	10.997	10.997
2	3.459	8.235	24.108	2.744	6.533	17.530
3	2.467	5.874	29.982	2.734	6.509	24.038
4	1.966	4.680	34.662	2.471	5.882	29.921
5	1.842	4.385	39.047	2.359	5.616	35.537
6	1.701	4.051	43.098	1.893	4.506	40.043
7	1.462	3.480	46.579	1.660	3.953	43.996
8	1.450	3.451	50.030	1.659	3.949	47.945
9	1.367	3.256	53.286	1.613	3.841	51.787
10	1.275	3.036	56.321	1.505	3.582	55.369
11	1.251	2.979	59.300	1.406	3.348	58.716
12	1.145	2.726	62.027	1.390	3.310	62.027
13	.997	2.373	64.400			
14	.965	2.298	66.698			
15	.945	2.250	68.948			
16	.912	2.172	71.120			
17	.826	1.966	73.086			
18	.819	1.950	75.036			
19	.796	1.895	76.931			
20	.701	1.669	78.600			
21	.681	1.621	80.221			
22	.660	1.571	81.793			
23	.611	1.455	83.248			
24	.599	1.427	84.675			
25	.573	1.364	86.039			
26	.562	1.337	87.376			
27	.539	1.283	88.659			
28	.483	1.149	89.809			
29	.463	1.102	90.911			
30	.432	1.028	91.939			
31	.413	.983	92.922			
32	.398	.948	93.870			
33	.383	.912	94.782			
34	.318	.757	95.539			
35	.312	.744	96.283			
36	.294	.700	96.983			
37	.281	.669	97.652			
38	.247	.588	98.240			
39	.229	.545	98.785			
40	.190	.452	99.237			
41	.163	.388	99.625			
42	.157	.375	100.000			

4.2 Scree Test Plots

The Scree test plots (Figure 4.1) the Eigen value against the number of factors, in their order of extraction, and is yet another way to determine the number of factors to be retained in the factor-analysis solution. From figure- 4.1, it can be observed that the curve drops sharply at first and then levels off as it approaches horizontal axis. In this exercise, the graph starts to flatten after factor 12, indicating that twelve factors are sufficient to explain the variance in the variables.

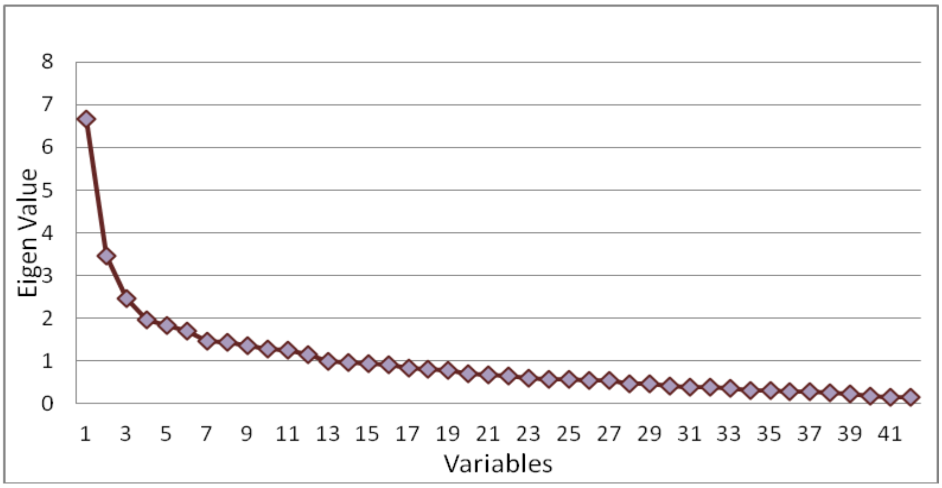

Fig. 4.1: Scree Plot

4.3 Extraction Method: Principal Component Analysis

After the determination of these 12 factors using Principle Component Analysis, all the variables are loaded into these factors by preparing the factor matrix. Further, these factors were rotated using Varimax procedure which is an orthogonal method of factor rotation to prepare a factor rotation matrix (reference table 4.4 below).

Table 4.4: Rotated Component Matrix[a]

	1	2	3	4	5	6	7	8	9	10	11	12
V1										0.644		
V2			0.430									
V3			0.842									
V4			0.867									
V5			0.727									
V6			0.486									
V7							0.703					
V8							0.657					
V9					0.412							
V10	0.479											
V11									0.402			
V12											0.623	
V13						0.764						
V14						0.728						
V15									0.754			
V16								0.717				
V17	0.684											
V18	0.747											
V19												0.725
V20					0.495							
V21					0.733							
V22				0.667								
V23					0.699							
V24											0.602	
V25				0.385								
V26				0.667								
V27				0.727								
V28					0.384							
V29										0.493		
V30		0.484										
V31		0.580										
V32		0.796										
V33		0.751										
V34		0.595										
V35	0.702											
V36	0.466							0.617				
V37							-0.437				-0.439	
V38	0.652											
V39	0.541				0.453							
V40	0.566											
V41	0.687											
V42												0.470

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.

a. Rotation converged in 14 iterations.

By using factor analysis, all the 42 variables were reduced to 12 major factors which influence Shale Gas Exploration in India. Table 4.5 below portrays the total variance explained for each factor and the factor loadings of each identified variable.

Table 4.5: Factors Influencing Shale Gas Exploitation in India

Factors	Factor Interpretation	Factor Loading	Variables included in Factor
Factor 1	Technical & Social Issues	0.479	Shale Plays location around insurgency prone area
		0.684	Preparation and Application of Fracking Fluids
		0.747	Exposure to work force and local populate
		0.702	Metal mobility
		0.652	Problems in casing, cementing and sealing
		0.541	Possibility of Volcanic eruption
		0.566	Heavy traffic movement
		0.687	Impact on Ozone layer
Factor 2	Risk & Uncertainties	0.484	Introduction of moratorium on Shale Gas E&E
		0.580	Number of wells drilling for Shale Gas E&E
		0.796	Rate of depletion of Shale Gas wells
		0.751	Uncertain rate of depletion of gas from Shale wells
		0.595	Cost of Offshore Shale Gas production
Factor 3	Technical & Service Support	0.430	Availability of Shale Plays data in public domain
		0.842	Availability of technology for Shale Gas E&E
		0.867	Availability of equipments
		0.727	Availability of skilled labour
		0.486	Experience of Indian E&P Companies
Factor 4	Government Support (Local, State & Central)	0.667	Support from local authorities
		0.667	Lease for government land
		0.727	Environmental & Forest Clearance
		0.385	Public awareness about Shale Gas & its exploration
Factor 5	Causal Effect of related Activities on Shale Gas E&E	0.412	Unexplored Large acreages under conventional E&P
		0.495	Inflation of cost of local housing and services around drilling services
		0.733	Diversification of resources for Shale Gas exploitation
		0.699	Investments in US Shale acreages by Indian companies
		0.384	Inclusion of "deposits before drilling" clause in upcoming Shale Gas-Policy
Factor 6	Land Related Issue	0.764	Land Acquisition
		0.728	Land Owners rights limited to Land

			Surface
Factor 7	Water related Issue	0.703	Requirement of huge quantity of water for fracking
		0.657	Disposal of Return Frac Water
		0.437	Return Frack Water treatment
Factor 8	Transportation Related Issue	0.717	Natural Gas Transmission Pipeline
		0.617	Cost of return frack water treatment
Factor 9	Cost of Production and Collection of Shale Gas	0.402	Cost of production of Shale Gas
		0.754	Smaller Pipeline Players outside regulatory provision
Factor 10	Policy Issue	0.644	Shale Gas Policy
		0.493	Market driven Gas pricing with transparency
Factor 11	Population & Environmental Issue	0.623	Dense Population over Shale plays
		0.602	Interference by Political or NGOs
Factor 12	Judicial/Market System	0.725	Indian Gas demand supply Scenario
		0.470	Judicial Activism and PILs

4.4 Emergence of Factors

After analyzing 42 Aspects or Variables from the research study based on the questionnaire, total 12 Factors emerge. The various aspects contributing to specific factor have been tabulated in Table 4.5.

It is noted from the grouping of the Aspect into 12 factors that all aspects find their places in various factors. The Aspect No. 25 i.e. Public Awareness about Shale Gas in its exploration and Aspect No. 28 i.e. “Inclusion of deposits before drilling” clause in upcoming Shale Gas Policy have found less weightage. The respondents have possibly thought that the Shale Gas E&P is a specialized subject and in Indian context the public awareness may not influence the exploration, exploitation and production activities. As a corollary to normal E&P the public awareness in India is negligible as compared to the public awareness in US. The simple reason for such high public awareness in US is that the landowners have the right to minerals under the land owned by them and the exploratory activities are widely spread including in the backyard of the residential accommodation of the housing complexes. The Aspect No. 28 i.e. “Inclusion of deposits before drilling” found less influence for the reason that in the Hydrocarbon E&E activities the financial deposits towards compensation has never been a problem as compared to obtaining Clarence or NOC for the land where E&E activities are to commence.

4.5 Discussions on Factors

The 12 factors that emerge out of the research analysis are discussed below:-

4.5.1 Factor No. 1, Techno-Social

This factor contains 9 aspects out of 42 mentioned in the questionnaire. This has emerged as a strongest factor encompassing the aspects like:-

(i) Geographical location of Shale Plays around insurgency prone areas (item no. 10 of the questionnaire)

(ii) Care for preparation and application of the fracking fluid which contains chemicals and carcinogens apart from water and sand (item no. 17 of the questionnaire)

(iii) Exposure to work force and local populate from the radioactive and other harmful materials associated with return frack water from Shale Gas bore hole (item no. 18 of the questionnaire)

(iv) Metal mobility due to acid formation from Shale exploration (item no. 35 of the questionnaire)

(v) Cost of return frack water treatment making it suitable for recycling for fracking (item no. 36 of the questionnaire)

(vi) Possibility of Volcanic eruption due to Shale Gas Exploration in India (item no. 39 of the questionnaire)

(vii) Exploration of Shale Gas creates heavy traffic movement in and around drilling area. (item no. 40 of the questionnaire)

(viii) Impact on Ozone layer due to more Methane escape to atmosphere (item no 41. of the questionnaire)

As the Shale Gas success has been established in US and Canada, the technology can be acquired as the global trade has no barrier. In fact the technology providers have been keenly watching the development in India. The issue of seepage from well (as brought out in GASLAND Video US) has also been technically resolved by better sealing of the well bore (Fig. 4.2). The researcher has personally interacted with such companies during various conference and energy roundtable discussions. Thus out of 9 traits/variables forming this factor only one could be termed as potential barrier that is the "Geographical location of Shale Plays around insurgency prone areas (item no. 10 of the questionnaire). However all identified Shale Plays in India are not located in the insurgency prone area. The Shale Plays located in Cambay Basin, Rajasthan, KG Basin, Cauvery Basin, Ganges Basin, Gondwana basin Damodar Valley (partly) and Ganges Basin including Vindhyas are away from insurgency areas. As such this trait can also not be a barrier for Shale Gas E&E in India

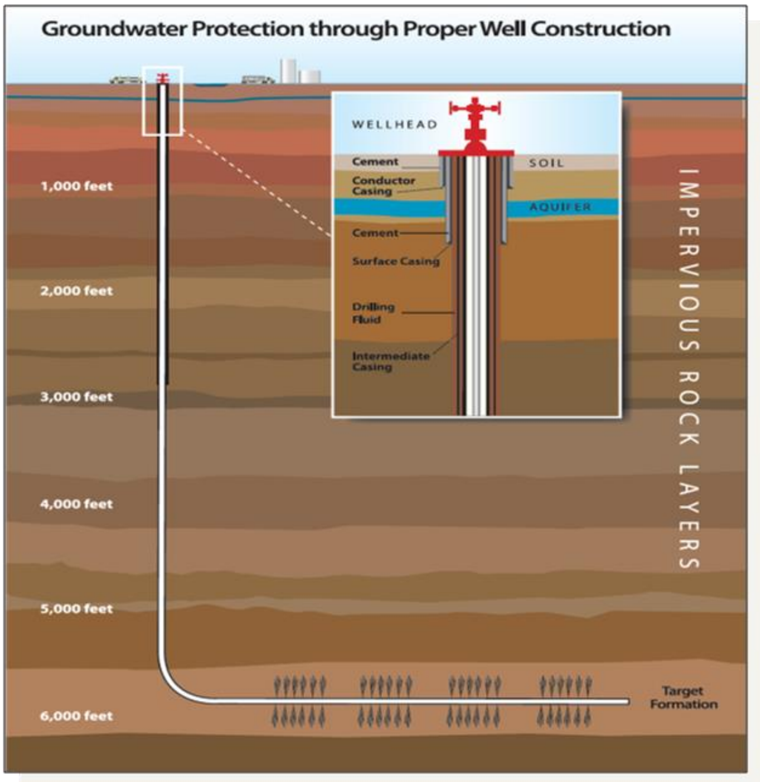

Fig. 4.2: Ground Water Protection by Proper Sealing (Gas Strategics Vol.33.2, 2011) & *(http://www.api.org/policy/exploration/hydraulicfracturing/ and EPA Frac Study Plan)*

4.5.2 Factor No. 2, Risk & Uncertainties

This Factor encompasses five variables/traits summarized below:

(i) Introduction of moratorium on Shale Gas drilling in India. (item no. 30 of the questionnaire)

(ii) Number of wells drilling for Shale Gas Exploration (item no. 31 of the questionnaire)

(iii) Rate of depletion of Shale Gas wells (item no. 32 of the questionnaire)

(iv) Uncertain rate of depletion of gas from Shale wells (item no. 33 of the questionnaire)

(v) Cost of Offshore Shale Gas production (item no. 34 of the questionnaire)

In any business venture, risk and uncertainties form part of investment decision. Excepting trait number (i) i.e. "Introduction of moratorium on Shale Gas drilling in India. (Item no. 30 of the questionnaire)" all others are manageable risks and cannot be termed as barriers in Shale Gas E&E in India. Also the chances of imposing moratorium on drilling are remote. Even if there arise such a situation, that will precede the bidding.

4.5.3 Factor No. 3, Technical & Service Support

This Factor encompasses five variables/traits summarize below:

(i) Availability of adequate data in public domain to undertake Shale Gas Exploration (item no. 2 of the questionnaire)

(ii) Availability of technology for Shale Gas Exploration in India (item no. 3 of the questionnaire)

(iii) Availability of equipments affecting Shale Gas Exploration in India (item no. 4 of the questionnaire)

(iv) Availability of skilled labor force affecting Shale Gas Exploration in India (item no. 5 of the questionnaire)

(v) Experience of Indian E&P Companies in Shale Gas Exploration (item no. 6 of the questionnaire)

The availability of data in public domain provides confidence to the operators for taking Shale Gas E&E. However since the Shale Gas behavior changes from Shale play to play and drilling Shale well is also not costly, the geological inference from the data elsewhere may give an indicative picture of the Hydrocarbon content. Moreover the technology is on continuous improvement for seismic, drilling, well completion, fracking, fracking fluid and the pore spacer, a technology and the equipment can be acquired. The availability of skilled force is a continuous concern globally and the efforts of industry and academia are in tandem for capacity building in this direction. Once the Shale Gas bidding process starts the capacity building is expected to follow. In regard to experience of E&P companies, many of the Indian players (RIL, ONGC, OIL, GAIL and IOCL) have already acquired interest in US Shales, their experience is certainly going to help Indian Shale Gas E&E, I would therefore not put this factor as a whole as a barrier except variable no. 2 i.e. **availability of adequate data on Shale Plays.** Also a glance on the comparative rating on foreign and Indian respondents indicates that the variables 4, 5, 6 are rated uniformly by both kind of respondents as not highly influencing the Shale Gas E&E (refer Para 6.6)

4.5.4 Factor No. 4, Government Support (Local, State & Central)

This Factor encompasses four variables/traits summarized below:

(i) Support from local authorities (item no. 22 of the questionnaire)

(ii) Lease for government land (item no 26. of the questionnaire)

(v) Environmental & Forest Clearance for Shale acreage (item no. 27 of the questionnaire)

(vi) Public awareness about Shale Gas & its exploration.(item no. 25 of the Questionnaire)

This factor encompasses four traits concerning support from local authorities, lease for government land, environmental and forest clearance and public awareness. The researcher has observed while interviewing the targets, there have been many instances where companies have abandoned the exploration blocks in absence of the clearances. This factor as a whole can be considered **as a barrier for Shale Gas E&E in India.**

4.5.5 Factor No. 5, Causal effect of related Activities on Shale Gas E&E

This factor encompasses variables like:

(i) Unexplored large acreages under conventional E&P in India. (item no. 9 of the questionnaire)

(ii) Inflation of cost of local housing and services around drilling services (item no. 20 of the questionnaire)

(iii) Diversification of the limited resources for Shale Gas Exploration affects conventional exploration (item no. 21 of the questionnaire)

(iv) Investments in US Shale acreages by various Indian companies affects investment in home country (item no. 23 of the questionnaire)

(v) Inclusion of “deposits before drilling” clause in upcoming Shale Gas Policy (item no. 28 of the questionnaire)

(vi) Possibility of Volcanic eruption due to Shale Gas Exploration in India (item no. 39 of the questionnaire)

This factor encompasses six traits e.g. Unexplored large acreages under conventional E&P in India, Inflation of cost of local housing and services around drilling area, Diversification of the limited resources for Shale Gas Exploration affects conventional exploration, Investments in US Shale acreages by various Indian companies affects investment in home country, Inclusion of “deposits before drilling” clause in upcoming Shale Gas Policy, Possibility of Volcanic Eruption due to Shale Gas Exploration in India. A micro analysis of the underlying traits it is revealed that none of them is a barrier to Shale Gas E&E rather the variables like “Investments in US Shale acreages by various Indian companies" and "Inclusion of deposits before drilling" clause in Shale Gas Policy will encourage Shale Gas E&E as the bidders will have confidence for undertaking Shale Gas E&E based on their learning in US (being a success) and deposit before drilling will ensure confidence on receiving various clearances for drilling.

4.5.6 Factor No. 6, Land Issue

This factor encompasses variables like:

(i) Land Acquisition Issue (item no. 13 of the questionnaire)

(ii) Exploitation of Shale Plays requires large land acquisition. (item no. 14 of the questionnaire)

This factor covers large land requirement for Shale Gas E&E and land acquisition related issues. Land acquisition in India will pose a problem as India being agriculture based economy and recent development in land acquisition for Real Estates, Infrastructure Projects, and Pipelines Laying Projects has been a problem. With development of Pad Drilling Concept (where less land will do) with directional drilling the displacement problems of the population is addressed to a great extend (Fig. 4.3). Similarly the water treatment issue has also been addressed in global context where recycling a major portion of return frac water can be achieved. This factor therefore is not considered as a barrier.

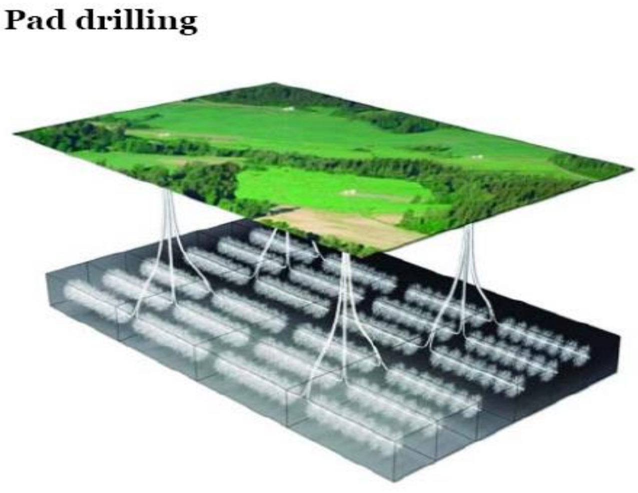

Fig. 4.3: Pad Drilling (Saves Land Requirement)

4.5.7 Factor No. 7, Water Related Issue

This factor encompasses the:

(i) Requirement of huge quantity of water for fracking (item no. 7 of the questionnaire)

(ii) Disposal of saline, toxic, and waste water from Shale Gas wells (item no. 8 of the questionnaire)

(iii) Return Frack Water treatment (item no. 37 of the questionnaire)

This factor covers the traits like huge water requirement for fracking, treatment of water for disposal into rivers/nala/ponds and the treatment required for recycling back for fracking. In India, there have been water shortages and many of the rivers have become waste water nalas, **this factor is therefore considered to be a barrier.**

4.5.8 Factor No.8, Transportation Related issue

This encompasses the variables like:

(i) Adequacy of the Natural Gas Transmission Pipelines (requiring PNGRB authorization) to transport Shale Gas to Consumers (item no. 16 of the questionnaire)

(ii) Cost of return frack water treatment making it suitable for recycling for fracking (item no. 36 of the questionnaire)

This factor covers the transportation of gas from wells to the end users. In India, though the pipeline network is not adequate (only 15,000 Km Pipelines) but the proactive action taken by PNGRB and initiative of various companies to develop pipeline network in India is encouraging and constrained only due to gas availability. This factor is therefore not considered to be a barrier.

4.5.9 Factor No. 9, Cost of Production and Collection of Shale Gas

This factor encompasses following variables:

(i) Cost of production of Shale Gas (item no. 11 of the questionnaire)

(ii) Existence of smaller pipeline players (not requiring PNGRB Authorization) owning gas gathering Pipeline Systems. (Item no. 15 of the questionnaire)

This factor addresses the issues like cost of production of Shale Gas compared to conventional gas and the collection of gas from well head to transmission pipelines. As the operator understands the characteristics of Shale E&E and the enthusiasm shown by many entrepreneurs for developing gas evacuation pipelines from wells to the transmission pipelines, during questionnaire administration, is also encouraging as it provides an independent business model since this part of pipeline network is outside the preview of PNGRB Act. Also the virtual pipeline concept (monetizing gas from isolated, marginal field including GGS of Shale Gas) is picking up in India. LNG by tanker from LNG Dahej Terminal got fully utilized within few years of its implementation. This factor is therefore not considered to be a barrier.

4.5.10 Factor No10, Policy Issue

This factor encompasses the variables like:

(i) Formulation of Shale Gas Policy in India (item no. 1 of the questionnaire)

(ii) Market driven Gas pricing with transparency and without interference in India (item no. 29 of the questionnaire)

This factor addresses the issues like Government approved Shale Gas Policy enactment and allowing market driven gas pricing. These are very important issues as nothing can move in absence of a policy. This is the sole reason that Shale Gas bidding/ award of acreage has not yet taken place in India. The interim policy guideline issued in October, 2013 which allow the PSU Companies to explore and exploit Shale Gas in the blocks awarded to them under nominated allocation of the blocks this does not provide a competition and refrains private companies from undertaking Shale Gas E&E therefore the interim policy is not going to be conducive to successful Shale Gas E&E in

India. Further the market determined gas price is very important issue. The producer needs to have certainty about the returns from his investment subject to assessable risk. The Indian domestic producers have been subsidizing the gas imports, which has retarded the E&P investment and hence the domestic Gas production. This factor is **therefore a barrier for Shale Gas E&E in India**.

4.5.11 Factor No.11, Population & Environmental Issue

This factor encompasses variables like:

(i) Shale Plays broadly identified in India have dense population living over. (Item no. 12 of the questionnaire)

(ii) Interference by Political or NGOs affects Shale Gas Exploration (item no. 24 of the questionnaire)

(iii) Partial treatment (dilution) of return frack water making it suitable to dump in local rivers (item no. 37 of the questionnaire)

This factor addresses the issues like dense population living over the Shale Plays, obstruction by NGOs, and treatment of return frac water to discharge it in the river/nala/pond. The population owning the land can be made as a party in Shale Gas E&E program by giving sufficient incentive but the treatment of water with the uncertainties of metal mobility from the well and the kind of frack fluid composition the treatment of the return water cannot be firmly considered as a non problem. India being an agricultural based economy this **factor is considered to be a barrier for Shale Gas E&E in India.**

4.5.12 Factor No. 12, Judicial/Market System

This factor encompasses variables like:

(i) Indian Gas demand supply Scenario (item no. 19 of the questionnaire)

(ii) Judicial Activism and PILs in India (item no. 42 of the questionnaire)

This factor encompasses the issue of gas demand-supply position and Judicial Activism in India. The gas demand-supply scenario is supporting upstream activities as the mid-term and long-term demand projection is about 100% more than the domestic production. The judicial activism is, though unpredictable, yet there has been no legal case so far obstructing exploration activities in India. Meanwhile we may not expect as supportive judiciary as in US but we can cite the example of US if need so arises. Thus this factor is not considered to be a barrier.

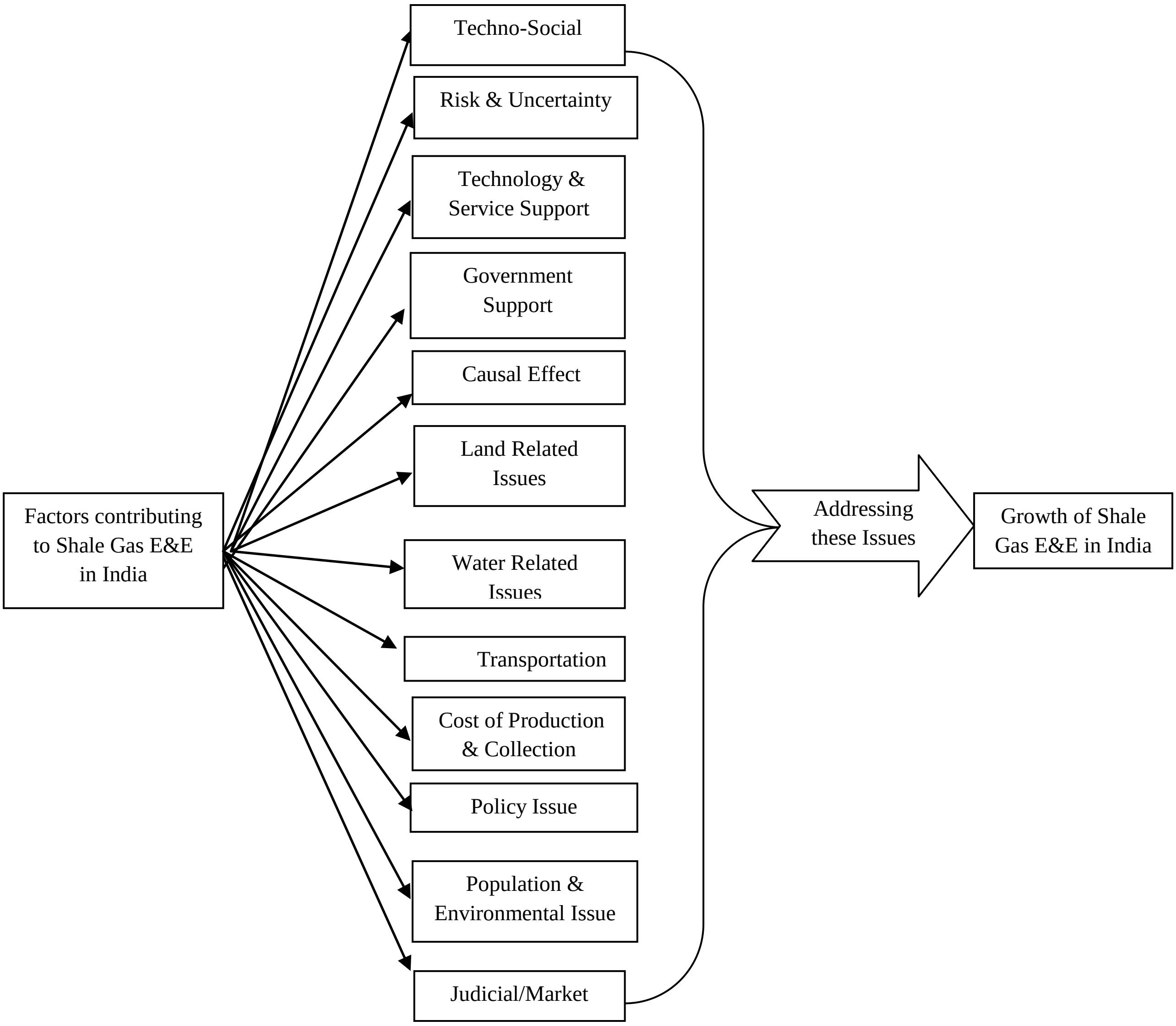

Fig. 4.4: Factors Influencing Shale Gas E&E in India

4.6. Barriers that prevents the Shale Gas E&E in India

Taking a reference from the emerging factors from the research study and the deliberation on each of the factor, we can find out the barriers in the way of implementation of Shale Gas E&E in India. All 12 factors are having considerable influence on Shale Gas E&E but the following factors if not addressed, will act as barriers.

(i) Availability of adequate data in public domain to undertake Shale Gas Exploration (item no. 2 of the questionnaire and part of factor 3)

(ii) Government Support - Local, State & Central (factor 4)

(iii) Water Related Issue (factor 7)

(iv) Policy Issue (factor 10)

(v) Population and Environmental issue (factor 11)

4.6.1 Addressing the Barriers

i. **Data in Public Domain -** There is a tendency in India not to share the data as unlike in US. It is therefore essential that an initiative comes from the Govt. to direct DGH and the PSUs or other companies who have undertaken Shale Gas exploratory initiative. As per the interim policy of the Govt. (October, 2013) only ONGC and OIL are authorized to undertake Shale Gas E&E and therefore Shale Plays data will mostly be available with them.

ii. **Government Support -** The Government supports needed for a transparent policy, clearances from environment, forest, defense and positioning of a competent authority for land acquisition. The DGH being a part of a Govt. the constructive and supporting monitoring of PSC will also be essential. It is therefore suggested DGH could be made as a Nodal agency for single window clearance required for Shale Gas E&E there is no substitute for this factor.

iii. **Water Related Issue -** The Shale Plays may have water requirement varying from 0-1000 gallon/mmbtu. In case of Shale with no water the frack water (3-4 million gallon/well) can be arranged by the operator and connate water can be treated for reusing in fracking to a large extent. For such situation even fracking can be achieved by propane, nitrogen, nitrogen foam or CO_2. However Shale Plays with excessive water will have to be provided with proper water treatment facility. A reference can be drawn for Marcellus and Utica Shale (North America) which has high water content.

iv. **Policy Issue -** This factor is a single important factor in the whole program of Shale Gas E&E Without a policy framework, nothing moves on. We have seen that China and India in 2010 were having same kind of Shale Gas status. China having moved with speed has already auctioned two rounds of Shale blocks and is preparing to auction 3rd round anytime. In India a draft policy of 2012 even after observation from various stakeholders has not been firmed up (proposal moved to CCEA - Business Standard Feb, 2013). The interim policy guideline in India were issued in Oct, 2013 allowing PSUs to undertake Shale Gas E&E in the conventional E&P blocks allocated to them on nomination basis before NELP was implemented. As an outcome of these policy guidelines ONGC plans to explore Shale Gas in 175 blocks and OIL in 15 blocks. ONGC has already drilled a Shale Gas well in Cambay basin and prepared for 2nd well. This explains the effect of Shale Gas E&E in India.

v. **Population and Environmental Issue -** Whereas population issue can be address by acquiring small part of the land (applying pad drilling technology) and compensating the land owners in the form of upfront payment good enough to compensate for the revenue accruing from the crops and also to share the revenue generated through marketing of Shale Gas when the field is monetized. The environmental issue mainly arises from the methane escape, connate water seepage and discharging treated in river/nala/pond. Whereas the methane escape can be minimize technologically and connate water seepage can also be stopped by proper cementing of the well but the treatment of return frac water making it suitable for discharge into public water system is considered to be an environmental issue and needs be constantly monitored.

4.7 Concluding Remarks

42 variables that constitute the core building blocks of Shale Gas E&E emerged as the outcome of extensive literature survey. A detailed questionnaire was developed and administered to 400 respondents who belong to different categories (Policy Makers, Regulators, Project Developer, Hydrocarbon Exploration & Production Operators, Equipment Manufacturers, Service Providers, Consultants and Academia) in the Exploration and Production domain both from Public and Private enterprises. In all 341 valid responses were received. These responses were factor analysed to find the underlying structure of the data. The respondent targeted included Indian as well as foreign who have domain knowledge and interest of Shale Gas E&E in India.

Twelve factors (Techno-Social, Risk and Uncertainty, Technical and Service Support, Government Support, Causal Effect, Land Issues, Water Issues, Transportation, Cost of Production and Collection, Policy Issues, Population Related Issue and Judicial/Market System) emerged from the analysis.

These factors have been elaborated and five of them emerged as barrier for Shale Gas E&E in India. To bring out solution, a study of the Shale Gas E&E in the countries which have taken Shale Gas E&E initiative has been done in the succeeding chapter so as to take necessary inputs for implementing Shale Gas E&E in India.

Chapter 5
Learning from Global Experience

5.1 Introduction

The countries which have been perusing Shale Gas E&E in the world have been studied in Chapter-2 (Literature Survey). The present Chapter outlines the learning from each of such country with a view to suggest its implication for India. This study therefore, summarizes the experience of various countries visited in Chapter-2 with a view to develop input references for India.

The technical issues which are common to all the countries have not been highlighted under any specific Country in the fore going analysis but described below for better understanding of the issues:

(i) Drilling more numbers of wells for Shale Gas exploitation as compared to conventional E&P.

(ii) Huge water requirement for fracking (although alternative have also been found)

(iii) The rate of production of Shale Gas is much less than that from conventional E&P.

(iv) The rate of depletion of Shale Gas well is faster than conventional E&P well. The production witnesses an early peak followed by rapid decline.

(v) Shorter time to first production from acreage that than from conventional E&P.

(vi) More methane is escaping to atmosphere as compared to conventional E&P.

(vii) Possibility of water coming out with Shale Gas due to the water trapped in the course of rock or near the Shale formation (connate water) or due to infiltration of the fracture into the underline saline water body.

(viii) Treatment and preparation of frack water.

(ix) Treatment and disposal of returned frack water.

(x) Fracking technology improvement – multi stage fracking (as many as 18 times fracking has been carried out)

(xi) Radio active metals in Shale Plays particularly in Devonian – age Shale.

(xii) Acid producing minerals may lead to metal mobility.

All above issues can be grouped under, Technical, Environmental, Fiscal and Infrastructural head.

5.2. US Experience

Table 5.1: US Experience - Lesson for India

S. No.	US Experience	Implication for India
1	The Shale Plays and the Shale contents are ever changing	Also true for India
2	US quickly identified its Shale potential.	India needs to take quick action
3	US wild - Caters have continuous experimented and improved drilling techniques and reducing cost	India needs to take quick action
4	The efforts to explore the Shale Gas had been for more than a decade before commercial production.	Indian activities started in 2010 only
5	The cost of production of Shale Gas has been more than the cost quoted at Trading Hubs. Only in 2008 when the natural gas price increase justified cost of production of Shale Gas, the Shale Gas exploitation activities witnessed a sharp growth.	India being importer of gas, domestic gas production is expected to be much less than imported LNG.
6	Increase in the cost of local housing and services around Shale Gas E&E	India needs to take note
7	The owner of the land has the ownership of the minerals under its property	Mineral under property are owned by the Govt.
8	The Ellenberger and Onondaga are water bearing formation below Barnett and Marcellus reservoir respectively. By contrasts some Shale Plays are very dry and do not have connate water for example a portion of Haynesville Shale (Louisiana).	India to take note
9	Active social lobby (opposing interest group) for example gas land video by Josh Fox	India to take note

	highlighting gas leakage in water mains.	
10	Supporting Interest Group - Collaboration between GE and Corporation of Mid Land Texas has resulted in water distillation process that reclaims nearly 70% of frack water.	India to take note
11	Acts, Rules and Regulations in place Delaware River Basin Commission published regulation for Marcellus Shale area drilling and abandoning. Shale Gas operator to take pollution policy which provide for gradual accident coverage which is better than general liability insurance, other (Clean Water Act 1972, Clean Air Act, 1972, Safe Drinking Water Act & Energy & Mineral Act, 2005).	Indian Shale Gas Policy to address the issue
12	Favorable Judiciary Range Resources Case and Huntley Case Louisianan Supreme Court ruled – Manufacturer of frack fuel need not disclose the composition of proprietary fluid for patent protection.	India to take note viz-a-viz UK reference Serial No. 9.
13	Government support (i) US 2005 Energy Bill exempted Shale Gas from Clean Air Act, Clean Water Act, Super Fund Law and other Environmental and Democratic Regulation giving rise to Shale Gas Exploration by big companies in almost 34 states out of 40. (ii) Congress exempted fracking with exemption of fracking with diesels fuels from the Safe Drinking Water Act.	Indian Shale Gas Policy to address the issue
14	Large pipeline network till 2010, about 8 lac km. of pipeline network exist.	Inadequate transmission network only 15000 km.
15	Smaller player (Loyal Mountain Mid Stream) for pipeline infra as group gathering pipelines more than transmission pipelines as GGS connecting 2620 wells owns 1600 km. of pipeline.	India to take note.
16	Slick water frack being replaced by Straight Nitrogen Gas or Nitrogen foam	India to take note
17	Clear demarcation among the authorities involves in Shale Gas E&E. Federal Govt. through State Government, Municipalities, other Inter State River Commission and Inter State Oil & Gas Compact Commission, FERC and EPA.	Indian to attempt a single window players

5.3 Canadian Experience

Table 5.2: Canadian Experiences – Lesson for India

S. No.	Canadian Experience	Implication for India
1	Shale prospect are highly promising - leading to Kitimat LNG plant in West Coast and also in the East Coast – St. Jon	India needs to take quick action to validate its Shale resources
2	Propane frack has been accomplished by corridor resources.	India needs to take note.
3	Public Awareness Program – combined efforts of all Canadian petroleum producers.	India needs to take note.
4	Exploration on hold in Quebec impact being studied.	Some sensitive Shale locations could be explored with due care.

5.4 Poland Experience

Table 5.3: Poland Experiences – Lesson for India

S. No.	Poland Experience	Implication for India
1	Initial estimate statuary – slashed down by more than 80% leading to exit of oil giants.	India needs to take note.
2	Private company (Lane Energy) and Polish refiners (PKN Orland) pursuing Shale Gas E&E.	India needs to take note.
3	Shale Gas driver – reducing gas import from Russia.	India's dependence on LNG to reduce.
4	100 Shale Gas licences issued but commercial discovery delayed due to red tape and difficult geology.	India needs to take note.
5	Policy haziness - PEPIO is concerned that government may get excessive control in Shale Gas E&E including new taxation.	India needs to formulate a firm Shale Gas Policy addressing on issues.
6	Large coal reserves – 90% electricity on coal /lignite.	True for India also but preservation of domestic resources and care for environment is suggested.
7	E&E company to take one partner from Poland.	Restriction not required in India.
8	Fuel cost in Europe is double of US	Indian appétit still higher.
9	France, Bulgaria and Netherlands banned fracking.	The issue has found a technical solution, no banning is required.

5.5 Ukraine Experience

Table 5.4: Ukraine Experiences – Lesson for India

S. No.	Ukraine Experience	Implication for India
1	PSA with global giant – Chevron, Royal Dutch Shell. Shale program to reduce dependence on Russian Gas (both) for financial burden and Russian pressure to prevent Ukraine from signing a free trade agreement with EU.	There is no other pressure on India expect current account deficit due to foreign exchange drain on petroleum and petroleum products import.
2	Ukraine has third largest (42 Tcf) recoverable Shale reserves in Europe. Induction of global majors expected to attract foreign oil services group.	India needs to take note.
3	Policy statement through PSA indicate sound energy policy including protection of investor right and rule of law	India needs to take note.
4	Russian gas price cut (to Belarus) level likely to make domestic production less lucrative.	Not applicable to India

5.6 Lithuanian Experience

Table 5.5: Lithuania Experiences – Lesson for India

S. No.	Lithuania Experience	Implication for India
1	Shale program to reduce dependence on Russian Gas.	India needs to take note.
2	Chevron pulled out after winning a tender for Shale Gas E&E due to changes to laws making less attractive terms after bid was closed.	Shale Gas Policy needs in place.
3	Lack of Regulatory Clarity	India needs to take note.
4	Absence of legal framework for Shale Gas E&E.	India needs to take note.

5.7 UK Experience

Table 5.6: UK Experiences – Lesson for India

S. No.	UK Experience	Implication for India
1	Shale Gas reserves estimated at 1300 Tcf.	India needs to take note.
2	Shale Gas E&E license issued to I-Gas for Northern England	India needs to take note.
3	Land owner association asked for revenue sharing from Shale gas.	India needs to take note.
4	Explorers have offered GBP 1,00,000 down payment and 1% of revenue sharing on production.	India needs to take note.

5	Demonstrator still obstructing drilling. Many of them are professional and not belonging to local area.	India needs to take note.
6	Civil society and academia (Royal Society and Royal Academy of Engineering) join to analyze the environmental, health and safety risk associated with Shale Gas E&E. The conclusion of this effort brought out that these risks could be managed effectively as long as operational gas practices are implemented and enforced through regulation. The Govt. has accepted all the recommendations.	India needs to take note.
7	So far fracking has been done at 1700 meter depth to 3100 meter depth. The penetration of frack water to the ground and the adjoining is ruled out.	India needs to take note.
8	Britain has the history of world class Oil & Gas regulation and a unique examination scheme where design, construction and abandonment of wells are reviewed by independence, specialist experts.	India to incorporate such provision in Shale Gas Policy.
9	Disclosure of fracking fuel composition is mandatory.	India needs to take note (also ref. US – 12)
10	Mineral rights are owned by the state	Same is in India

5.8 Chinese Experience

Table 5.7: China Experiences – Lesson for India

S. No.	China Experience	Implication for India
1	China explorable Shale Gas reserves of 888.5 Tcf have been revised to 1115 Tcf (June, 2013).	India needs to take note.
2	China roped in global major Royal Dutch Shell to jointly undertake Shale Gas E&E 1999.	India needs to commence bidding round for Shale Gas after bringing out a firm policy
3	In 2013, China became one of the 3 countries (with US and Canada) to produce Shale Gas in commercial quantities.	India needs to take note.
4	In 2012, 19 Shale Gas blocks awarded to 16 local companies (6 state run companies, 8 energy investment firms, and 2 little know private firm). China now prepared for 3rd round of bidding.	India needs to take note.
5	China ranked as largest holder of Shale Gas resources among the 41 countries having technically recoverable Shale resources.	India needs to take note.

5.9 Indonesian Experience

Table 5.8: Indonesia Experiences – Lesson for India

S. No.	Indonesia Experience	Implication for India
1	Indonesia holds 1000 Tcf of Shale Gas reserves at average depth of 600 meters	India needs to take note.
2	Policy of Shale Gas development under preparation.	India needs to take note.
3	In 2006, drilling in Java led to eruption of Mud Volcano killing 13 people and displacing more than 30000 people. Indonesia govt. considering not allowing drilling for Shale gas.	India needs to take note.

5.10 Indian Experience

Table 5.9: Indian Experiences

S. No.	India Experience	Implication for India
1	Shale Gas reserves estimate varies from 63 Tcf to more than 500 Tcf in its Shale Gas basin.	India to validate its Shale Gas reserves for increasing participation in Shale Gas E&E.
2	Shale Gas draft policy announced in April, 2012. In October, 2013 PSU companies holding conventional E&P acreages are allowed to explore Shale Gas in their respective acreages.	India to come out with a firm Shale Gas Policy addressing all related issues.
3	Some of the operating companies have undertaken Shale Gas pilot project and some others have struck Shale Gas while pursuing conventional E&P activities.	India to take note.
4	Location of Shale Plays happens to be in sensitive area including Naxal prone area	Adequate major can be taken to explore such areas
5	Many prices of domestic gas. Major volume of gas is price control.	Minimum price being doubled with Rangarajan Committee Recommendations

5.11 Australian Experience

Table 5.10: Australian Experiences – Lesson for India

S. No.	Australia Experience	Implication for India
1	Estimated Shale Gas reserves 396 Tcf. Shale Plays are scattered in North, East West, South and Central region. Cooper Basin in Central Australia is the best Shale play outside North America.	India needs to take note.
2	Gas price and infrastructure favorable in Central Australia.	India needs to take note.
3	Shale Gas from Cooper Basin is to compete with Queens Land CBM (Shale Gas being cheaper than CBM).	India needs to take note.
4	Most of the Shale Plays are connected with pipeline.	India needs to complete its National Gas Grid connecting all Shale plays.
5	Protests against hydraulic fracking	India needs to take note.
6	Large number of operators & service providers	India to take note

5.12 Summarizing learning from Global Experience

From the deliberations of the experience of various countries for Shale Gas E&E, experiences which have relevance and possible impact for Shale Gas E&E in India are detailed below:

(i) **The Shale Plays are ever changing –** that means no two Shales are expected to be similar. Apart from geologic maturity, their TOC depth and thickness including the rock properties are expected to vary a large. It is therefore essential that a reasonably good estimate of the Shale characteristic including gas in position and gas good for monetization should be done by the Govt. or DGH. In Poland slashing down the Shale Gas estimate let to exit of big players affecting badly the Shale Gas program in Poland. (US, Poland, UK, Australia, China)

(ii) **Quickly Identifying the Shale Potential –** India as a country has not yet identified it Shale potential. The experimental data collected by RIL, GSPC, JTI, ONGC & OIL are only suggestive and the Shale Gas potential assessed by Society of Petroleum Engineers, EIA, McKenzie etc. are based on secondary data. (US, Poland, China)

(iii) **Wild Cat Exploration –** something like open acreages policy for conventional E&P India should allow any party interested to invest in Shale Gas E&E as the part of its policy to explore the area for collection of data. This concept has very well contributed to US success story. (US, North-West Africa)

(iv) **Land Issue –** the land laws in US allow ownership of the mineral under his property as against India & UK land laws where the minerals right under a property vests with the government. The land acquisition has always been a problem as India is an agriculture based economy. The land acquisition is single largest road block in the infrastructure project (FICCI – EU Report 2012). We can however take lesson from a combination of experience of US & UK. In US the operators offer $1.0m upfront for a well to be drilled in any property and pay 10% of the revenue from the gas sales. In UK the operators have offered GBP 100,000 upfront payment and 1% revenue sharing. This has however not yet been accepted.

The land acquisition issue has seen an aggravation during last few years for acquisition of land for Industry, Real Estate and even Pipeline Lying. The government has responded to land issue by amending the original Land Acquisition Act, 1894 and National Policy of 2007 by "Land Acquisition, Rehabilitation and Resettlement Act, 2013 (RFCTLARR 2013)"

Taking a clue from land acquisition guideline in Himachal Pradesh. Gujarat, Andhra Pradesh & Haryana, it is suggested that the farmers could be assured of the income from his acquired land as much as the revenue accruing from agriculture. He should also be made a party for harnessing the fruit of Shale Gas production to the extent of 1-5% on the revenue for the sale of Shale Gas. This should however be as a part of the policy. (US, Canada, UK, India)

(v) **Water Related Issue –** As in US and Canada, Marcellus and Utica Shale Plays have much water and Haynesville Shale has no water. Similar disparity may occur in Indian Shale Plays in various basins. India therefore needs to prepare for excess water to no water situation.

In case Shale Plays are non water bearing and, water if available for fracking nearby it will not have problem. In case water is scares, India can take advantage of Propane fracking as has been done in Canada. In US slick water frack is begin replaced by straight nitrogen gas or nitrogen foam fracking. In case of excess water, it would be treated to re-use to the extent it struck a proper balance between reused and discharge to river/nala. (All country studied)

(vi) **Policy, Rules and Regulations –** India needs to notify a clear policy on Shale Gas E&E defining thereby a clear procedure for Shale Play allocation and applicability of various acts for land acquisition, environmental clearance, defense clearance, water act and environmental act. Further the Govt. support for Shale Gas E&E is also required in case of any ambiguity or implementation difficulty. In US both government and the judiciary support was available to Shale movement. In India a clear regulatory regime in a defined policy framework are expected to minimize judicial intervention. The intermittent change of policy affects the E&P program. Lithuania tried to change the laws making Shale Gas E&E less attractive after bid was closed, led Chevron pulling out of the tender after winning. (US, Poland, Lithuania, UK, China, India)

(vii) **Evacuation Infrastructure –** The US experience coupled with the feedback from the respondent is suggestive that the Shale Gas evacuation infrastructure has large effect on Shale Gas E&E. India therefore needs to quickly complete all the transmission pipeline authorized by the PNGRB to various entities and PNGRB needs to take proactive action to connect various Shale Plays basin with pipelines. (US, Europe, China, Australia, India)

(viii) **Public Awareness Program –** Canadian experience indicates that public awareness program is helpful for the support of the community for Shale Gas E&E similar experience is also cited by European players. (Canada, US, UK)

(ix) **Encouraging Participation of Global Experienced Players -** US success story is difficult to be replicated elsewhere by and large as US

Shale movement is more than 2 decade old, there were wild cat experience mostly led by the private players and favorable land laws, other countries will have to associate globally experienced party in their respective country. Poland invited Exxon Mobil, Ukraine associated Chevron, Royal Dutch Shell, China associated Royal Dutch Shell and Lithuania invited Chevron (Europe, China, Australia, and India).

(x) **Market Determined Price for Gas –** As per the global experience the initial cost of Shale Gas production is higher than that produced from conventional resources as the program develops, more Shale Gas volumes are produced, the price falls due to market forces playing in tandem, such a mechanism will assure a competitive benefits to the players (US, Europe, China, Australia, India).

Chapter 6
Conclusions and Recommendations

6.1 Introduction

Domestic energy resources are unable to meet the requirement to fuel India's growing economy. India therefore needs every avenue of energy resource to power its economy. However, Shale Gas in India is an untapped source. Initial studies show reasonably good potential exists for Shale Gas E&E in India.

Some of the Shale Gas basins like Cambay Basin (Gujarat), KG Basin (Andhra Pradesh), Damodar Basin (Jharkhand), Cauvery Basin (Tamilnadu), Ganges Basin (UP, Bihar), Assam Arakan Basin (NE States), Gondwana and Bengal Basins are the promising basins for Shale Gas E&E in India.

As found from research study, India must address twelve factors – Techno-social Issues, Risk & Uncertainties, Technology & Service Support, Government Support (Local, State & Central), Causal Effect of Related Activities, Land Related Issue, Water Related Issue, Transportation Related Issue, Cost of Production and Collection of Shale Gas, Policy Issue, Population & Environmental Issue, Judicial /Market System, to embark on the Shale Gas E&E.

6.2. Conclusion

From the present research study and analysis, the following conclusions have been reached. The 42 variables identified from literature survey and peers survey converged into 12 factors on the basis of the response of the target population. These factors are:

i. Techno-social

ii. Risk and Uncertainties
iii. Technical and Service Support
iv. Govt. Support (local, State and Central)
v. Causal Effect
vi. Land Issue
vii. Water Related Issue
viii. Transportation Issue
ix. Cost of Production and Collection of Shale Gas
x. Policy Issue
xi. Population and Environmental Issue
xii. Judicial/Market System

These factors have varying influence on the Shale Gas E&E in India. As deliberated at Para 4.6 the following 5 factors emerged as the barrier:

- Availability of Adequate Data in Public Domain
- Government Support
- Water Related Issue
- Policy Issue
- Population and Environmental Issue

Para 4.6 also describes the procedure and suggestions for mitigating the barriers.

6.3 Observations

Having gone through the entire exercise of studying available literature on the Shale Gas E&E globally, preparation of questionnaire, administration of the questionnaire to target population, attending various conferences globally, processing the response of the target respondents and arriving at the factors having influence on Shale Gas E&E in India, following observations are made with a view to consider the same for initiating the Shale Gas E&E in India.

i. **Captive Market for Shale Gas in India:** It can be concluded from the market analysis of energy demand–supply scenario in India that, as long as the demand and supply gap for natural gas continues to grow, (as it is at the present), there will be a captive market of consumers available in India for Shale Gas. All studies undertaken by the Government Department, Planning Commission or Independent Consultants show a large gap between demand and supply. India is becoming more and more import dependent for Gas. Four LNG import terminals are operational with a capacity of above 25mmtpa LNG Regasification and 18 more are at different stage of project implementation.

ii. **Financial Feasibility of Shale Gas E&E is Encouraging:** Though all Shale Plays are not alike but the US and Canadian experience indicates that Shale Gas E&E is economically viable. The upcoming experience in Australia and China also supports this. For gas importing countries it is bench marked with LNG or Pipeline import of gas. When Shale Gas based LNG is getting viable in US, Canada and Australia from where India has contemplated to import LNG (GAIL contract with Chenier for Sabine Pass LNG, and from Dominion Cove Point LNG), the domestic Shale Gas will certainly be acceptable to the market.

iii. **Access to Technology and Services:** India is an emerging economy with a vast consumer market, the technology and service providers for Shale Gas E&E from the whole world are interested to do business in India. It may be safely concluded that technology and service expertise will no more be constraint for pursuing Shale Gas E&E in India.

iv. **Land Issues including Thick Population:** With enactment of new law for land acquisition (Land Acquisition Act, 2013) the land acquisition will not be as difficult as it used to be. We can further improvise the same taking experience of the initiative taken by state Govt. of Himachal, Gujarat, Andhra Pradesh and Haryana. The suggestion made earlier to compensate the farmer equal to the benefit accruing from cultivation plus sharing of the revenue from Shale Gas monetization is expected to help land acquisition to a great extent.

v. **Water and Environmental Issue:** The treatment of return frack water shall have to be carried out to meet the national standards for discharging such waters into nala /river/ponds. Still the studies going on for crafting best use of water coming with the Shale Gas since this is the major environmental pollutant. The methane discharge to atmosphere though higher than the normal conventional hydrocarbon production yet the awareness of this aspect has not been alarming anywhere in the world.

vi. **Policy Issue:** The policy of the Govt. is the single major consideration to make or mar the Shale Gas movement in India. Though late, Govt. now seriously considering coming out with a regular Shale Gas Policy. The interim policy guideline issued in October, 2013 are not likely to effective as private players participation and competition will not be forth coming. It would be advisable to notify the policy after considering all the inputs on the draft Shale Gas policy.

vii. **The Appetite for Gas in Indian Market:** The demand supply projections discussed in this report indicate that there is a huge gap between demand and supply of natural gas (almost 100% of the domestic production). This factor is the single most powerful driving force for Shale Gas E&E in India.

6.4 Recommendations

Based on the inputs from the global learning, findings of present research study and the considered opinion of the peers, the following recommendations are made to encourage the growth of Shale Gas E&E in India:

(i) Develop and communicate the policy: The Shale Gas Policy needs to be notified at the earliest. The interim policy guidelines will not suffice as the Shale Gas E&E needs more competition coming from more players, most of whom the private players. The public comments including those offered by the authors need be considered before notifying the policy. The experience of successful countries in Shale Gas (US, Canada, Australia, China) indicate that the policy frame work has been the most effective driver for Shale Gas movement.

(ii) Accurate data on Shale Plays: This is an important input for attracting the players to undertake Shale Gas E&E. The feedback from the NELP rounds for conventional E&P bidding including CBM has not been encouraging in as much as many operators have either surrendered the block or trying to exit by selling out their participating interest (PI). DGH should therefore undertake exploratory drilling to gather the Shale Plays data and place the same in public domain so as to attract the participants taking a clue from US experience, making such data open to public has provided more competition.

(iii) Nodal agency for faster approvals: The Indian experience of taking clearances to start E&P activities in the blocks awarded to the entity has been painful not only there are large number of clearances required from many government departments there has been lack of coordination amongst such departments and also with the administrative ministry, MoPNG. We therefore, suggest a single window clearance concept for various clearances concerning Land Acquisition, Environmental Clearance, Defense Clearance, DGMS, etc., is required to be in position. At present, DGH works like a department of the government which needs to be strengthen to take up nodal agency role as well as the repository for exploration data on Shale Plays.

(iv) Dedicated areas identified for Shale Plays E&E*:* From the various Shale basins identified in India, the government needs to prioritize the Shale Plays in such basins for undertaking E&E activities ("Pre-identification of the sweet-spots which will attract the player for participation in the Shale Gas program"). The identified Shale Plays should be such that they encounter least of the barrier factors identified through the research study..

(v) Evacuation Infrastructure: The share of natural gas in Indian energy basket has temporarily increased to 11% in 2010 and maintaining a share of less than 9% as against a global average 24% +, and that is the reason that the gas pipeline infrastructure in India has not grown. As of now we have only 15,000 km of transmission pipeline and 11,000 km authorized but not executed. The Shale Gas E&E will have large numbers of wells to be drilled in various Shale Plays which will need connectivity to the gas market. Therefore, two kinds of gas evacuation infrastructure are essential for Shale Gas program. The first one, is the main transmission pipeline network which India needs to expeditiously complete the PNGRB authorized pipelines and additionally take proactive action to connect the entire Shale basin particularly Assam Arakan Basin connecting to existing National Gas Grid. In addition Shale Gas E&E will need a large network of connectivity to each well producing Shale Gas. This is analogous to Group Gathering System (GGS) of conventional E&P but with much larger network as the number of wells is comparatively much more. It is suggested that India can attempt to replicate US model of private companies developing this network as it is possible to do so within the framework of PNGRB Act, 2006 since such pipelines are not governed by the Act.

(vi) Legally enforceable gas pricing mechanism: India has witnessed many varied gas pricing mechanism since beginning of commercial application of natural gas. As of now there are more than five pricing mechanism prevailing in India. The latest one, the Rangarajan committee recommendation, is hotly debated in India even though the cabinet has approved its implementation. The Rangarajan committee has suggested implementation of market determined price after five years. As the gas sector pricing mechanism has reached to a stage of “Now or Never”, it is understood that for the larger interest of the country these recommendations will be implemented. Even if the Shale Gas E&E starts now i.e. 2014, the commercial gas availability will take more than 3 years. Nearing that the market determined gas pricing mechanism era is expected to begin.

(vii) R&D Efforts: The Shale Plays are ever changing so as the technology. In the Shale E&E domain, the data collection processing and interpretation, the drilling technology (from vertical to horizontal), the fracking technology (single to multi stage fracking), propellant (from sand grit to polyethylene prills), the fracking fluid and well cementing have undergone high degree of change. There are continuous efforts to upgrade the technology and reduce the cost of production of Shale gas. For many companies continuous advancement have changed their business domain for Shale Gas E&E. The company which undertook well drilling than specialized for fracking fluid now invented specialized polyethylene propellant. Shale Gas E&E is a green field area for R&D because the system and technique may need modification to suit Indian geological and environmental condition. Even though R&D is not a factor emerged from the research study but this is suggested to cope up for technical and service support under factor 3 and this will also provide capacity building for Shale Gas E&E within the country.

(viii) Financial incentives for green field projects: The Shale Gas E&E comprises of the Shale Plays having reasonably accurate data and those plays for which such accurate data are not available. Such frontier areas where the secondary data are suggestive of Shale existence should have special incentive for attracting international players who have more experience on geological behaviour of different Shale plays and are capable of extrapolating the data (though no two Shale Plays are alike). In addition, Tax holidays for initial 5-10 years on the gas sale, gas to be notified as "a declared good" and application of VAT will encourage the E&P sector.

(ix) Developing a conceptual framework: A conceptual framework for effective implementation of Shale Gas E&E in India is developed as shown in Figure 6.8. This framework helps in sorting out the issues identified through literature survey, peer's survey and the identification of factors for the research study having employed statistical tool.

(**x) The bidding process for Shale Gas**: Based on the experiences of auctioning hydrocarbon blocks under NELP regime, and the changes been contemplated, the additional input from the conceptual frame work developed here in, India can start a bidding process for Shale Plays (the Shale Gas Policy will have to be notified before hand) (Fig 6.1).

(xi) Capacity building: This will address the issues of access to technology, services, consumables, and manpower. The technology providers, service providers and equipment & consumable suppliers and the academia will have to be incentivized to devote attention.

(xii) Diffusion of innovation: The process of absorbing the knowledge base available globally shall have to be set in motion. Both "two step flow" model and "one is to one" models will have to be encouraged to absorb the knowledge base available globally that could be applied to India *(Rogers, 1995)*.

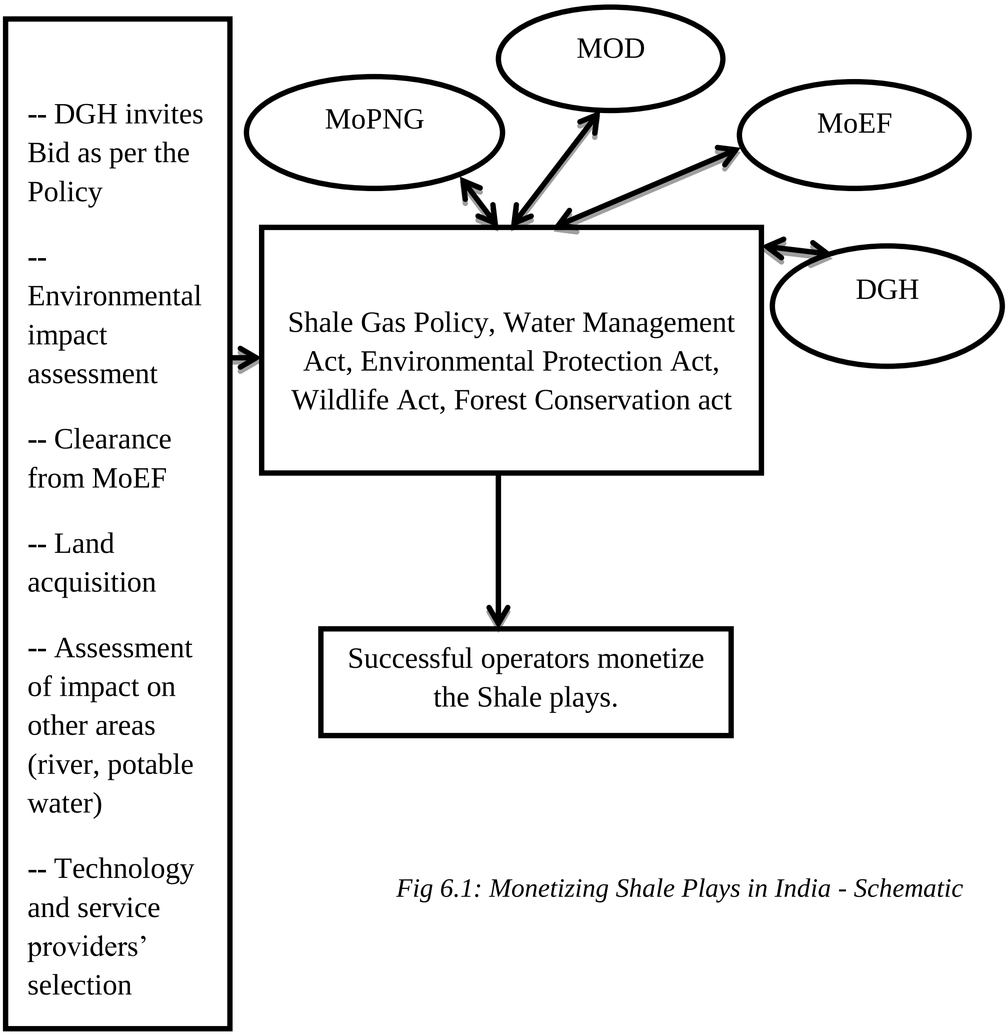

Fig 6.1: Monetizing Shale Plays in India - Schematic

6.5 Best Practices that could be adopted by Indian Shale Gas E&E Industry from the global experience

Based on the response received during data collection, the qualitative response is received through questionnaire has been separately analysed and is placed at Appendix-F. In response to descriptive question no. 1*, " Which of the countries experience in Shale Gas E&E can be replicated in Indian context",* indicates that the maximum choice is for pursing US model (47%), followed by China (19.4%) and similar response. (19.4%) have suggested the India should have its own model which should be high-breed type model suiting to Indian condition. Interestingly the European model happened to be the least choice at 3.3%.

The second question sought the respondents' opinion on "*the most problematic issues influencing Shale Gas Exploration in India."* The response indicates that the large number of respondents feel the policy issues are the most important (57%), followed by technology (44%). The water and environment concerned 20% and 18% of the priorities. The other concerns are rather newer areas identified are sensitization of the populate through the media (6%) and inadequacy of the gas evacuation infrastructure (7%)

Question third asked for the suggestion for "*implementing Shale Gas E&E in India"*. Majority of the respondents suggest "a few pilot blocks for exploration and data collection be commissioned (54%), followed by 28% of the respondents desiring "to attract US and foreign participation for technology and investment', next two suggestions are 'fast action by Government (18%), Skill development (13%).

Observations

It is clear that for India, replication of the experience of any country is not practical and therefore not advisable. India needs to have a hybrid program taking advantage of the experience gathered by other countries having initiated

Shale Gas program which are at various stages of success. Learning for India from global experience is placed at Figure 6.2.

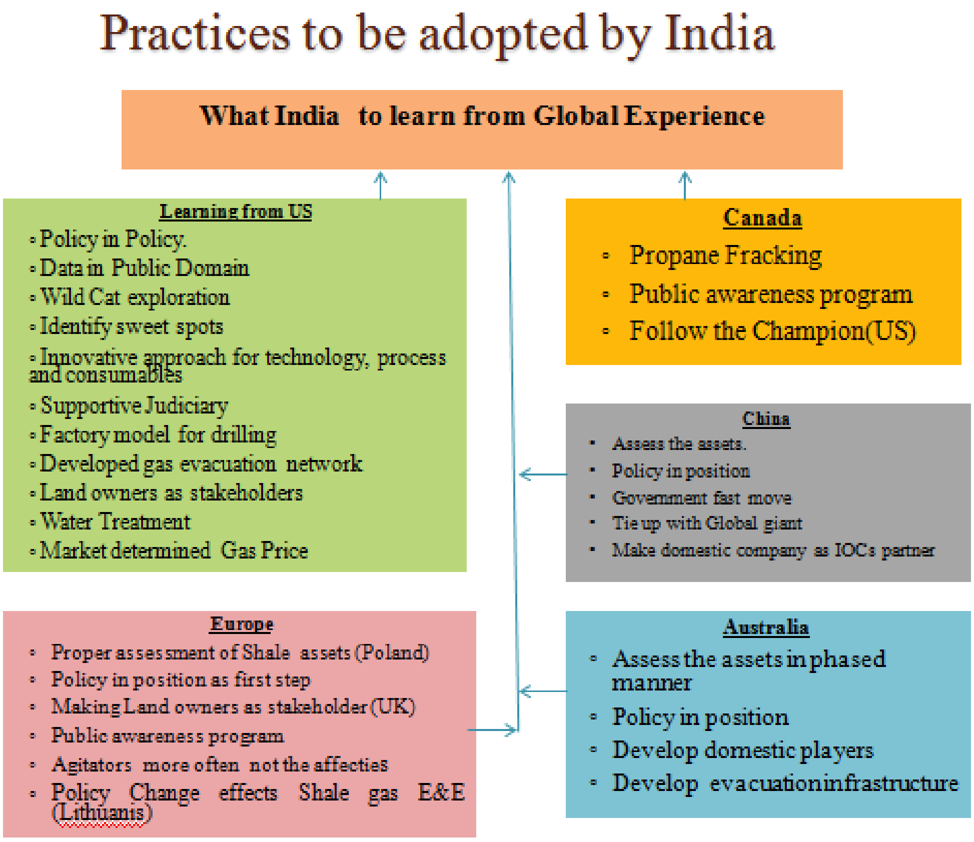

Fig. 6.2: Learning from Global Experience

Further, the global experience has also been analysed in such a way as to address each of the 12 factors emerged as an outcome of this research. Such an analysis is placed in Figure 6.3.

Actions required to be taken in a phased manner to employ gainfully the learning from this research study are placed at Fig. 6.4 as Action Plan. When implemented, India will reap the fruits of successful implementation of Shale Gas E&E.

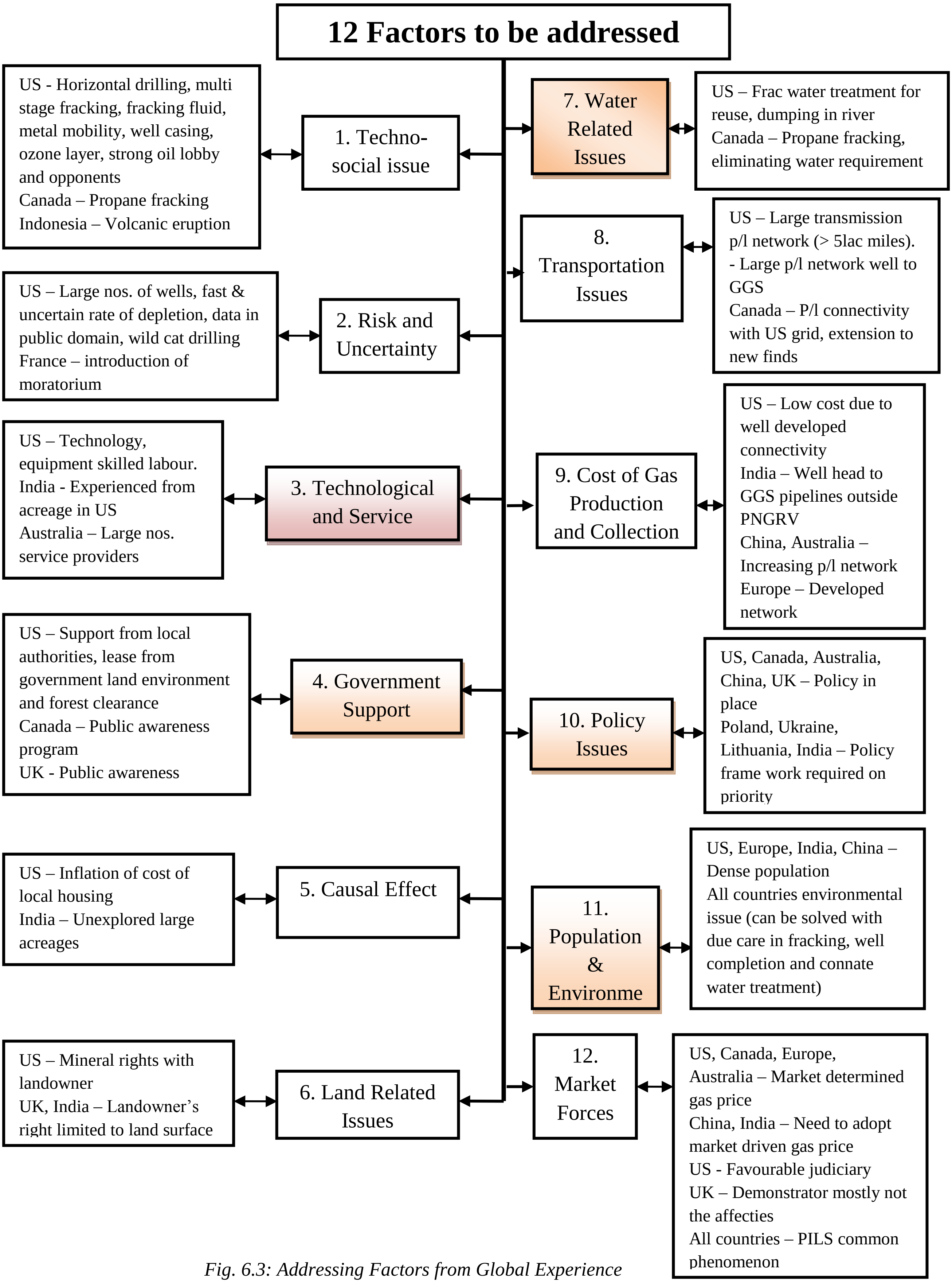

Fig. 6.3: Addressing Factors from Global Experience

Action Plan for India Based on Global Experience

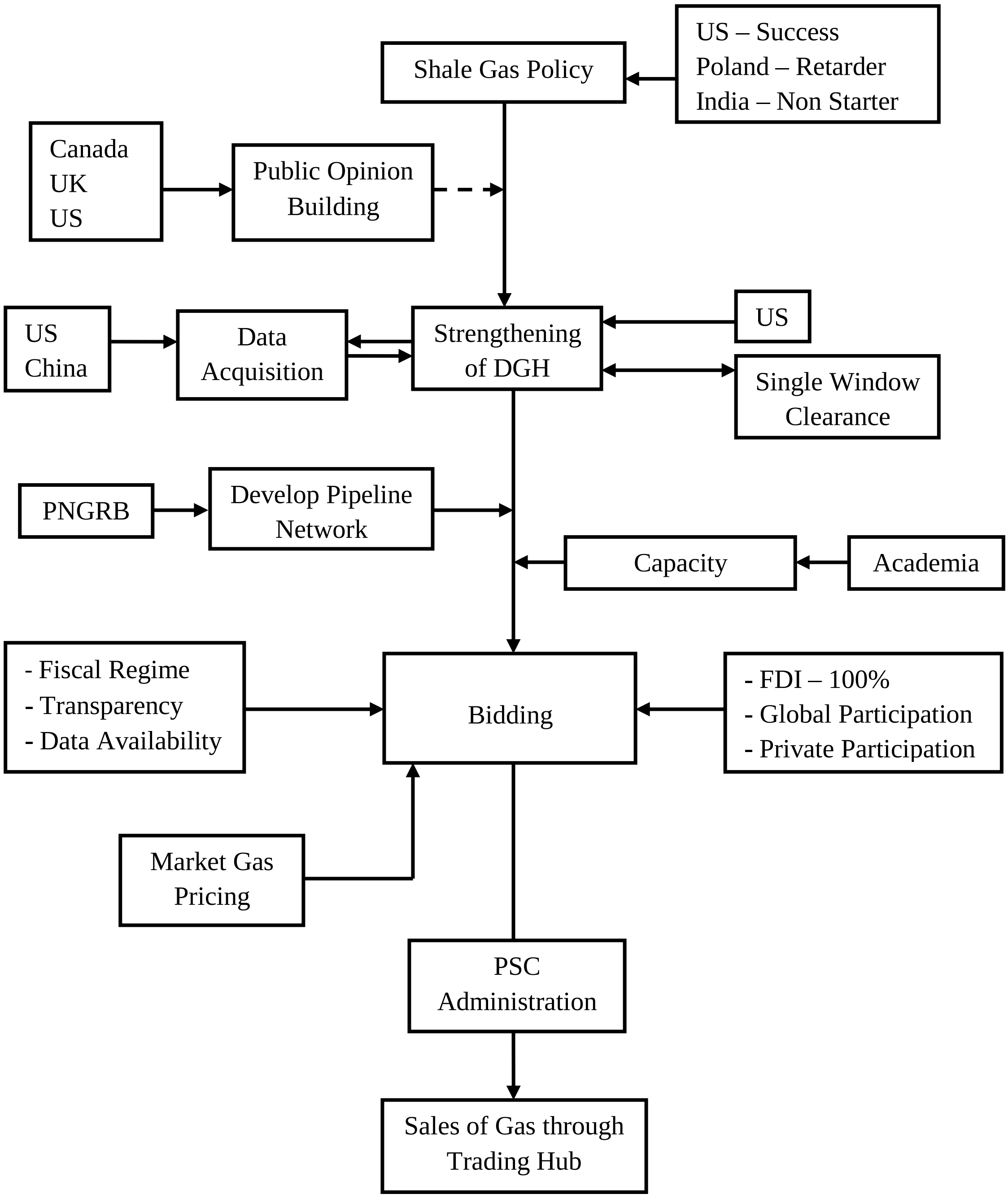

Fig. 6.4: Action Plan for India (based on Global Experience)

6.6 Comparative Study of the response from Indian and Foreign Respondents

As the extent of the research covers all nationals from across the globe and the experience of the respondents varies widely in view of growing stage of Shale Gas movements in different countries and so is the experience of individual respondent. The biases are evident from the experience that stakeholder/respondent has undergone in pursuit of shale gas program.

The responses from the Indian and the foreign participants who responded to the questionnaire indicate large similarity of the perception on the various aspects influencing Shale Gas E&E in India. Combining responses bearing strong influence and the influence (likert scale 6 and 7) and non-influencing and strongly non influence (likert scale 2 and 1) and taking a percentage of the Indian and Foreign responded, the response bar charts have been drawn and placed below in Figure 6.5 and Figure 6.6.

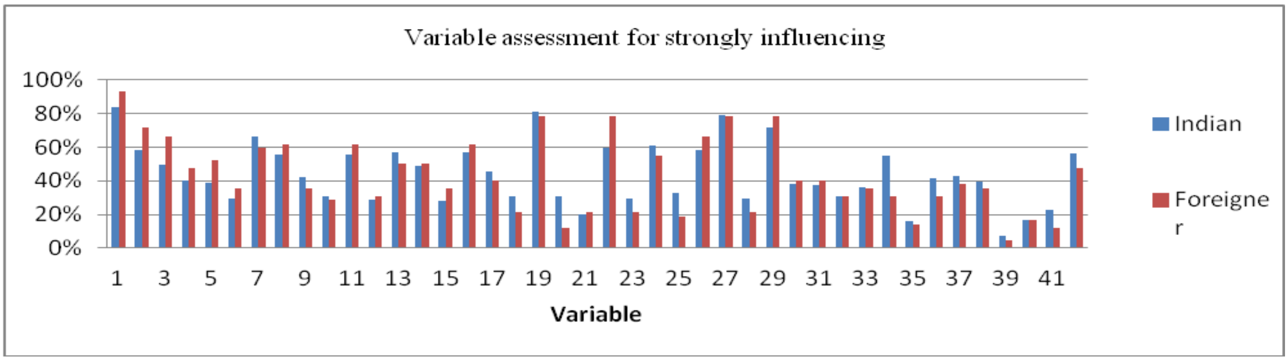

Fig. 6.5: Comparison of Respondent India V/S Foreign Participation

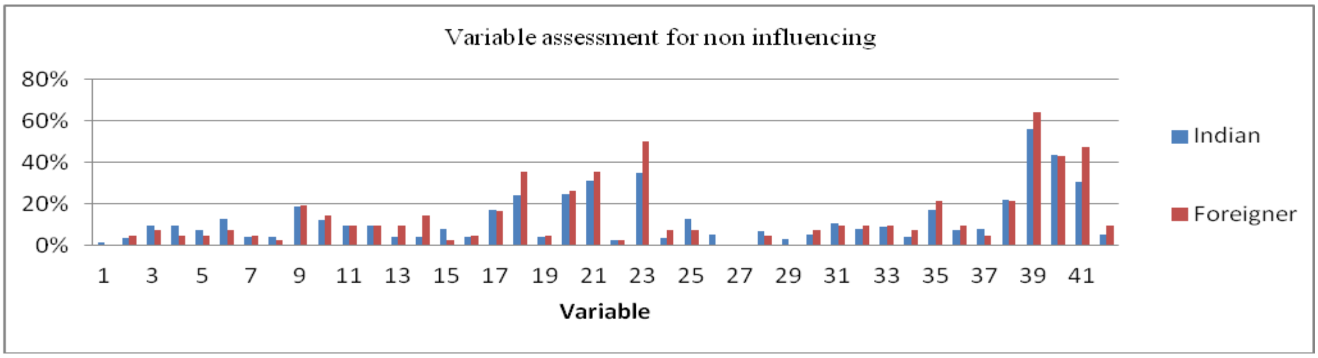

Fig. 6.6: Comparison of Respondent India V/S Foreign Participation

Observations on the response

Comparison of the response on the 42 indentified variables in the study has been as under:

(i) Both category of respondents shown high influence (more than 50% rating, above 6 on likert scale) of variables like policy, data in public domain, availability of technology, water requirement for fracking, disposal of saline water, cost of production of Shale Gas, large land requirement, land owner resistance, transportation pipelines, gas demand supply scenario, support from local authorities, land lease, environmental & forest clearance, political & NGOs interference, market driven gas pricing and judicial activism & PILLs.

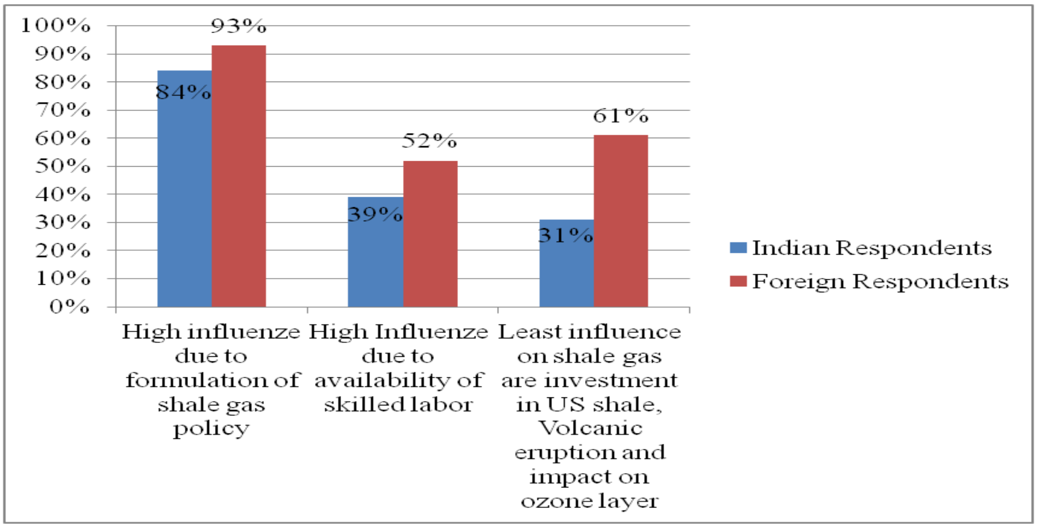

Fig. 6.7: Comparison of Respondent India V/S Foreign Participation

(ii) The higher score of above 70% respondents rating above 6 on likert scale is for policy issues, gas demand supply, support from local authorities, environmental & forest clearance and market driven gas price.

(iii) The most influential variables scoring above 84% response is the formulation of Shale Gas Policy where Indian respondent gave 84% influence and foreigner 93%.

(iv) The variable which are least influenced are the traits like exposure of work man to radioactive frac water, cost of housing, diversification of limited resources for Shale Gas exploration to affect conventional exposure, investment in US Shale acreages, volcanic eruption, traffic jam and impact on Ozone layer.

(v) The variables on which there is considerable variation of the opinion between Indian and foreign respondents relates to the trait like availability of skilled labor (39% of Indian respondents feel its influence whereas 52% of the foreigners feel its influence). On off shore Shale E&E, 55% of Indians as against 31% of foreigners feel its influence. Similarly for local support, 60% of Indian feels its impact where as 78% of the foreigner feel so. Similarly investment in US Shale Acreages less than 40% feel the influence where as more than 50% of the foreigners feel its impact. On the whole there is no significant variation in the responses of Indian and foreign respondents.

Thus it is seen there is no significant variation in the responses of Indian and Foreign respondents except for perception based on their experience.

6.7 Framework for effective Shale Gas E&E in India

To capture the findings of this research study and other inputs gathered during the course of conducting this study, a conceptual frame work has been designed with a view to implement the inputs for gainfully achieving the success of Shale gas E&E in India. This framework is, in fact the extract of the practical aspects found from this research study. However as the time passes, some of the actions would have taken different shape than the one envisaged in this framework, therefore there would be a need for partial modification of this framework, but the basic structure would remain same.

6.7.1 Premises for Establishing Framework

Following are the basic premise on which a theoretical framework for implementation of Shale Gas E&E in India is developed:

(i) All input from objective- 1 and -2 are considered for development of a conceptual theoretical framework.

(ii) The framework will integrate regulators and policy makers on the one hand with the stakeholder on the other hand.

(iii) The stakeholders need to absorb technology, process and other innovation through diffusion of innovation process.

(iv) The academia need to support through capacity building for skill development and establishing center for excellence.

(v) The Government is to notify shale gas policy which should be conducive to global participation of IOCs / MNCs and other private players.

(vi) The framework is devised keeping in mind the short term measure which can be implemented with existing structure of policy making and regulations. The long term measures will need some structural changes in the policy and regulatory (upstream) system.

(vii) Short term measures:

(a) DGH, remaining as a part of the Govt. may be augmented with a group dedicated for data acquisition on shale plays and putting such data in public domain before bidding can start

(b) DGH to have another group dedicated for single window clearance for land acquisition, environment, forest and defence clearance

(c) The gas pricing policy as approved by the cabinet may continue as recommended for five years

Note: Framework with short term measures, will appear as placed at Figure 6.8)

(viii) Long term measures:

(a) DGH to be made independent as upstream regulator

(b) The single window clearance to be a part of the Government (through Ministry of petroleum and Natural Gas).

(c) The gas pricing to be fully de controlled and left to the market forces to decide.

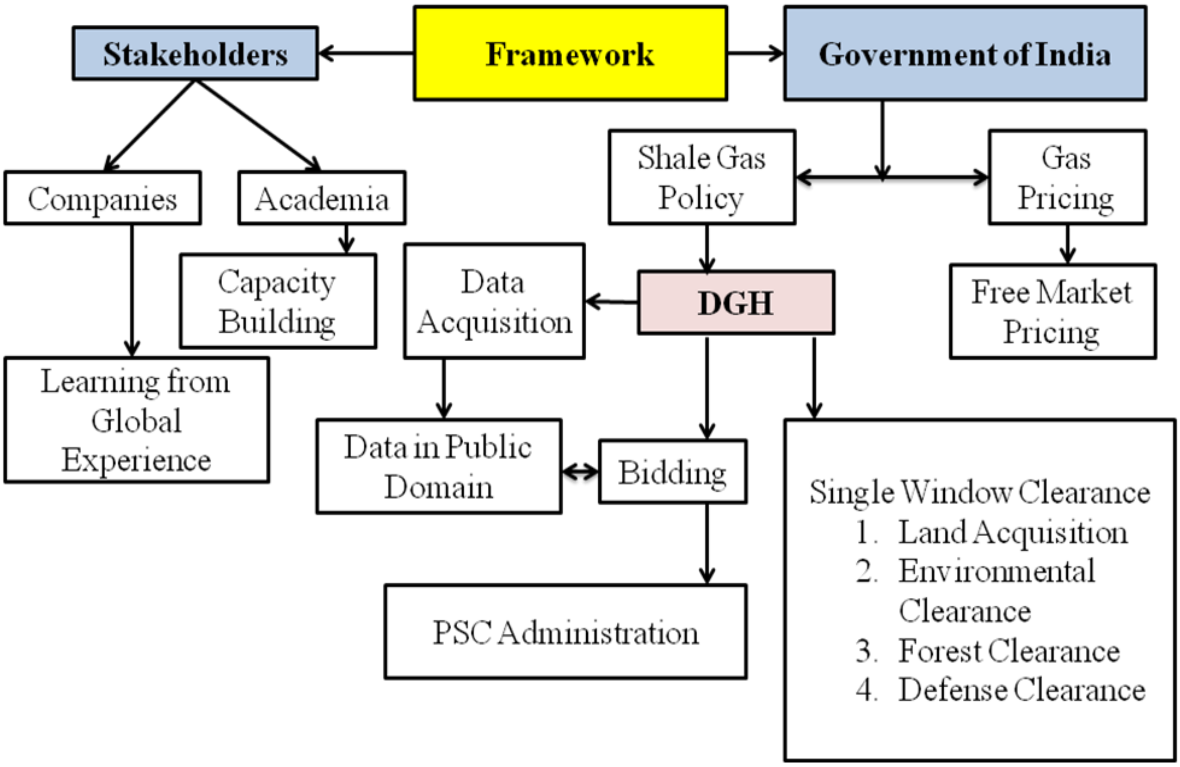

Fig. 6.8: Conceptual Framework for India for Effective Implementation of Shale Gas E&E

6.7.2 Action Plan for implementing framework

Stakeholders and Government are the two main arms of the framework. Stakeholders comprise of the Companies (owners, operators, service providers), Public (land owners, gas consumers) and Academia (to create capacity including R&D) and the Government (includes policy makers and regulators). Action plan will therefore include the actionable points for all these bodies/entities.

(i) Government of India has to take the following actions

(a) Develop a shale gas policy which will be regulated by DGH

(b) DGH has to be given the powers for data acquisition and for issuing licenses (through competitive bidding) under PSC regime

(c) Single window clearances on land acquisition and acquiring environmental , forest and defense clearances

(d) Ensure that the Gas prices are market determined

(ii) Various stakeholders such as Organizations, Public and Academia also need to act;

(a) Organizations should adopt best practices from the industry forerunners, and should be open for technology adoption

(b) Academia should create capacity (Engineers and Craftsmen) invest time and efforts in R&D and should start the Center of Excellence in Shale Gas

(c) Public/ land owners should have awareness of the Shale gas E&E program and co operate to achieve a win- win deal for all stakeholders including the environment.

6.8 Implementation of framework leads to solving Business problem

Following illustration shows that the implementation of he proposed framework will achieve solving the business problem to a large extent.

i. All studies (Hydrocarbon vision 2025, integrated energy policy 2006, working group 12th & 13th plan, IEA/ EIA 2004) indicate that Indian gas market will continue to grow and has high appetite for gas and will remain supply driven.

ii. During 2012, 14.4 bcm of gas was imported (constraint only due to LNG re-gas facility) against a domestic production of 40.2 bcm, an import of 35.8% (BP Stats 2013).

iii. By the year 2035, the natural gas import is expected to rise by 573% over 2012 (BP Energy Outlook 2035), which makes the import burden to 82.512 bcm or 58.7 mmtpa of LNG.

iv. This much gas can be produced with 57Tcf of Shale gas assets (on a 20 years profile for the Shale plays). This is less than the least Shale reserves estimated for India. Thus the production of shale gas will substitute this import to the extent it is produced in India.

v. India may expect a shale gas galore and may even plan for natural gas export which is a viable option as India has gas starved neighbors like Japan, South Korea and Taiwan.

vi. The weighted average price of long term LNG import to India (7.5 mmtpa from Qatar (P=$12.67%B), 1.35 mmtpa from Australia (P=$14.5%B) and 5.8 mmtpa from US (P=$ 1.15H+3) give a weighted average landed price at $12.82/mmbtu (where, P=LNG Price in $/mmbtu, B=Brant Crude price in $/bbl and H=Gas price at Henry Hub, Shipping charges ex Qatar 0.30/mmbtu, Australia $0.75/mmbtu and ex US $2.5/mmbtu).

vii. The landed cost of LNG to cope up with 82.512 bcm gas will be $14.65 b (Rs 87900 Cr) at crude prevailing price of $100/barrel.

viii. Such a foreign exchange saving is worked out at lower limit of the assumption of the LNG pricing. That means the indicated saving above is on the lower side and actual saving can be more.

ix. Further India can earn foreign exchange by Gas exports; India has high gas demand countries like Japan, South Korea and Taiwan as its neighbor.

x. The LNG pricing is assumed as weighted average of long term contract which may not be applicable to future contracts. LNG expected price in future will be more than this.

6.9 Limitations of the Study

The research is limited to Indian geography for the current status of the Shale Gas E&E. So, while the study has been done for the global scenario of Shale Gas E&E the thrust has been for corroborating such experience for lesson to be learnt for India. Global experience also being limited, the identification of the variables has been done based on such knowledge.

Analytical tools were used to identify the factors. The sample size validation and method validation have also been carried out. The results obtained are specific to the sample size undertaken in the survey and restricted to defined strata applicable to India. The results cannot be directly extrapolated or tweaked for another country. Similar study, if done, for other countries in the world may yield different results, as conditions may be different.

Research work in Shale Gas E&E is at a nascent stage in India. Very little literature is available on Shale Gas E&E in India. (In fact the present thesis is one of the seminal works on Shale Gas E&E in India). So there will be some learning curve for all the respondents of the survey. Different factors may gain importance about Shale Gas E&E in India, once the learning is incorporated.

Presently, there is very little official data available on the Shale Gas E&E in India. This research has used available, published data to do the analysis. Detailed study needs to be carried out, once official data on the Shale Gas E&E in India is made available by DGH or the PSUs.

6.10 Future Scope of the Study

Detailed research can be carried out in subsequent studies by other scholars to quantify each factor in the Logistic regression model to calculate the exact probability of the contribution of each of the factor in Shale Gas E&E in India.

Detailed study can be carried out to identify the achievable potential of each of the renewable energy resource, as they will be strong competitors to Shale Gas. Such a study will focus on India’s energy basket based on environmental and economic consideration.

As India has a large appetite for natural gas, four of the LNG import terminals are operating and 18 more are at different stages of implementation, a study can be undertaken to critically examine the imputed cost of Shale Gas produced in India Vis-a-Vis the weighted average cost of LNG imports.

6.11 Concluding Remarks

The study has identified Twelve factors – Techno-Social, Risk & Uncertainties, Technical & Service Support, Government Support (Local, State & Central), Causal effect of related Activities, Land Issue, Water related Issue, Transportation issue, Cost of production and collection of Shale Gas, Policy Issue, Population & Environmental Issue, Judicial/Market system that influence Shale Gas E&E in India.

These factors have both positive and negative influence on the program. A micro analysis of the study indicates that the following five factors act as major barriers. It is so, because until these factors are first addressed, Shale Gas E&E cannot be commercially implemented in India.

- Data in public domain,
- Government Support,
- Water related Issue,
- Policy issue
- Population and Environmental issue.

It is expected that once these factors are adequately addressed Shale Gas program implementation in India will be a success and thus the present research study has been able to achieve its objectives.

Appendix-A *(Ref. Page - 44)*

Paper Presented in National and International Conference

1. Indo-US Shale Gas Conference 2010, Delhi November, 2010 (organized by DEW), Keynote address in the Inaugural Session.

2. Shale Gas World- Europe 2010, Poland December, 2010 (organized by Terrapin), Paper Presented: "Shale Gas an Indian Scenario".

3. Shale Gas world-Asia, Global Conference June, 2011 Beijing China, (organized by Terrapin), Paper Presented: "Constructing an Evolving & Conducive Shale Gas Partnership Frame Work for International Co operation".

4. Shale Gas Conference 2011, Delhi, November, 2011 (organized by DEW), Paper presented: "Analysing Reasons for Slow progress of Shale Gas E&E in India".

5. Shale Gas World-Asia April, 2012 Singapore, Global Conference organized by Terrapin) paper Presented: "Policy issues in Shale Gas E&E in India".

6. Shale Gas Conference 2012, Delhi, December, 2011 (organized by DEW), Chaired a panel discussion on "Technical Issue Concerning Shale Gas E&E in India".

7. Addressing the Safety and Environmental issues relating to Shale Gas E&E - CIDM 2013 in Goa (organized by FICCI, PNGRB and NDMA) a presentation on a safety issue relating to Shale Gas E&E was made and the response on audience in respect to;-

   The possibility of volcanic eruption, seepage of frack water into the water table and the possibility of oil and gas seepage into adjoining area was addressed.

In view of fact that in India we do have any such experience as no tangible effort so far have been done for Shale Gas E&E. However, the experience of U.S. was explained in details to audience highlighting clearly the view and approach of proponent and opponent of Shale Gas E&E in U.S. The theme of GAS-LAND documentary wad also explained including the judgment of supreme court of Luciana and Pennsylvania wherein the rule in favors of:

(a) The manufacturer of fracking fluid upholding their rights in respect to non-disclosure of the formulation of the fracking chemicals which is their proprietary and patented items,

(b) Limiting the rights of the local municipality for carving the land use within their respective limits but not interfering in drilling and the other application of the land not reserved for specific application.

8. "Natural Gas Pricing in India- Availability, Accessibility and Affordability", presented and Published in the proceedings of India's Oil & Gas Review Summit (IORS) -2012" in Bombay (Authors Negi B.S., Dr Pahwa M.S., Ms. Surbhi Arora)

9. **"**Shale Gas Revolution- Is India ready"**-** presented during International Conference on Energy Infrastructure (ICEI) - PDPU Gandhinagar, Jan. 2013, published in SSRN. Communication received from the publisher is as under: Quote

"Dear Bhagwat Singh Negi:

Your paper, "SHALE GAS REVOLUTION – IS INDIA READY?", was recently listed on SSRN's Top Ten download list for: PSN: Environment (Topic). As of 02/07/2012, your paper has been downloaded 17 times. You may view the abstract and download statistics at: http://ssrn.com/abstract=1979726.

Top Ten Lists are updated on a daily basis. Click the following link(s) to view the Top Ten list for: any network, sub network, E-Journal or topic on the Browse list (reachable through the following link:

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Sincerely,
Michael,C.Jensen
Chairman
Social Science Research Network"

Unquote

10. Shale Gas Conference 2013, Delhi November, 2013 (organized by DEW), Chaired a panel Discussion on "

11. PETROCOAL World 2014, Delhi 15-17 Feb 2014 (organized by Energy & Environment Foundation), Chaired a session on Unconventional Hydrocarbons Resources - Shale Gas, CBM and CMM"

12. Conference on "India's Readiness for tapping Unconventional Hydrocarbon resources" organized by Infraline Energy on 13th March 2014, in Delhi.

Appendix-B *(Ref. Page - 112)*

Observation & Suggestion on Draft Shale Gas Policy

(*by B. S. Negi)*

A. General Observations

1. Shale Gas Pays Exploratory Data

The exploratory data from various Shale Plays are required for a competitive bidding. As of now we do not have enough data on most of our Shale plays. Shale oil/gas Policy therefore needs to define the time bound acquisition of field exploratory data indicating the "Sweet Spots" and the responsibility for such data acquisition as a project. The role of DGH shall have to be defined in the Policy frame work.

2. Shale Gas price

Whereas the draft policy suggests that the Shale oil can be sold as oil produced from conventional E&P blocks with import parity. The policy does not bring clarity in respect to marketing of Shale gas. It only states that the Shale Gas can be marketed as per Gas Pricing and Gas allocation policy of the Government. This is a negative factor because it neither gives the freedom to market nor it assures market driven price. This is very important issue as it has badly impacted the present gas production in India. Shale Gas normally has higher production cost as compared to CBM and gas from conventional E&P, therefore leaving the Shale Gas marketing issue an open-ended is not likely to encourage investment in Shale Gas Exploration & Exploitation (E&E).

Suggestion: *To begin with, producers should have freedom to market gas at arm's length at a price not less than the weighted average cost of domestic gas and LNG import price (other than spot cargos)*

3. While addressing Fiscal issue, the Shale Gas Policy needs to provide 7 year tax holiday as provided in CBM policy.
4. Shale Gas E&E has three kind of water management namely :

   (i) Preparation of frac water- requires huge quantity of water and small quantity of proprietary frac chemicals.

   (ii) Treatment of return frac water making it suitable for reuse.

   (iii) Partial treatment of return frac water making it suitable for discharging in river/nala/sea.

   The water management in Shale Gas E&E is very cost intensive and has high environmental impact. As mentioned in the Dft. Shale Gas Policy, the applicable provisions are the Water (prevention and control of pollution) Act 1974 but the same does not answer all these questions. It is therefore suggested that based on global experience, we carve out the process and parameters for all these issues. This would avoid any ambiguity in the minds of the bidders (specially the foreign bidders)

5. India has very high population density with highly fractured land holding pattern. This would make land acquisition a difficult task for Shale Gas E&E. A profit sharing provision for individual land owner in proportion to the area of their land acquired may provide a solution.

Suggestion: *Production sharing from Shale Plays may either be made as bidding condition with flat rate of production sharing mentioned in the bid document or it could be a biddable parameter (having the weightage of say 10% marks carved out 5% each from work programme and production sharing with the government or alternatively 10% marks carved out of production sharing provision alone)*

6. I have studied various issues/ aspects/ factors that influence Shale Gas Exploration and exploitation in India based on extensive literature review, deliberations in the conferences and discussions with the pears. A many as 42 of such aspects have been tabulated for further analysis in the form a questionnaire as a part of research study. This same is

attached herewith with the suggestion that these aspects may be considered while framing Model Contract.

7. Since the natural gas transmission pipeline network in India is quite inadequate to meet the requirement of collecting gas from large numbers of Shale Gas production wells, it therefore suggested to allow growth of unregulated gas gathering pipelines (on US pattern). Policy should therefore mention that the PMP Act shall be applicable to such entrepreneurs.

B. The observations on various sections of the draft policy are as follows

Sub section 2.2.4 –

The present policy though covers Shale oil and gas but we need to understand that the Shale Plays and conventional hydrocarbon deposits are more often located under the same earth surface. Till NELP- IX round of bidding almost 50% of the sedimentary basins have been awarded for E&P of conventional Hydrocarbon Resources. The policy should therefore address the issues of E&E of all basins for effective and efficient exploration and exploitation of Shale gas.

It is therefore suggested to attempt for a ***Composite Shale Gas Policy*** which will address the issues of Exploitation of hydrocarbon resources efficiently and economically.

i) The conventional E&P blocks which are already awarded to various entities if found to have Shale Gas resource, may be allowed to be exploited by the same lessee/contractor. The terms at which such exploitation should be allowed may be the one most favourable to the government (owner/lessor) obtained under the Shale Gas bidding round.

ii) The above suggestions is based on the premise that the Contractor/lessee/contractor is technically qualified since he has already been awarded E&P blocks and therefore he deemed to have met the technical requirement and the sole consideration should only be the, production sharing basis which should be based on the most favourable bids received during the bidding.

iii) Alternatively if a Shale Gas block found to have conventional reserve post award, the same contractor should be allowed to exploit such reserves. As a corollary of (ii) above, technical qualification shall be considered to have been met and exploitation of conventional H/C resource be allowed on the basis of production sharing of hydrocarbons (it is on the premise that the government will revise the condition of NELP bidding to the extent to get away with cost recovery parameter and award the block on the basis of highest production sharing bid. As a win-win situation the most favourable bid to the government on production sharing could be applied to such cases.

Sub section 2.5 - Sub Para iv -

a) The mandatory provision of multiple casing should extend a depth of a minimum 10 m below the bed of the bottom most fresh water aquifer.

b) The Annexure-I is supposed to deal with water management issue, therefore point (III) and (IV) of annexure-I need to be placed in Annexure - II and III respectively since Annexure-II deals with environmental issues related to water and Annexure - III deals with fiscal regimes and broad contract terms.

Sub section 2.6 -

Reference has been made to US Safe Drinking Water Act (SDWA), Water (prevention and control of pollution) Act 1974 and National Environment Policy Act, 2006. Whereas the SDWA and National Environment Policy Act are the provision of US Government and Water (Prevention and Control of Pollution) Act, 1974 refers to India. Therefore it is suggested that reference to US provision may not form part of the Indian Shale Gas Policy and the provision of Water Prevention and Control of Pollution Act, 1974 may only be mandated. The provisions of US policies may find suitable place in model Shale Gas E&E contract.

Subsection Para 3.3 -

Whereas the concept of suggested Integrated Shale Gas Policy finds an application in this Para but the new bid for Shale Gas for the blocks which are already awarded under conventional E&P, are likely to be very less and non competitive for the simple reason of coordination issues. Therefore even the allocation on first right of refusal basis to the existing contractor is going to be far from realization of actual value of natural resources to the government. Hence the suggestion at 2.2.4 above will be most practical.

Subsection 3.4 -

This provision is an extension of Para 3.3 with the rider that the block for which bids would be invited should only be in the exploration phase and the blocks which have entered in to development/production phase shall be excluded from the bidding for the Shale gas. This provision is self defeating because the incentive to the contractor will only be available if the resources potentials are established and development/production phase has started. Therefore it is suggested that the provision proposed at sub Para 2.2.4 above should override the provision at Para3.3 and 3.4

Subsection Para 6.1

Secretary MOPNG may have the role of member secretary in the empowered committee of the Secretaries. Also, there should be a provision of 2 technical domain experts from India other than Director NEERI.

Para 8.2

Effort should be made to reduce as minimum as possible the negotiable clauses in model contract. The idle Model Contract should have zero negotiable clauses.

Sub-Para 10.1 (v)

MOPNG to induct three domain experts (1 financial and 2 technical) for drafting model contract

Sub-Para 10.1 (vii)-

Observation same as offered under General Observation at (2). 1 Shale Gas price above.

Annexure-4 (Para 1)

The weightage for the work programme should only be the physical parameters and not the cost. The investment should only be indicated for reference.

(Para IV)- Net worth of the bidder should be indicated positive only without any quantifying amount. This is to avoid the discretion.

(B. S. Negi)

Former Member (Petroleum and Natural Gas Regulatory Board - India)

Cell No. 9810408999

Unquote

Note:* (Additional comments were also sent incorporating the views from industry experts on the basis of round table discussions and observations during conferences)*

Appendix-C *(Ref. Page - 151)*

Questionnaire

Influence of Various Issues / Aspects on Shale Gas Exploration in India

(Note: ***This information is purely for the purpose of research and will never be disclosed to anyone anywhere.*****BSN)**

Name__________________________________ **Designation:** ________________________

Gender: Male / Female **Age**________ yrs. **Mobile No.**___________________________

Organization: ___________________________ **Experience:** ________________________

Educational Qualification(s): ____

Please consider the following while filling the questionnaire:

Level of Agreement	Strongly Agree/ Influences	Agree/ Influences	Somewhat Agree/ Influences	Can't Say	Somewhat Disagree/ Non-influence	Disagree/ Non-influence	Strongly Disagree/ Non-influencing
Points	*7*	*6*	*5*	*4*	*3*	*2*	*1*

Note: Give points as per your level of agreement with respect to the following issues / aspects / attributes affecting Shale Gas Exploration in India by putting a tick **(** √ **)** mark in appropriate box..

	Particulars	**7**	**6**	**5**	**4**	**3**	**2**	**1**
1	Formulation of Shale Gas Policy in India							
2	Availability of adequate data in public domain to undertake Shale Gas exploration							
3	Availability of technology for Shale Gas Exploration in India							
4	Availability of equipments affecting Shale Gas Exploration in India							
5	Availability of skilled labor force affecting Shale Gas Exploration in India							
6	Experience of Indian E&P Companies in Shale Gas Exploration							

7	Requirement of huge quantity of water for fracking							
8	Disposal of saline, toxic, and waste water from Shale Gas wells							
9	Unexplored large acreages under conventional E&P in India.							
10	Geographical location of Shale Plays around insurgency prone areas.							
11	Cost of production of Shale Gas							
12	Shale Plays broadly identified in India have dense population living over.							
13	Exploitation of Shale Plays requires larger land acquisition.							
14	Resistance of land owners due to their rights limited to land surface							
15	Existence of smaller pipeline players (not requiring PNGRB Authorization) owning gas gathering Pipeline Systems.							
16	Adequacy of the Natural Gas Transmission Pipelines (requiring PNGRB authorization) to transport Shale Gas to Consumers							
17	Care for preparation and application of the fracking fluid which contains chemicals and carcinogens apart from water and sand							
18	Exposure to work force and local populate from the radioactive and other harmful materials associated with return frack water from Shale Gas bore							
19	Indian Gas demand supply Scenario							
20	Inflation of cost of local housing and services around drilling services							
21	Diversification of the limited resources for Shale Gas Exploration affects conventional exploration							
22	Support from local authorities							
23	Investments in US Shale acreages by various Indian companies affects investment in home country							
24	Interference by Political or NGOs affects Shale Gas exploration							
25	Public awareness about Shale Gas & its exploration.							
26	Lease for government land							
27	Environmental & Forest Clearance for Shale acreage							

28	Inclusion of " deposits before drilling" clause in upcoming Shale Gas Policy							
29	Market driven Gas pricing with transparency and without interference in India							
30	Introduction of moratorium on Shale Gas drilling in India.							
31	Number of wells drilling for Shale Gas exploration							
32	Rate of depletion of Shale Gas wells							
33	Uncertain rate of depletion of gas from Shale wells							
34	Cost of Offshore Shale Gas production							
35	Metal mobility due to acid formation from Shale exploration							
36	Cost of return frack water treatment making it suitable for recycling for fracking							
37	Partial treatment (dilution) of return frack water making it suitable to dump in local rivers							
38	Problems in casing, cementing and sealing may lead to natural gas or fracking chemicals seeping to contaminate local water table.							
39	Possibility of Volcanic eruption due to Shale Gas Exploration in India							
40	Exploration of Shale Gas creates heavy traffic movement in and around drilling area.							
41	Impact on Ozone layer due to more Methane escapes to atmosphere							
42	Judicial Activism and PILs in India							

Q.1. To best of your knowledge, which of the countries experience in Shale Gas Exploration and can be replicated in Indian context?

USA	Europe	China	Australia	None	Can't Say

Q.2. In your opinion which is (are) the most problematic issue(s) influencing Shale Gas Exploration& Exploitation in India?

____

____

Q.3. Please give your kind suggestions for implementing Shale Gas Exploration in India.

____

____

Appendix-D *(Ref. Page - 153)*

D-1 Variables Identified from the Literature Review

1. Shale Plays location around insurgency prone area
2. Preparation and Application of Fracking Fluids
3. Exposure to work force and local populate
4. Metal mobility
5. Problems in casing, cementing and sealing
6. Possibility of Volcanic eruption
7. Heavy traffic movement
8. Impact on Ozone layer
9. Introduction of moratorium on Shale Gas E&E
10. Number of wells drilling for Shale Gas E&E
11. Rate of depletion of Shale Gas wells
12. Uncertain rate of depletion of gas from Shale wells
13. Cost of Offshore Shale Gas production
14. Availability of Shale Plays data in public domain
15. Availability of technology for Shale Gas E&E
16. Availability of equipments
17. Availability of skilled labour
18. Experience of Indian E&P Companies
19. Support from local authorities
20. Lease for government land
21. Environmental & Forest Clearance
22. Public awareness about Shale Gas & its exploration
23. Unexplored Large acreages under conventional E&P
24. Inflation of cost of local housing and services around drilling services
25. Diversification of resources for Shale Gas exploitation
26. Investments in US Shale acreages by Indian companies
27. Inclusion of "deposits before drilling" clause in upcoming Shale Gas-Policy
28. Land Acquisition
29. Land Owners rights limited to Land Surface
30. Requirement of huge quantity of water for fracking
31. Disposal of Return Frac Water
32. Return Frack Water treatment
33. Natural Gas Transmission Pipeline
34. Cost of return frack water treatment
35. Cost of production of Shale Gas
36. Smaller Pipeline Players outside regulatory provision

37. Shale Gas Policy
38. Market driven Gas pricing with transparency
39. Dense Population over Shale plays
40. Interference by Political or NGOs
41. Indian Gas demand supply Scenario
42. Judicial Activism and PILs

D-2 Operating Definitions of the Variables found from Literature Survey

The operating definition of the variables found from literature survey is given in the Table 3.1, to give a common understanding and better clarity on what they mean. All these variables are independent variables (which load on 5 factors as shown in factor analysis chapter-4) with E&E of Shale Gas in India being the dependent variable

Table D.2.1 - Operating Definitions of Variables Identified through Literature Survey

S. No.	Components/Building Blocks/Variables
1	**Shale Gas Policy:** Is the basic policy document for bidding and award of the Shale Plays in India **ready?**
2	**Availability of Shale Plays Data in Public Domain**: To enable any prospective bidder to be interested in the E&E of Shale Gas in India, data relating to Shale Plays are the primary requirement.
3	**Availability of Technology for Shale Gas E&E:** Technology provides confidence to the bidders for undertaking new or frontier area of activities. This also helps in creating the confidence level for the investment.
4	**Availability of Equipments**: Shale Gas E&E is equipment intensive activities as secondary activities like fracking required to be done apart from large no of well drilling for Shale Gas exploitation.
5	**Availability of Skilled Labour:** Shale Gas E&E being new area the skilled work force is required.
6	**Experience of Indian E&P Companies:** Indian E&P companies mainly have exposure in conventional E&P. For undertaking Shale Gas E&E these company need to gain experience by participating in producing Shale place globally, or higher experience persona.
7	**Requirement of Huge Quantity of Water for Fracking:** Shale Gas E&E being unconventional exploration of hydrocarbon resources, for the secondary process like fracking huge quantity of water (varying from 1-7 million gallon per well) is required. In India water being scarce commodity and many of the expected Shale place do not have sufficient water for fracking.
8	**Disposal of Return Frac Water:** The Shale rock may contain various kinds of minerals, In addition the fracking fluid contains hundreds of chemicals thus return frac water is expected to be saline and toxic.
9	**Unexplored Large acreages under Conventional E&P**: Indian sedimentary basins is less than 50% explored so far, thus the opportunity to pursue conventional E&P in India.

10	**Shale Plays location around Insurgency Prone Area**: Indian track record of conventional E&P in the areas of insurgency has not been encouraging. To what extent this will get replicated for Shale Gas E&E.
11	**Cost of Production of Shale Gas:** The Shale Plays being both a source rock and a reservoir, even with secondary process like fracking the Shale Gas production rate is not comparable with the conventional well. Also a large no. of wells are required to be drilled to achieve production rte of a conventional well.
12	**Dense Population over Shale plays:** India being next to China for population density. Displacement of the people (if required – with new technologies Shale Gas exploitation could be undertaken with least displacement of the local populate) may be an issue to be address.
13	**Land Acquisition**: Land acquisition in India is a perennial problem in regard to unwillingness of the land owners for sparing their lands and also with respect to compensation. (To facilitate land Acquisition the Government of India has amendment the Land Acquisition Act in 2013)
14	**Land Owners Rights Limited to Land Surface**: Unlike in US, in India land owner right is limited to land surface. Any treasure including Oil and Gas found inside belongs to the government and therefore land owner has no interest to sell or lease his land for exploitation.
15	**Smaller Pipeline Players Outside Regulatory Provision:** As the number of wells for Shale Gas is too large and Shale Plays are too wide, the small dia pipeline from production well to Group Gathering stations and upto Transmission pipeline and to the injection point in Transmission pipeline constitute a large length of pipeline of such an activity is out source that will provide an incentive to new investor in such pipeline and ease out Shale Gas operator from this activity so as to concentrate on production side.
16	**Natural Gas Transmission Pipeline:** For a country like India the density of Transmission pipeline has just reached 4km/1000 km^2 and the pipeline have not reached to all expected Shale Plays.
17	**Preparation and Application of Fracking Fluids**: Fracking Fluids continue to be proprietary items thereby not disclosing the composition of chemicals it contains some of the chemicals are toxic or may be carcinogenic.
18	**Exposure to Work Force and Local Populate:** Preparation of fracking fluid, its application and handling of the return frac fluid have the chances for the work force and the local populate to get exposed to such harmful material.
19	**Indian Gas demand supply Scenario:** Various studies sponsored by the Govt. indicate that the Indian Gas demand will continue to rise and the domestic gas production may be just sufficient to meet 50% of the demand.
20	**Inflation of cost of Local Housing and Services Around Drilling Services:** This is as observed during various project implementations in India.
21	**Diversification of Resources for Shale Gas Exploitation:** Indian E&P sector is not yet robust. Undertaking Shale Gas E&E will result in Diversification of resources from conventional E&P to Shale Gas Exploitation.
22	**Support from Local Authorities:** For successful implementation of any project the local support plays a vital role.
23	**Investments in US Shale acreages by Indian Companies:** The intent of investment in US Shale acreages could either be business fit for commercial benefit or acquiring experience to imply in India or both.
24	**Interference by Political or NGOs**: This is of late has been on increase in India but is not replicating the effect of "GAS LAND' documentary of Jone Fox (US).
25	**Public Awareness about Shale Gas & its Exploration:** This may help Shale Gas E&E if properly disseminated.

26	**Lease for Government Land:** Time taken for lease agreement of government land has been quite high. Efforts are being made to improve upon the same.
27	**Environmental & Forest Clearance:** Time taken for environmental and Forest clearance has been quite high. Government is required to look in to this.
28	**Inclusion of "Deposits Before Drilling" Clause in upcoming Shale Gas-Policy**: This is in a way to have unrestricted exploration & exploitation activity as the payment having made will amount to unrestricted permission being available. However it will put financial burden on the explorer(s).
29	**Market driven Gas Pricing with Transparency**: India has seen various price regimes starting from APM to Pre-NELP (JV companies for Panna, Mukta, Tapti, Ravva, and Ravva satellite) to post NELP (PSC Regime), to LNG (long term contracts to Spot Cargo). How and when India to have fully market driven gas pricing.
30	**Introduction of Moratorium on Shale Gas E&E:** Possibility of India adopting the line followed by France for Shale Gas E&E.
31	**Number of Wells Drilling for Shale Gas E&E:** Normally, large number of wells is required to be drilled to optimally exploit Shale plays.
32	**Rate of Depletion of Shale Gas Wells:** Shale Plays being source rock and the reservoir as well; the well depletion rate is more than that of the conventional well.
33	**Uncertain Rate of Depletion of Gas from Shale Wells:** Since, there is no fix volume reservoir the geometry of the pores even after fracking remains quite uncertain
34	**Cost of Offshore Shale Gas Production:** US haS not so far tried offshore Shale production, Canada has only done on Experimental basis.
35	**Metal Mobility:** The fracking fluid dissolves some of the metal within Shale plays.
36	**Cost of Return Frack Water Treatment:** In view of the uncertainty of the Gas composition Inside the well vis-à-vis liquid H/C and the minerals, therefore the treatment of return frack water shall have to be almost a tailor made solution.
37	**Return Frack Water Treatment:** Depending upon the provision of the Govt. regulations the return frack water shall have to be treated to such norms, before dumping into the Nalas and rivers.
38	**Problems in Casing, Cementing and Sealing:** Shale Plays normally are located in the shallow depth. At certain locations, this depth may be in the vicinity of ground water table**.** In case the casing, cementing and sealing is not properly done it may lead to escape of gas/frack fluid to adjoining area.
39	**Possibility of Volcanic Eruption:** Due to the geological formation and fracking configuration there could be disturbances in and around Shale exploitation area.
40	**Heavy Traffic Movement**: Large no. of wells drilled, multi pass fracking carried out including other activities near Shale plays
41	**Impact on Ozone Layer:** The more the gas well drilling the more escape of methane takes place to atmosphere.
42	**Judicial Activism and PILs:** This has been latest trend in India, the judiciary and regulator in US has been favorable to Shale Gas exploitation.

Appendix-E *(Ref. Page - 154)*

Factor Analysis & Definition of Terms Used

Factor analysis is used to uncover the latent structure [dimension] of a set of variables. It is basically used for the data reduction purposes so as to get a small set of variables [preferably uncorrelated] from a large set of variables [most of which are correlated to each other]. It is also being used to reduce the data for the modeling purposes.

There are several different types of factor analysis that is basically used for the research purpose and they are as follows:

1. *Exploratory Factor Analysis [EFA]* seeks to uncover the underlying structure of a relatively large set of variables. This method is used when there is no prior theory and uses the factor loadings to intuit the factor structure of the data.
2. *Confirmatory Factor Analysis [CFA]* seeks to determine if the number of factor and the loadings of measured (indicator) variables on them conform to what is expected on the basis of pre established theory.

For the purpose of extraction of factors from a set of data there are various methods such as

i. *Principal Components Analysis [PCA]:* it is statistical analytical tool that is used to explore, sort and group the variable. It is generally used when the research purpose is data reduction [to reduce the information in many measured variables into smaller set of components.

ii. *Principal Factor Analysis [PFA]:* it is used to test specific hypothesis about the structure or the number of dimensions underlying a set of variables. It is also used to determine whether the number of factors and the loadings of measured variables on them conform to what is expected on the basis of pre-established theory. CFA is preferred when the research purpose is detecting data structure or causal modeling, as in structural equation modeling [SEM].

The researcher for the study purpose has used EFA as there is no prior theory on various factors which prevents or drives the implementation of Shale Gas E&E in Indian E&P industry. For the extraction purpose the researcher has used PCA as the study is to reduce the data from a large set of variables.

Methodology of doing Factor Analysis

Identification of Variables: the review of various literatures (as outlined in Chapter-2) coupled with interviews and group of discussions identified 42 parameters that could influence the Shale Gas E&E in India.

Designing the Questionnaire: The researcher designed a questionnaire with the identified variables on a Likert scale ranging from one to seven with seven being strongly agree and one being strongly disagree. This questionnaire was sent for pilot study to various people who have experience and exposure in upstream Hydrocarbon (in India and Abroad) for [using Cronbach Alpha] of the questionnaire. The reliability of the questionnaire was verified [using Chronbach Alpha] based on the responses received from the pilot study of the sample of 30 respondents. Cronbach's Alpha is a measure of internal consistency; it is commonly used as an estimate of the reliability of a psychometric test for sample of examinees. As the Cronbach's alpha value was satisfied, the researcher finalized the questionnaire for the study purpose [The value greater than 0.7 is considered to be highly reliable (Nually, 1978)

Sampling: In this study the questionnaire were given to Policy makers, regulators, E&P companies, Downstream & Midstream companies (both Public Sectors and private Sectors), Academia and Service providers in India and abroad. [With a total of 400 in numbers]. The researcher has used the stratified random sampling [strata: proportionate] for sample size of 336 (Yamane, 1967)

Data collection: Through online media, physically handing over (One to one), distributing in the conference and class rooms the questionnaire were administered to 400 respondents but the response rate was only 85% [341 response received], which compared to the similar studies is considered to be high (Rohdin, Thollander, & Solding, 2006) (Velthuijsen, 1995) (Ramirez, Patel, & Blok, 2005). This data was further analysed using the SPSS 16 software.

For the extraction purpose the researcher has used PCA as the study is to reduce the data from a large set of variables. The various statistic tools have been used in this analysis to reduce the data.

KMO Statistic: It predicts the sampling adequacy to check if data are likely to factor well, based on correlation and partial correlation, KMO varies from 0 to 1.0 and KMO overall should be 0.60 or higher to proceed with factor analysis (Kaiser & Rice, 1974). For example table 4.2 shows that the KMO statistic is 0.722 which shows that the sample size being considered for the study is adequate.

Eigen values: Eigen values measure the amount of variation in the total sample accounted for by each factor. A factor's Eigen value may be computed as the sum of its squared factor loadings for all the variables. Before the extraction, there were 41 linear components within the datasets and the Eigen value associated with each factor represents the variance explained by that particular linear component and SPSS also displays eigen values in terms of percentage of variance explained. For example in all 42 components are needed to explain 100% of the variance in the data. However, using the conventional criterion of stopping, 12 components account for 67% of the variance in the data. Hence, only 12 of the 41 factors were actually extracted in this analysis.

Scree Plot: The Cattell Scree test plots the components as the X axis and corresponding Eigen values as the Y axis. As the graph is plotted to the right, toward later components, the eigen values drop ceases and the curve makes an elbow toward less steep decline, this test says to drop all further components after the one starting the elbow.

Factor Rotation: Varimax rotation is the most common rotation method that is adopted in factor analysis. Each factor will tend to have either large or small loadings of any particular variable. A Varimax solution yields results which make it as easy as possible to identify each variable with a single factor. For example in Appendix I, the variables loaded into each factor is colour coded.

By using the factor analysis the 42 variables that influence the implementation of Shale Gas E&E in India, has reduced to 12 factors.

Procedure of Analysis through SPSS 16.0

Step 1: Access the main dialog box using analyze, selecting data reduction and choose factor menu path. Transfer the entire variable under study to the box labelled variables

Step 2: From the various options available from the box opened in step 1, select descriptive and check KMO and Bartlett’s test of sphericity to analyze the sample adequacy.

Step 3: From the various options available from the box opened in step 1, select extraction and opt for PCA, check correlation matrix in analysis, check Scree plot in display and extract Eigen values over 1.0.

Step 4: From the various options available from the box opened in step 1, select rotation and choose Varimax method. Also check rotated solutions and loading plots.

Step 5: From the various options available from the box opened in step 1, select scores and check on save as variables.

Step 6: From the various options available from the box opened in step 1, select option and check exclude cases pair wise. Run the box from step 1.

Definition of Terms Used

1. **Lithology:** is defined as the physical characteristics of a rock or stratigraphic unit.
2. **Micro-seismic Monitoring:** Monitoring technologies are used to map where fracturing occurs during a stimulation treatment and include such techniques and micro seismic fracture mapping. Micro seismic monitoring is the process by which seismic waves created during the fracturing of a rock formation are monitoring and used to map the location of the fracture generated.
3. **Play Fairways:** A stretch of ground (play) free of obstacles.
4. **Positivist (noun), or Positivism (adjective):** A philosophical system founded by Auguste Comte, concerned with positive facts and phenomena, and excluding speculation upon ultimate causes or origins.
5. **Shale Gas Storage in Shale Rocks:** shale Gas can be stored interstitially within the pore spaces between the rock grains or micro fractures in shale or it can be adsorbed to the surface of organic components contained within the shale rock.
6. **Shale Play:** the term play is used to refer to a geographic area which has been targeted for exploration due to favourable geo seismic survey result, well logs and production results from a new "wild cat well" in the area. An area becomes a play when it is generally recognized that there is an economic quantity of oil & gas to be formal.
7. **Stratigraphy:** is a branch of geology which studies rock layers (strata) and layering (stratification). It is primarily used in the study of sedimentary and layered volcanic rocks. Stratigraphy includes two

related subfields: lithologic stratigraphy or lithostratigraphy, and biologic stratigraphy or biostratigraphy.

8. **Sweet Spot:** To minimize risk of dry drilling the operators acquire and analysis surface seismic data before deciding where to drill. The sweet spots are the hydrocarbon rich pockets within Shale Plays.

9. **Wildcat Drilling:** A drilling industry term describing companies that look for oil & gas where other doesn't believe it is located.

Appendix-F *(Ref. Page - 193)*

Analysis of Qualitative Response in the Questionnaire

The Shale Gas questionnaire also had provision for qualitative response. This part of the questionnaire being optional, many of the respondents have refrained from giving their observations and some of the respondents have endorsed multiple choice/ option for their response. Against question no. 1 (**Which of the countries experience in Shale Gas E&E can be replicated in Indian context**) – 206 persons responded and the response are tabulated below:-

Table No. - 1

	USA	**Europe**	**China**	**Australia**	**None**	**Can't Say**
Response	97	7	40	11	40	27
Percentage	47	3.3	19.4	5.3	19.4	13.1

Which indicates that the maximum choice is for pursing US model 47%, followed by China 19.4% and similar no. (19.4%) have suggested the India should have its own model which should be high-bred type model suiting to Indian condition. Interestingly the European model happens to be the least choice at 3.3%.

The second question sought the respondents' opinion on most problematic issues influencing Shale Gas E&E in India. The respondent who gave their opinion in this category have been 184.

The Policy and regulatory issues has also been covered by many of the respondent under question 3 with specific observations like:-

(i) The policy should be investor friendly (4 respondents).

(ii) The policy to have the provision for allowing existing operator of E&P block be allowed to explore Shale Gas (5 respondents).

(iii) Policy to have provision for the first right of refusal to existing players pursing conventional E&P. (2 respondents).

(iv) Policy to provide level playing field to all players (2 respondents).

(v) The policy should minimize the Govt. role *(to give more power to regulator and PSC to be sacrosanct)* (2 respondents)

(vi) Policy to provide optioning of block with “Sweet Spot” (1 respondent).

(vii) Policy to attract foreign participation in technology and or investment (18 respondents). Since the foreign participation could also be under existing provision of the policies a separate head has been made for this.

The total number of respondents who had exclusively responded for such issues are 7 and other being common to question and question 3, the net number of respondents in this category becomes 191. Various issues highlight by them and the percentage are shown in the table below:-

Table No. – 2

	Environmental	**Technology**	**Water**	**Activism**	**Govt. Initiative & Support**	**Policy & Regulatory Frame Work**
Response	35	84	38	6	11	109
Percentage	18	44	20	3	6	57

	Good Fiscal Regime Moratorium for 7years	**Market driven gas price to producers**	**Dense Population**	**Land Acquisition**	**PPP Mode for Shale E&E**
Response	18	30	4	33	22
Percentage	10	16	2	17	12

	Skill Resources	**Gas Allocation Policy**	**Sensitization through Media**	**Clearances**	**Gas Evacuation Infrastructure**	**SHE**
Response	17	1	11	13	14	1
Percentage	9	0.5	6	7	7	0.5

	Legal	**Incentive to New Entrance**	**Drilling Infrastructure Augmentation**
Response	1	5	2
Percentage	0.5	3	1

The maximum indicates that the policy issues are the major importance (57%) followed by technology 44%. The water and environment concerned

20% and 18% of the priorities given by the respondent. The other concerned rather newer areas identify are sensitization of the populate through the media (6%) and inadequacy of the gas evacuation infrastructure (7%)

Question third asked for the suggestion for **implementing Shale Gas E&E in India**, the responses was provided by 121 respondents. The observations were further scrutinizes such that the issues stated at Sl. No. (i) to (vii) above have been clubbed with the response of question no. 2 and such stand alone respondents numbering 22 and existing for such respondents, the total respondent for question no. 3 thus remain 99. The suggestions with the numbers of respondents and the percentage shown in table below:-

Table No. - 3

	A few pilot blocks for Exploration, Data Acquisition	**National Workshop on Shale Gas Policy**	**Fast Action by Govt.**	**Indian should not pursue Shale Gas**	**Assets Acquisition in US**
Response	53	4	18	1	3
Percentage	54	4	18	1	3

	Attract US and Foreign Participation for technology and Investment	**Skill Development**	**DGH Hard Line Approach**	**R&D on PPP Model**
Response	28	13	4	1
Percentage	28	13	4	1

Majority of the respondents suggest "a few pilot blocks for exploration and data collection be commissioned (54%) followed by 28% of the respondents desiring" to attract US and foreign participation for technology and investment', next two suggestions are 'fast action by Government (18%), Skill development (13%).

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