UNIVERSITY OF LJUBLJANA
FACULTY OF ECONOMICS

MASTER’S THESIS

AN ANALYSIS OF NATURAL GAS MARKET IN INDIA AND THE PERSPECTIVES FOR FUTURE DEVELOPMENT

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AUTHORSHIP STATEMENT

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INTRODUCTION

The United Nations (hereinafter: UN) project that the earth's population will rise from 7 billion to 9.6 billion by 2050, which will automatically trigger a massive demand for energy (United Nations News Centre, 2013). The most fundamental challenge that lies ahead is provision of water, food and energy to the population for a sustained period. Energy is one of the critical issues among the three. Lot of discussion on energy across the world focuses on fossil fuels primarily, coal, oil and gas. The discussions solely revolve around the issues of availability, price and risk to the environment with the increased usage of all the three non-renewable sources of energy. In its report, Annual Energy Outlook – 2014, the United States Energy Information Administration (hereinafter: USEIA) (2014a, p. iii), stated that the world-wide demand for fossil fuels is increasing rapidly and at the same time known resources are diminishing. It is certain that energy is an important economic factor and that any shock to the supply or demand side is likely to have spiralling negative effects on the stability of the economic system. The challenge for many countries world-wide is to ensure a long-term supply of energy resources. This makes the energy sector a hot interest area for long-term investors.

In the periodical released by the Manhattan Institute's Centre for Energy Policy and the Environment (CEPE), Considine, Watson and Blumsack (2010, pp. 7-11) analyze the current technological advancement in the exploration of natural reserves, as well as their economic and environmental impacts. The improved drilling and production technologies, which were once thought uneconomical to produce, have unlocked large reserves of oil and natural gas in many developed nations. However, the risks, safety hazards and environmental impact have to be weighed against the economic benefits. The increasing population and the industrialisation have rapidly increased the consumption of these resources leading to accelerated production. Technically called hydrocarbon, burning of these fossil fuels pollutes the air. More profound usage of these three primary hydrocarbon fuels by the industrialised human societies results in huge carbon emissions.

Of the three fossil fuels natural gas is cleaner than coal and oil. The UN report also resounds that natural gas will have larger influence on climate change in the positive format. In the 2012 UN summit on climate change its President, Al-Attiya remarked that "a few years ago there was uncertainty about enough supply to the world. Today the gas will give the world 300 years of security. I believe this is good news and it will give the consumer more trust in gas" (King, 2012). The World Energy Outlook 2012 report of the International Energy Agency (2013) predicts a **golden age of gas**. It focuses on the key role played by natural gas in achieving a nation's clean energy future.

Over the past two decades the global demand for natural gas has sharply increased. The demand for natural gas is expected to rise due to the increasing need in energy production and the lesser environmental effects it has compared to other fossil fuels. The Ministry of

Petroleum and Natural Gas (2013a) (hereinafter: MOPNG) of the Government of India has stated in its official report, namely the Indian Petroleum and Natural Gas Statistics 2012–13, that natural gas has emerged as the most preferred fuel in India due to its greater fuel efficiency, cost effectiveness and environmental friendliness. The MOPNG has termed natural gas as the fuel of the twenty-first century. With increasing demand the natural gas industry is growing and globalising. A few decades ago natural gas was just a bit more than a waste product of the oil industry. But today it is the fuel of choice and is viewed as a major contributor to sustainable development.

The primary challenge is the sourcing of natural gas and the biggest technological challenge is the sustainable production from the sources for a longer duration. Soeder (2012), geologist in the US department of Energy, considered as a pioneer in natural gas research across the US, rightly remarked, “The amount of recoverable gas is always a fraction of the Gas in Place (GIP), under the assumption that 100 percent of the gas will never be recovered, even under the best of circumstances”. It is true that, 100% of any natural reserves identified can never be explored and utilized. The biggest technological advantage of today is maximizing production from the available resources in an economical and sustainable way. Currently, the production of natural gas from shale formations has created huge impact on the gas market in the US and Canada. The shale gas production is expected to greatly influence the volume and direction of global energy trade flows.

Hughes (2013) geo-scientist and fellow of post carbon institute, upon his research of unconventional fuels, primarily on shale gas for sustainable future, summarised that the US, which was the largest consumer of energy and a large energy importer is now moving towards becoming self-sufficient. In future the US will also export some of its surplus shale gas extracted. The exploration and production of natural gas from the non-conventional resources, such as shale gas, requires very huge investments and an infrastructure which posts a bigger challenge for developing nations like India. However, this is not true only for India. In an article in the periodical Energy Insights, Fischer (2013, pp. 31-33) briefs about the shale gas revolution in Europe. He argues that today most of European nations are dependent on Russian gas. The European nations face a huge challenge due to the severe economic crisis, which are therefore not investing in new natural gas reserves. Shale gas investments, exploration and research require very high investments for a longer period of time. Therefore, at this critical juncture due to the economic downturn, the future of energy security has been postponed by many nations.

India is also looking at various sources for exploring natural gas domestically to bridge its demand-supply gap. Batra (2013) forecasts, that the prospects for the increase in natural gas production of India from the conventional reserves are very high. Unfortunately, there have been many delays in decision-making and lack of better co-ordination between various government agencies, as well as the corporate sector. India is also looking into options for natural gas explorations from unconventional resources. However, Batra (2013) warns India to look before it leaps into new age gas explorations on unconventional resources. India with a huge population of about 1.2 billion is keeping all its options open, for example, the importing of cheaper Liquefied Natural Gas (hereinafter: LNG), signing agreements for trans-national pipelines from the Persian Gulf region, improving the existing domestic production and adding new discoveries of natural gas both from conventional and from unconventional sources such as shale gas, gas hydrates and coal bed methane.

Purpose of the thesis: This thesis shall analyze the current Indian natural gas market and the future prospects. This thesis starts with the understanding of the global energy demand and the important role of natural gas in contributing towards the energy requirements of various leading nations of the world. The thesis discusses the global perspectives of natural gas exploration, production, distribution and trade. These concepts are later narrowed down to the Indian context, understanding the current Indian technical, as well as business aspect of the natural gas business market. It points out the various shortcomings of the Indian natural gas market and the underlying reasons in the scarcity of the natural gas supply in India. It also analyses the importance of natural gas and the various alternatives that must be initiated by the government and other energy leaders for resolving the natural gas scarcity. The purpose of this thesis is to show the potential of natural gas, which is done through an in-depth analysis of the Indian natural gas business scenario, as well as to develop a roadmap for the future.

Thesis objective: The objective of this thesis is to have an overview on the important contribution of natural gas to the energy basket of the world. In order to better understand the technological and commercial part of natural gas sourcing, the thesis collates data and analyses the details of the various natural gas sourcing options across different regions of the world, identify the exporting and importing nations and deliberating the economic, as well as environmental impacts of natural gas exploration, production and trade throughout the world. Furthermore, India’s demand and supply of natural gas is analysed in depth, by interpreting various statistical data on the reserves, exploration, production, import, etc. The infrastructure for natural gas transportation across the Indian nation, the import facilities and modus-operandi are discussed. To conclude, the objective of the thesis is to identify India’s future natural gas energy prospects and to develop a noteworthy road map for future navigation.

Research methodology: This research is based on an archival strategy. As the principal source of data it uses administrative records and documents and inevitably, secondary data analysis. Although the term archival has a historical connotation, this thesis focuses on the most recent authentic data that is the binding factor in order to develop a more accurate and meaningful vision for India’s natural gas business.

The **first chapter** addresses the role of natural gas in the primary energy mix of the world. Apart from the understanding the usage and importance of natural gas as the clean energy, the first chapter of this thesis collate data to so understand the demand and supply projections and its skewed distribution across various regions of the world. In addition, this part also brings out overall global picture on natural gas trade movements across the globe.

The **second chapter** of this thesis is an in-depth analysis of the Indian energy basket and the contribution of natural gas to the energy security of India. It addresses the current Indian natural gas market, the sourcing, exploration, transportation, sale, distribution, pipeline infrastructure, import, pricing and specific governmental policies and regulations.

The **third and final chapter** of this thesis is a future perspective of the natural gas market in India. Based on the views of experts in the field of oil and gas collected from the internet, this part identifies various technological and commercial challenges of the development of India's natural gas business. It analyses the various conventional reserves and new, non-conventional natural gas resources of India and deliberates among the various options between the natural gas demand and supply gap. To sum up, this thesis is an in-depth analysis of the current, as well as future Indian natural gas industry, which is to develop a more appropriate road map in the natural gas contribution to the energy security of India in a sustainable way.

The main **research questions** on the future of Indian natural gas market discussed in this thesis are:

1. What role natural gas market plays for the **energy security** for India? Both current and future scenario.
2. Does India have the domestic natural gas **sources** or whether it is dependent on imports?
3. How productive are the domestic sources? Does **technology** prevail for rich yield of gas from the domestic sources?
4. Will **shale gas explorations** be successful in India?
5. Does India have plans for necessary **pipeline and gas transportation** infrastructure to cater for future natural gas market?
6. Are there **specific policie**s (both internal and foreign) with India for natural gas exploration especially with respect to unconventional sources such as shale gas, gas hydrates, coal bed methane?
7. Can India source required quantum of natural gas from imports? Could it get cheaper gas especially **LNG**?
8. How politically sensitive is the issue of **trans-national pipeline** from Persian gulf region?
9. How **sustainable** is the natural gas market of India?

1 OVERVIEW OF NATURAL GAS MARKET

1.1 World energy mix

Today the world is faced with an unprecedented uncertainty in energy sector. The basic challenge that underlies the global economic growth and human development is fundamental requirement for reliable, affordable, clean and secure energy supplies. The World Energy Issues Monitor 2014 (World Energy Council, 2014, pp. 6-7) discusses the challenges faced by today's energy leaders. The three main challenges of energy security, energy equity and environmental sustainability are referred to as the "energy trilemma". The primary hurdle of economic development faced by the elected governments and policy makers is creating a framework that simultaneously delivers a secure, affordable and environmentally sustainable energy system. So they have to make daunting and critical decisions in developing energy sources and expand the infrastructure for the delivery of energy from the source to the consumer. Amidst all challenges and bottlenecks in sourcing and distribution, the aptitude for energy consumption is on a constant rise. In comparison to 2012 there was a net increase in energy consumption in 2013.

Table 1. Cumulative primary energy consumption of the major countries and regions in the world in 2009–13 in million tonnes oil equivalent (mtoe)

Countries (regions) / Year	2009	2010	2011	2012	2013	Index: 2013/2012	Share in 2013 (in %)
	Consumption in million tonnes oil equivalent						
Regions							
North America	2690.4	2778.4	2779.7	2723.4	2786.7	102.3	21.9
South & Central America	592.0	616.4	640.5	656.9	673.5	102.5	5.3
Europe & Eurasia	2839.1	2948.8	2932.3	2942.6	2925.3	99.4	23.0
Middle East	679.7	714.4	737.1	764.4	785.3	102.7	6.2
Africa	372.4	389.4	386.7	402.4	408.1	101.4	3.2
Asia Pacific	4152.3	4508.2	4755.1	4993.5	5151.5	103.1	40.5
European Union	1691.2	1752.8	1691.2	1685.5	1675.9	99.4	13.2
Countries							
US	2205.9	2284.9	2265.4	2208.0	2265.8	108.9	17.8
China	2104.3	2339.6	2544.8	2731.1	2852.4	104.4	22.4
India	483.8	510.2	534.6	573.3	595.0	103.7	4.7
Total World	**11325.9**	**11955.6**	**12231.5**	**12483.2**	**12730.4**	**101.9**	**100.0**

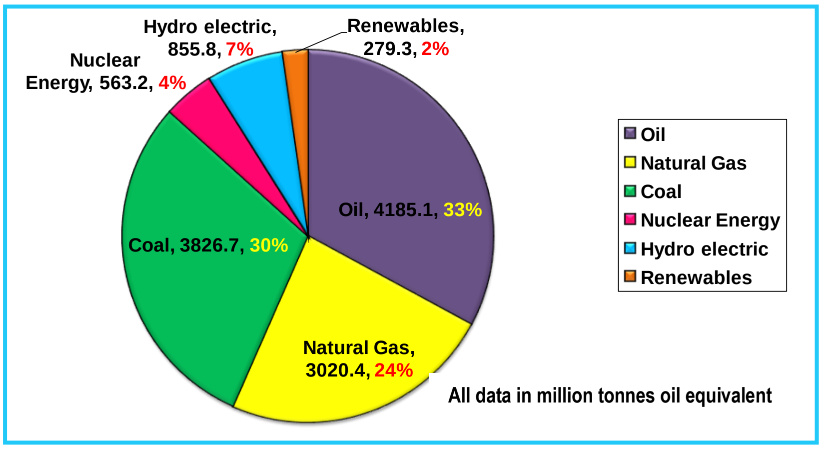
Note: In this review, primary energy comprises commercially-traded fuels oil, natural gas, coal, nuclear energy, hydroelectricity and modern renewables used to generate electricity.

Source: BP[1], *BP Statistical Review of World Energy*, 2014, p. 40.

[1] BP stands for M/s. BP Plc. referred by its former name British Petroleum, is a British multinational oil and gas company, headquartered in London.

The BP Statistical Review of World Energy 2014 (BP, 2014, p. 2), reports acceleration in the growth of global energy consumption despite stagnant global economy. Table 1 highlights in brief the net energy consumption of different regions of the world and some specific countries. There is a net increase in energy consumption in the world, primarily attributed to the increased energy usage in the US and China. Contrarily, the energy consumption in Europe declined in 2013 when compared to 2012. The energy consumption of India, having an ever increasing population increased in 2013 over 2012. India still not being able to quench its thirst for energy and was driven by scarcity. The complete table showing the primary energy consumption of all the regions and the countries is placed in Appendix B. The BP report also specifies the major fuels contributing towards this primary energy production are coal, oil, natural gas, hydroelectric, nuclear and renewables (BP, 2014, p. 41). Figure 1 represents the world energy mix in terms of primary fuel.

Figure 1. The structure of the world energy consumption in 2013 in terms of the primary fuel (volume in mtoe and share in %)



Source: BP, *BP Statistical Review of World Energy 2014*, 2014, p. 40.

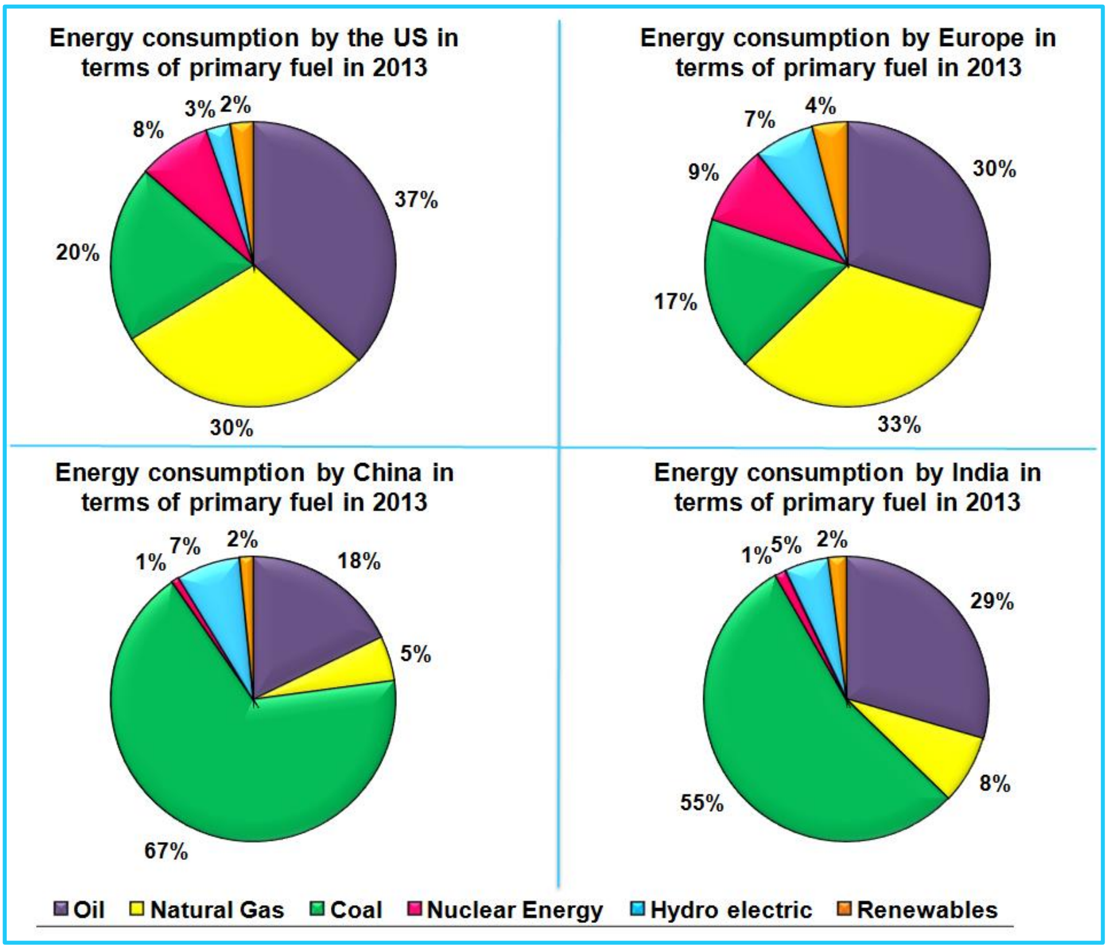
Table 2. Energy consumption of the US, Europe, China and India in 2013 in terms of the primary fuel in mtoe

Countries	**US**		**Europe**		**China**		**India**		**World**	
Primary Fuel	Volume in mtoe	Share in %	Volume in mtoe	Share in %	Volume in mtoe	Share in %	Volume in mtoe	Share in %	Volume in mtoe	Share in %
Oil	831.0	36.7	878.6	30.0	507.4	17.8	175.2	29.5	4185.1	32.9
Natural gas	671.0	29.6	958.3	32.8	145.5	5.1	46.3	7.8	3020.4	23.7
Coal	455.7	20.1	508.7	17.4	1925.3	67.5	324.3	54.5	3826.7	30.1
Nuclear energy	187.9	8.3	263.0	9.0	25.0	0.9	7.5	1.3	563.2	4.4
Hydroelectric	61.5	2.7	201.3	6.9	206.3	7.2	29.8	5.0	855.8	6.7
Renewables	58.6	2.6	115.5	3.9	42.9	1.5	11.7	2.0	279.3	2.2
Total	**2265.8**	**100.0**	**2925.3**	**100.0**	**2852.4**	**100.0**	**595.0**	**100.0**	**12730.4**	**100.0**

Source: BP, *BP Statistical Review of World Energy 2014*, 2014, p. 41.

Table 2 shows that in 2013, oil as a primary fuel has contributed to approximately 32.9% of the total energy consumption of the world. In the US oil contributed to 36.7% of the total energy consumed, while Europe was dependent on Russian gas. Natural gas in Europe contributed to 32.8% of the total primary energy consumption. Coal was the fastest growing fossil fuel in China and India as they have huge coal reserves and the majority of their power generation is dependent on coal. Coal as a primary fuel contributed to 67.5% and 54.5% of the total primary energy generated in China and India respectively. The renewables accounted for 2.2% of primary energy consumption of the world. Europe topped the list among the nations in contribution of renewables to the primary energy consumption accounting for 3.9% of the share of the total energy. This indicates the robust policy on the renewables adopted by the European Union. Figure 2, gives the pictorial representation of data of Table 1.

Figure 2. The structure of energy consumption of the US, Europe, China and India in 2013 in terms of the primary fuel in mtoe



Source: Adapted from Table 1.

The energy production in 2013 was also majorly impacted by geo-political events across the world. This consequently created an impact on the production of primary fuels, as well as their trade supplies. Oil production dropped in the middle-east. From Table 3 it is seen that oil production from the Organization of the Petroleum Exporting Countries (hereinafter: OPEC) declined in the face of renewed civil unrests. The production of oil and gas in 2013 was disrupted in a number of other countries as well. In the face of these disruptions and heightened risks to supply, average oil prices exceeded 100 US dollars (hereinafter: US$) per barrel (BP, 2014, p. 15). The supply disruptions forced policy makers across the world to rethink the strategies to strike a right balance between policy framework and market forces.

Table 3. Cumulative oil and gas production in countries and regions in 2012 and 2013 in million tonnes

Countries (regions) / Year	Oil production				Gas production volume			
	Volume in million tonnes		Index: 2013/ 2012	Share in 2013 (in %)	Volume in million tonnes oil equivalent		Index: 2013/ 2012	Share in 2013 (in %)
	2012	**2013**			**2012**	**2013**		
US	394.1	446.2	113.2	10.8	620.8	627.2	101.0	20.6
Canada	182.6	193.0	105.6	4.7	140.4	139.3	99.2	4.6
North America	720.6	781.1	108.3	18.9	812.4	817.5	100.6	26.9
South & Central America	374.7	374.4	99.9	9.1	156.8	158.7	101.2	5.2
Europe & Eurasia	837.7	837.5	99.9	20.3	925.3	929.6	100.5	30.6
Middle East	1342.1	1329.3	99.0	32.2	490.9	511.4	104.2	16.8
Africa	445.0	418.6	94.1	10.1	194.7	183.9	94.4	6.0
Asia Pacific	399.8	392.0	98.0	9.5	436.4	440.1	100.8	14.5
China	207.5	208.1	100.3	5.0	96.4	105.3	109.2	3.5
Russian Federation	526.2	531.4	100.9	12.9	533.1	544.3	102.1	17.9
India	42.0	42.1	100.2	1.0	36.3	30.3	83.5	1.0
Libya	71.1	46.5	65.4	1.1	11.0	10.8	98.2	0.4
Total World	**4119.8**	**4132.9**	**100.3**	**100.0**	**3016.6**	**3041.3**	**100.8**	**100.0**
OPEC	1776.3	1740.1	98.7	42.1	-	-	-	-
Non-OPEC	1670.3	1711.6	102.5	41.4	-	-	-	-
European Union	72.9	68.4	93.9	1.7	133.1	132.1	99.2	4.3

Source: Adapted from BP, *BP Statistical Review of World Energy*, 2014, p. 8 for oil and p. 22 for gas.

Table 3 shows that the front-runner to escape the global energy recession was the US. The year 2013 saw the US as the country with the largest increase in oil production in comparison to previous years. This is the result of massive investments made in the last decade by the US government and companies in research, development, exploration and production of oil and gas from unconventional resources, primarily “shale” and other “tight” oil formations. These new supplies offset the numerous disruptions seen elsewhere. The complete table of oil and gas production in the years 2012 and 2013 for all the countries and their regions is placed in Appendix C.

1.2 Natural gas overview

Today, natural gas is a vital component of the world's supply of energy. Natural gas is one of the cleanest and most abundant energy fuels available, and can be supplied more reliably for a longer duration of time. In today's world energy mix, the power generation and transportation sector have shifted from oil, which used to be the pioneer fuel, to natural gas. The most obvious reason attributing to this drift is pricing while other major reason are geo-political events occurring in the region of the middle-east, leading to frequent supply disruptions. Alexander Medvedev, Deputy Chairman of the Management Committee of Gazprom and Director General of Gazprom Export, regards natural gas the pioneer fuel (Gazprom, 2012b):

- a source of heat, power and transportation that is clean, plentiful and reasonably priced,
- an energy source that is readily available in global markets today,
- an energy source that has accessible resources to provide a stable and secure supplies well in the future.

Most countries today consume natural gas in both, domestic and industrial sectors. The domestic requirements consist of the use of natural gas for cooking appliances and space heating in certain countries during the winter. Fertilizer plants use natural gas as raw material for their fertilizers produced while power plants use it as fuel. Few industries use it as raw material for producing several petrochemicals. The power sector is the largest consumer of gas, constituting around 40% of global gas demand as the fuel contributes to even small incremental power demand for short span of time. The use of natural gas varies among countries depending on availability and the sourcing of the gas (International Energy Agency, 2014a).

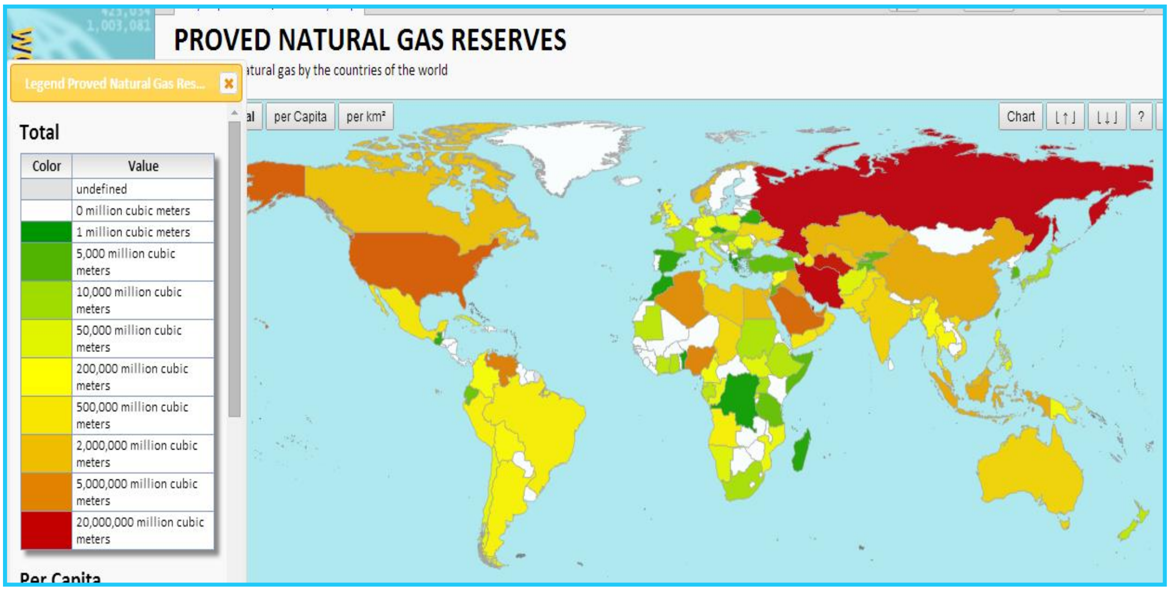
The importance of natural gas is rising exponentially. The natural gas transportation through pipelines and, as LNG by carrier ships has revolutionised the global trade markets. Natural gas is seen as the dominant fuel of the future by 2035.The main impediments in this race are media speculations and certain communities of environmentalists branding natural gas as a "dirty" hydrocarbon, adding to the carbon footprint. But to decarbonise the entire universe by curtailing hydrocarbon usage reduces the choice of renewables and other un-conventional sources. The availability of such resources in large quantities which would be devoid of hydrocarbon and would be used as the staple source of energy which would satisfy the increasing global population is very remote in the current energy world (Gazprom, 2012b). In the future, the contribution of hydro-electric, nuclear and renewable source of energy, such as solar, wind, tidal, geo-thermal etc., to the primary energy production was 13% in 2013 (from Figure 1). This shall increase with ongoing research and development and technological advancements. But still the energy production devoid of oil, coal and gas which occupies 87% of the total primary energy produced in 2013 seems far from reality.

Inspired by the decarbonisation theory the European Union (hereinafter: EU) derived the energy-climate package in 2008. The decarbonising of the EU to meet their 20–20–20[2] vision has another strategic reasoning. José Manuel Durão Barroso, the former Portuguese prime minister and the present President of the European commission adds another rationale to the debate. The perturbing cloud of uncertainty on the Russian gas supply through Ukraine is a stronger logical reason for the EU to adhere to the directives. The Ukrainian crisis provoked energy leaders to move towards renewables and other sources, looking into the continent's threat of energy security on the long run if they solely dependent on Russian gas imports. The leaders fear that each metre cube of gas coming from Russia is a political weapon. But to rebut the issue, Russia has stood by its commitment to Europe for more than 40 years and has continued supplies even during times of natural disaster and wars (Barroso, 2011, pp. 6-10). Many countries are moving in a strategic direction to secure energy access. Europe has prioritised renewables and other sources of non-hydrocarbon energy. The US has put on huge investments in shale gas. Russia already has a large amount of gas and is investing further for sustainable production. India is trying to explore all possible methods of achieving energy security.

1.2.1 Exploration and production

The natural gas explored today is millions of years old. Oil and gas commonly referred as hydrocarbons are a result of the transformation of organic matter under a specific temperature and pressure conditions millions of years ago.

Figure 3. Proved natural gas reserves and their volume in cubic metres in 2012



Source: Adapted from World.bymap.org, *Proved Natural Gas Reserves*, 2014.

[2] 20–20–20 vision has set three key objectives for the year 2020. (i) 20% reduction in EU greenhouse gas emissions from 1990 levels. (ii) Increasing the share of EU's energy consumption produced from renewable resources to 20% (iii) Improving EU's energy efficiency by 20%.

Based on geological survey data it is technically reckoned, that there is an abundance of natural gas reserves distributed all across various parts of the world. They are unevenly distributed across the world, in ancient sedimentary basins as can be seen from Figure 3 displaying the proven oil and gas reserves across the world. The BP Statistical Review of World Energy 2014 (BP, 2014, p. 20) features the data, as shown in Table 4. Few selected countries are shown in Table 4.

Table 4. The natural gas reserves and production of major countries of the world at the end of years 2003, 2012 and 2013 in tcm and their R/P ratio

Countries (Regions)	**Reserves in tcm* at the end of year:**			**Share in the total world reserves in 2013 (in %)**	**Production in 2013 (tcm)**	**R/P** Ratio**
	2003	**2012**	**2013**			
Iran	27.6	33.6	33.8	18.2	0.167	**202.8**
Russian Federation	30.4	31.0	31.3	16.8	0.605	**51.7**
Qatar	25.3	24.9	24.7	13.3	0.159	**155.7**
Turkmenistan	2.3	17.5	17.5	9.4	0.062	**280.3**
US	5.4	8.7	9.3	5.0	0.688	**13.6**
Saudi Arabia	6.8	8.2	8.2	4.4	0.103	**79.9**
United Arab Emirates	6.0	6.1	6.1	3.3	0.056	**108.9**
Venezuela	4.2	5.6	5.6	3.0	0.028	**195.9**
Nigeria	5.1	5.1	5.1	2.7	0.036	**140.8**
Algeria	4.5	4.5	4.5	2.4	0.079	**57.3**
Australia	2.4	3.8	3.7	2.0	0.043	**85.8**
Iraq	3.2	3.6	3.6	1.9	0.001	**5786.7**
China	1.3	3.3	3.3	1.8	0.117	**28.0**
Norway	2.5	2.1	2.0	1.1	0.109	**18.8**
Egypt	1.7	2.0	1.8	1.0	0.056	**32.9**
Kuwait	1.6	1.8	1.8	1.0	0.016	**114.4**
Libya	1.5	1.5	1.5	0.8	0.012	**129.3**
Kazakhstan	1.3	1.5	1.5	0.8	0.018	**82.5**
India	0.9	1.3	1.4	0.7	0.034	**40.2**
Netherlands	1.4	0.9	0.9	0.5	0.069	**12.4**
Pakistan	0.8	0.6	0.6	0.3	0.039	**16.7**
Ukraine	0.7	0.6	0.6	0.3	0.019	**33.4**
Syria	0.3	0.3	0.3	0.2	0.004	**63.9**
Bangladesh	0.4	0.3	0.3	0.1	0.022	**12.6**
UK	0.9	0.2	0.2	0.1	0.036	**6.7**
Total World	**155.7**	**185.3**	**185.7**	**100.0**	**3.370**	**55.1**

Note: * tcm stands for trillion cubic metres; ** Reserves-to-production (R/P) ratio – If the reserves remaining at the end of any year are divided by the production in that year, the result is the length of time that those remaining reserves would last if production were to continue at that rate.

Source: BP, *BP Statistical Review of World Energy*, 2014, p. 20.

Table 4 presents the total proved natural gas reserves of the world at the end of the year of 2013, which stood at 185.7 trillion cubic metres (tcm), reckoned as sufficient to meet 55.1 years of global production. Iran with 33.8 tcm and Russia with 31.3 tcm hold the world's top two proven natural gas reserves. Iran's reserves are reckoned to last for more than 200 years while Russian reserves should last for 51.7 years. The last column of Table 4 shows the reserves-to-production (R/P) ratio. The R/P ratio reveals the length of time that those remaining reserves should last if production were to continue at that same rate as today. The complete list of natural gas reserves and production of all the regions and countries of the world adapted from the data from BP Statistical Review of World Energy 2014 is placed in Appendix D.

Despite its abundance, natural gas is a non-renewable source and has taken millions of years to form. The understanding of the reserves and the exploration process are essential to know how difficult and expensive it is to drill kilometres into mother earth as accurately as possible to ensure rich harvest of gas in sustainable basis. A common misconception about natural gas is that it is going to extinguish and that it will not last longer. This is remarked as the natural gas paradox (Gazprom, 2012b, p. 5). The reasons for this belief are price spikes that occur intermittently, as the price rise is commonly attributed to the increase in demand and shortage in supplies due to the depletion of reserves. But sure to say this fact is far from truth. Research and development agencies, geo-technological institutes, reservoir studies scientists etc., are working hard to identify new sources, the quality and quantity of gas in it and to identify, as well as develop suitable technology to bring the reserves to the surface. A vast amount of natural gas is reckoned to be still underground. However, the advanced technology has drastically changed the older practice of identifying natural gas and petroleum deposits.

In the early days, the geologists search for surface evidences of seepage of oil and gas above ground land strata in order to identify the underground formations of oil and gas. This process of scanning each square area of land, searching for such seepages was difficult and inefficient. With the rising demand, scientists and technocrats understood the need for developing accurate methods of locating these deposits. Today with improved technology the success rate of locating natural gas reservoirs accurately is very high. The biggest breakthrough in petroleum and natural gas exploration came through the use of basic seismology. Seismology refers to the study of behaviour of energy in the form of seismic waves which moves through the earth's crust and interacts differently with various types of underground formations. Preliminary geological survey and seismic studies are only pilot studies which roughly estimate the quantity and longevity of the natural gas reserves. Nearly accurate inferences and estimation could be made when the drilling is carried out and commercial production commences. With new technologies, these estimates are becoming reliably more accurate (NaturalGas.org, 2014a).

Upon identifying the natural gas deposits, the drilling team and its experts drill down to the point where the reserves were predicted. The decision whether to drill a well or not, depends on a variety of factors but mostly it comes down to cost economics. It costs a huge amount of money for exploration and production companies to search and drill for oil and gas, besides there is always the inherent risk that no oil or gas will be found. Technology has aided to locate the reserves more accurately decreasing the risk factor considerably. Under-the-ground natural gas is not exactly the same as gas distributed to domestic and industrial consumers through pipelines. Commercially used natural gas is predominantly methane. During exploration natural gas is also associated with wide variety of other gases, components, oil as well as water. Similar to oil, natural gas is also processed to get rid of unwanted associates. The processing of natural gas is not as complex as the processing of oil, but it is a very important process. Natural gas processing involves removing of undesired hydrocarbon gases and fluids from the underground natural gas, in order to produce 'pipeline quality' dry natural gas. This ensures safe and smooth pipeline operation without internal corrosion on a longer run (NaturalGas.org, 2014a).

1.2.2 Transportation and distribution

The structure of the natural gas industry has changed radically in the last 15 years. The natural gas industry provides one of the cleanest burning alternative energy fuels (Wang, Ryan, & Anthony, 2011, p. 8196). Historically, the market was very simple, had limited flexibility and natural gas delivery options were very limited. The exploration and production companies sold their product at the well-head[3] to large transportation pipeline companies. These pipeline companies transported the natural gas through their long cross-country pipeline infrastructure and delivered to local distribution utilities as per their agreed terms, which finally distributed and sold that gas to its customers. The well-head prices and also the prices for the producers, transporters and distributors were regulated. All the activities were regulated by the government. Large transportation pipelines and distribution companies were monopolies and the market had no competition. The incentives to improve the service to customer and innovation were absent. However, this was the practice of the past.

In the past the natural gas market had a limited number of suppliers and there were only big, vertically integrated companies. Today, the industry has changed drastically. The liberalization of the natural gas market unregulated the activities of exploration, production and trade, as well as the supply to the consumer. These activities became market driven. However, the transportation and distribution remain regulated. Nowadays, the consumers have more choice. The market in many countries is open to more competition. Well-head prices are no longer regulated. The price of natural gas today is more dependent on supply

[3] Well-head refers to the component at the surface of an oil or gas well that provides the structural and pressure-containing interface for the drilling and production equipment. Here it is used with regard to prices which are at the source or at the well.

and demand interactions. Cross-country and inter-state pipeline companies no longer own the gas. They work on the common carrier principle. The transportation companies only lend their pipeline for transportation and earn the tariffs, as well as market margin. The pipeline transportation is still regulated all around the world by federal legislations. Local distribution companies continue to offer bundled products to their customers in order to attract them. Customers have the choice to purchase natural gas directly from the producers or from the local distribution companies. The basic difference in the current structure of the market in comparison to the ancient days is the presence of natural gas marketers. Marketers facilitate the movement of natural gas from the producer to the end user and the marketers act as the intermediaries between producer and end consumer. They facilitate the sale or purchase of natural gas and sometimes they are even contracted for transportation and storage. The marketers may own the gas or only lease out their storage outlets, depending on their contract understanding. Essentially, a myriad of different ownership pathways exist for natural gas to proceed from the producer to the end user. In India the well-head prices for natural gas are regulated by the central government. While the price of the oil is on par with international oil prices, the natural gas market is regulated (NaturalGas.org, 2014b).

LNG has added more impetus to the natural gas trade today. LNG is natural gas converted to liquid form for ease of storage and transport. The liquid takes up about a 1/600th volume of natural gas in the gaseous state. Liquid takes up less space than gaseous state, allowing easy, much more efficient shipment in higher volumes. It has properties similar to that of natural gas. The natural gas is condensed into liquid at close to atmospheric pressure by cooling it to approximately −162°C (Green & Perry, 2007). This is then transported through specially insulated road tankers and big LNG carrier vessels by maintaining maximum transport pressure set at around 4 psi. The use of LNG allows the production and marketing of natural gas deposits that were previously not economically recoverable. LNG transportation is a large market all around the world. Long term and shot term agreements between producers and users firm up the market.

1.3 Natural gas pricing and trade across the globe

Besides oil, the natural gas industry has also become an extremely important contributor to a country’s economy. In addition to providing one of the cleanest burning fuels, it also provides a much valuable commerce to the country. Economies with rich oil and gas resources have a great impact on the world’s oil and gas trade (Gandolphe & Dickel, 2002, p. 13). However the physical properties of gas make it more expensive to transport than other energy commodities. Historically, there was no international trading of gas while oil trading prevailed since the medieval period, when it was being transported in wooden barrels. Traditionally, natural gas was produced and consumed locally or regionally.

Kate, Varro and Corbeau (2013, p. 10) explain that there are primarily two ways to set up a wholesale price level for natural gas. The first option is market-based pricing and the second option is through government regulations. In the market pricing mechanism, the price of natural gas is determined by the demand-supply fundamentals. The demand-supply indexing does not necessarily relate to the natural gas market directly. The price indexation may be influenced by the behaviour of market forces in other energy markets such as oil, coal or even sometimes depend on changes in electricity trading markets. In simple terms the pricing is decided by the market forces not by governmental regulations. The second option of regulated or controlled price markets can be based either on a standard mathematical formula or other pricing index mechanisms of the government.

1.3.1 Pricing mechanism of natural gas

In traditional commodity markets, supply and demand are usually balanced by the price mechanism. The nature of the gas market is not exactly the same as other competitive commodity markets. In the gas markets, demand is not particularly flexible. The consumers invest in gas-fired equipment with a commitment to use natural gas as a fuel for a longer duration of time. They cannot change quickly to other fuels. Mostly residential and commercial domestic customers are practically unable to switch with ease to alternative fuels or alternative suppliers and distributors. These small consumers also cannot store gas like big industries. Hence, these small domestic consumers do not react easily to price changes especially during the increase of the price. In other words, these customers have a rather price-inelastic demand. On the other hand, industrial customers with power generation systems can easily switch, provided they have dual fuel options. The incentive to switch depends on the price of the alternative fuel. The investment for a dual fuel establishment is expensive. In the gas industry the supply-demand mechanism works under the primary principles of (Gandolphe & Dickel, 2002, pp. 10-15):

- increasing gas production to match demand,
- to have a buffer system to store gas during non-peak requirement to cater for the peak requirement,
- the third option is simply to reduce the supply if demand is not being able to be met.

Various markets adopt different natural gas trading practices. A natural gas trading hub is where the title of natural gas is exchanged between number of traders and buyers. The North American market trades natural gas openly like other commodities in the market. In the US, natural gas flows through various trading hubs having multiple natural gas prices. The main trading hub is Henry hub[4] in Louisiana. The Henry hub is the best functioning

[4] The Henry hub is a distribution hub on the natural gas pipeline system in Erath, Louisiana, owned by Sabine Pipe Line LLC, a subsidiary of Chevron Corporation. Henry hub was selected by New York Mercantile Exchange (NYMEX), as it is centrally located and sufficiently interconnected for exchange of natural gas ownership.

trading hub not only for the US but for the entire North America. Today in the US, natural gas prices are kept floating and the titles are traded in the stock market (Kate, Varro, & Corbeau, 2013, p. 36). There are many other regional trading hubs in the US, namely, Transco zone 3 natural gas price, Transco zone 6 NY natural gas price, Panhandle East natural gas price, Opal natural gas price, Marcellus NE PA natural gas price and Haynesville N.LA natural gas price (Quandl, 2014). These hubs trades natural gas at a price different than that from the Henry hub, taking into account the regional disparities and multiple overheads in production, transportation etc., relevant to that trading hub.

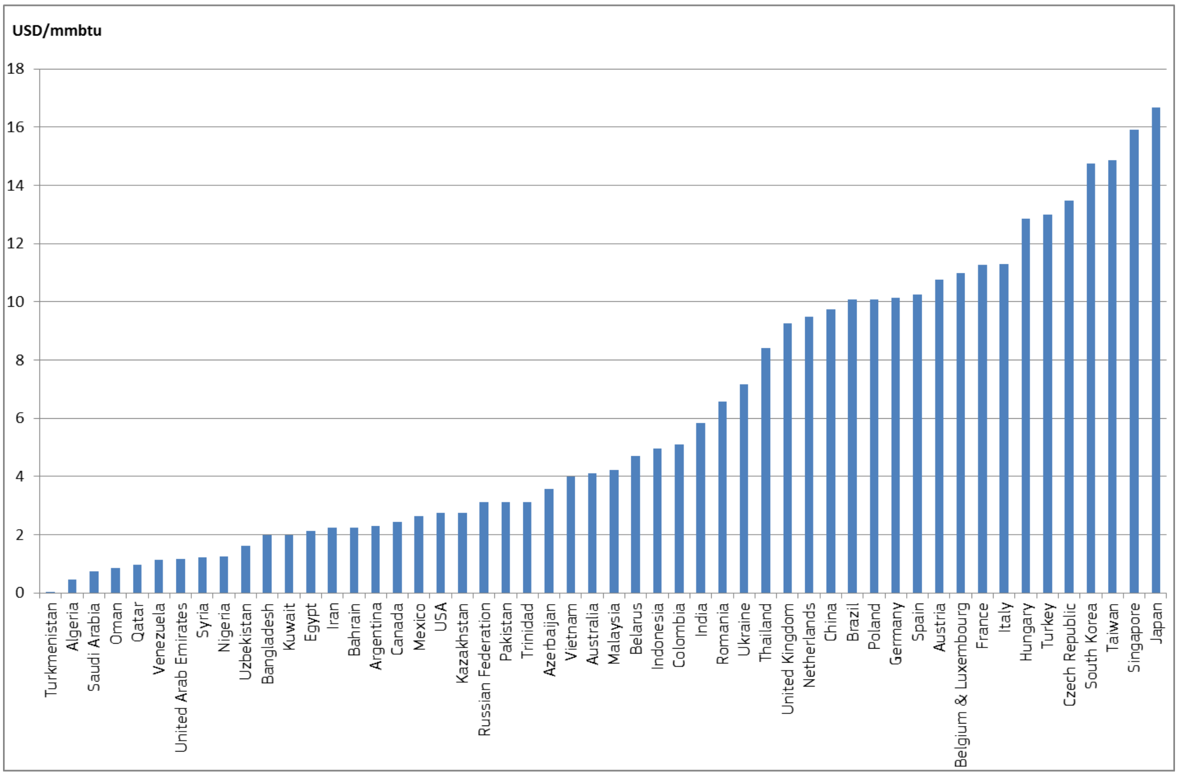
In Canada, the price of the gas is determined based on the local survey by the Department of Energy, of the Alberta Government. It fixes natural gas prices on monthly basis for the local consumers, based on a local survey of actual sales. The Alberta Natural Gas Reference Price (ARP) is a monthly weighted average field price of all gas sales in Alberta. ARP rates are set on a monthly basis in response to the changes in market prices and based on any balances or credits carried forward from previous months (Alberta Government, 2014).

The European market is driven by liquid hub prices, primarily by the UK NBP, Dutch TTF, the German NCG and Gaspool and the Belgian Zeebrugge. The National Balancing Point (NBP) is a virtual trading location for the sale, purchase and exchange of UK natural gas. It is the primary trading point of Europe and has a major influence on the domestic gas prices. The concept is similar to that of the Henry Hub in the US, but it differs as it is not a physical location. The Title Transfer Facility (TTF) is another virtual trading point for natural gas in the Netherlands. It is similar to NBP but trades within the boundaries of a Dutch network. Net Connect Germany (NCG), based in Ratingen and Gaspool Balancing Services based in Berlin are the virtual gas trading hubs of Germany. Zeebrugge is another virtual trading hub interconnecting the UK and Norwegian natural gas markets with the rest of the European countries. The Asian region is primarily dependent on LNG imports. The pricing of gas in this region is substantially high in comparison to the US and European hub prices (European Commission, 2014).

1.3.2 Natural gas pricing across the globe

A number of factors influence natural gas prices in the market, for instance storage levels, weather, pipeline capacity etc. The government, the regulators, distributors and utility companies do not have any control over the markets. Natural gas prices tend to be higher in the fall and winter months when colder weather increases demand and prices fall in the summer months when demand decreases. The lack of supply and a pipeline functioning under its capacity also result in price hikes during peak periods (US Energy Information Administration, 2013a). The European Commission’s working document on Energy Prices and Costs Report (2014) highlights that, the wholesale prices vary significantly among countries as shown in Figure 4. Contrarily, the variation in the international oil pricing is within a small range.

Figure 4. Wholesale prices of gas in major countries in 2012 (in US$/MMBtu)



Source: European Commission, *Commission Staff Working Document: Energy Prices and Costs Report*, 2014, p. 172, Figure 110.

According to the report, highest wholesale prices in 2013 were found largely in the LNG dependent countries in Asia Pacific, namely, Japan, Singapore, Taiwan and South Korea. Next in the ladder were European countries, such as the Czech Republic, Turkey, Hungary, Italy, France etc. The UK and the Netherlands have lower gas prices in comparison to the main gas importing countries in Europe, and even slightly less than China. Despite increase in gas consumption in the US and Canada, the prices are very low in comparison to Asia, Europe and Latin America. Spot prices in North American markets of the USA, Canada and Mexico remained lower than in a whole range of countries including India, Indonesia and Malaysia. The natural gas prices of the Russian Federation were marginally higher in comparison to those in the US. Only the prices in the Middle-East and Africa were lower than those in the North American market, as the government regulates the domestic prices of natural gas in these countries. The European commission report analyzes the factors attributing to the wide gap in natural gas pricing across different countries of the world. The report states that the widening gap has been driven by factors such as the US shale gas boom, increases in oil-indexed gas prices in Europe and the huge gas demand in Japan in the aftermath of the Fukushima incident. Even within the EU, there was significant difference between the lowest and highest wholesale gas prices. According to the report, "member States with a diverse portfolio of gas suppliers and supply routes and well-developed gas markets reap the benefits by paying less for imports and generally having lower prices" (European Commission, 2014).

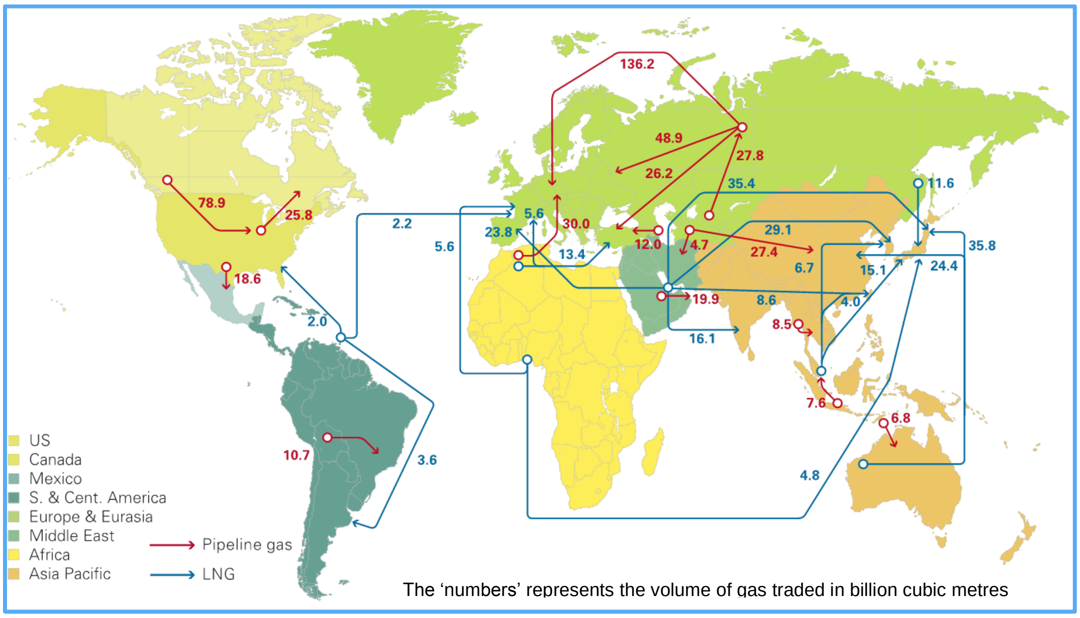
1.3.3 Natural gas trade movements

Open and easy access to infrastructure by buyers and suppliers has boosted the global natural gas trading. Trading hubs are usually formed where several pipelines meet, more often near storage sites and areas of high demand. Five major bench-mark prices that are followed across the globe for natural gas trading are:

1. Japan LNG import rates cif (cost + insurance + freight).
2. Average German import price cif.
3. UK Heren NBP Index.
4. US Henry hub.
5. Canada's Alberta price.

The trading occurs between the countries on one of the above mentioned international bench-marks as agreed in the contract. The traded currency is US$ usually in energy terms of million british thermal units (hereinafter: MMBtu) commonly referred as US$/MMBtu (BP, 2014). The taxes, cost of transport depending on the agreement, marketing margins etc., are added to the international bench-mark pricing. Understanding the intricacies of gas pricing is not easy as trading patterns are not unique. Still major trade movements happen among nations across the world as shown in the Figure 5.

Figure 5. Major trade flows of pipeline gas and LNG in 2013



Source: Adapted from BP, *BP Statistical Review of World Energy*, 2014, p. 29, Figure Major Trade movements in 2013.

There is a huge volume of gas transported among the neighbouring nations through pipelines and as LNG through big carrier vessels between the nations that are wider apart. The volume of gas transported through pipelines and as LNG collected from the BP Statistical Report of world energy 2014 is reproduced in Table 5 (BP, 2014, p. 29). It may be concluded that the Russian Federation is the largest exporter of pipeline gas accounting for 29.73% of the world total in pipeline exports. The European nations are the primary importers of the Russian gas. Germany is the largest importer in Europe constituting a share of 13.48% of the total imports through pipelines across the world. Qatar was the largest exporter of LNG in the world, comprising 32.47% of global LNG exports. Japan was the largest LNG importer importing 119 billion cubic metres (hereinafter: bcm).

Table 5. Gas trade in billion cubic metres in 2013 both pipeline and LNG

Countries	**Pipeline imports**		**LNG imports**		**Pipeline exports**		**LNG exports**	
	Volume in bcm	**Share (in %)**	**Volume in bcm**	**Share (in %)**	**Volume in bcm**	**Share (in %)**	**Volume in bcm**	**Share (in %)**
US	78.9	11.10	2.7	0.84	44.4	6.25	0.1	0.03
Canada	25.8	3.63	1.1	0.32	78.9	11.10	-	-
Mexico	18.6	2.62	7.8	2.40	-	-	-	-
France	30.5	4.29	8.7	2.69	1.1	0.16	0.6	0.19
Germany	95.8	13.48	-	-	15.1	2.12	-	-
Italy	51.6	7.26	5.5	1.70	0.2	0.03	-	-
Netherlands	21.5	3.03	0.8	0.24	53.2	7.49	0.2	0.06
Norway	-	-	-	-	102.4	14.41	3.8	1.18
Spain	15.3	2.16	14.9	4.59	0.9	0.13	2.6	0.81
Turkey	38.2	5.37	6.1	1.86	0.6	0.09	-	-
UK	41.9	5.90	9.3	2.85	8.9	1.26	-	-
Other Europe	102.2	14.39	6.1	1.89	11.9	1.68	-	-
Russian Federation	27.8	3.91	-	-	211.3	29.73	14.2	4.38
Ukraine	26.9	3.79	-	-	-	-	-	-
Qatar	-	-	-	-	19.9	2.80	105.6	32.47
Algeria	-	-	-	-	28.0	3.94	14.9	4.59
China	27.4	3.85	24.5	7.53	2.8	0.39	-	-
Japan	-	-	119.0	36.57	-	0.00	-	-
Indonesia	-	-	-	-	8.9	1.25	22.4	6.89
South Korea	-	-	54.2	16.67	-	-	-	-
Asia Pacific	28.5	4.01	40.4	12.42	16.9	2.38	-	-
India	-	-	17.8	5.47	-	-	-	-
Others	79.7	11.22	24.1	7.42	105.2	14.81	85.6	26.31
Total World	**710.6**	**100.0**	**325.3**	**100.0**	**710.6**	**100.0**	**325.3**	**100.0**

Source: BP, *BP Statistical Review of World Energy*, 2014, p. 29, Table Gas trade in 2013.

2 ANALYSIS OF INDIAN NATURAL GAS MARKET

Energy is one of the most important building blocks of human development and is therefore a key factor in determining the economic development of a country. The Indian energy sector is rapidly growing, in an effort to meet the demands of a developing nation, which has a huge population. In the areas of resource exploration, capacity enhancement and the energy sector reforms have been revolutionized. India is still in the transition mode. It is moving from a planned economy which has extensive central controls, to one based increasingly on the operation of market forces. Although economic liberalisation began in 1991, its cumulative impact became visible in the second half of the last decade, as India emerged to become the fourth-largest economy in the world in purchasing power parity (PPP) terms, as well as gross domestic product (GDP) growth rates averaging 8% per annum (The World Bank, 2014). The basic objective of the Indian economic policy has been to make basic goods and services available and accessible to the poor.

2.1 Indian energy mix

India's energy-mix is comprised of both, non-renewable like coal, petroleum and natural gas and renewable energy sources such as hydro, wind, solar, biomass, cogeneration bagasse[5] etc. The contribution of each primary fuel towards the energy requirement in 2012 and 2013 is shown in Table 6. The data also brings out the contribution of the primary fuels for the Total Primary Energy Demand[6] (herinafter: TPED) of India and that of the world for easy distinction.

Table 6. Consumption by type of fuel (in mtoe) and share in TPED (in %) of India and world in 2012 and 2013

Type of fuel	India in 2012		World in 2012		India in 2013		World in 2013	
	Volume in mtoe	Share of TPED (in %)	Volume in mtoe	Share of TPED (in %)	Volume in mtoe	Share of TPED (in %)	Volume in mtoe	Share of TPED (in %)
Oil	173.6	30.3	**4138.9**	33.2	175.2	29.5	**4185.1**	32.9
Natural gas	52.9	9.2	**2986.3**	23.9	46.3	7.8	**3020.4**	23.7
Coal	302.3	52.7	**3723.7**	29.8	324.3	54.5	**3826.7**	30.1
Nuclear	7.5	1.3	**559.9**	4.5	7.5	1.2	**563.2**	4.4
Hydro-electric	26.2	4.6	**833.6**	6.7	29.8	5.0	**855.8**	6.7
Renewables	10.9	1.9	**240.8**	1.9	11.7	2.0	**279.3**	2.2
Total	573.3	100.0	**12483.2**	100.0	**595.0**	100.0	**12730.4**	100.0

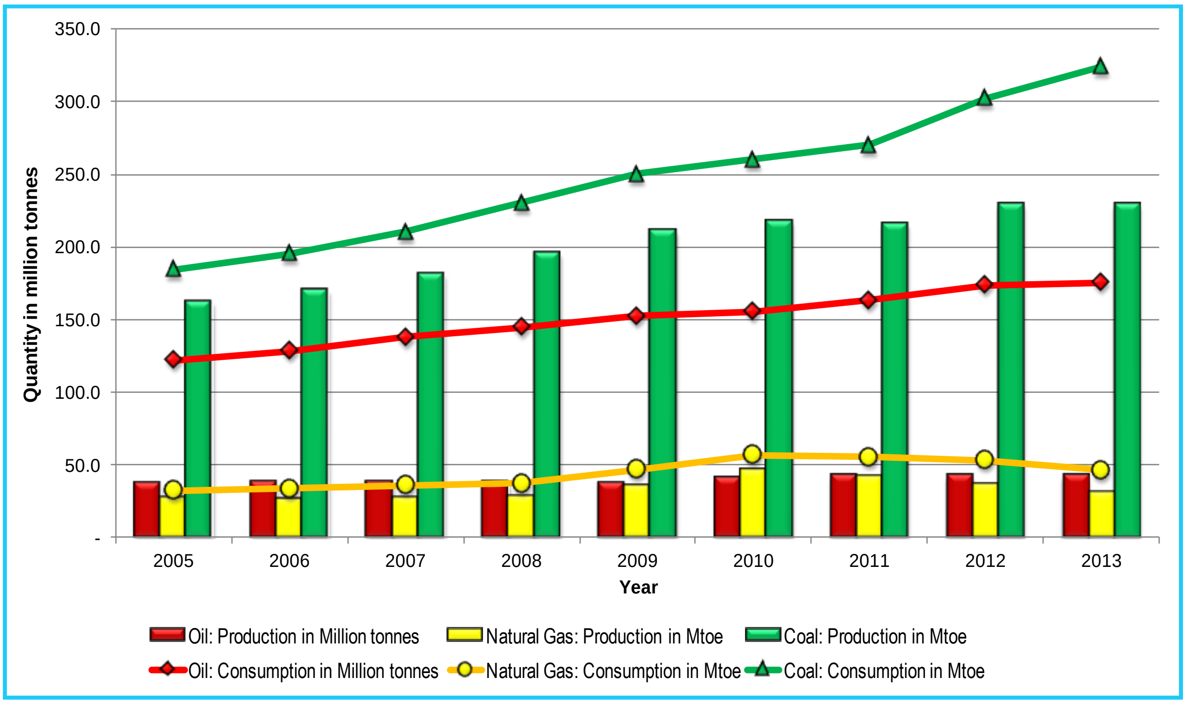
Source: BP, *BP Statistical Review of World Energy*, 2014, p. 41.

[5] Bagasse is the fibrous matter that is left over after crushing of sugarcane to extract their juice. It is used as a biofuel.
[6] Total Primary Energy Demand (TPED) refers demand of primary energy which means an energy form found in nature that has not been subjected to any conversion or transformation process.

The Table 6 reckons that in 2013, nearly 91.8% of the total contribution to the primary energy demand of India is from the fossil fuels i.e. coal, oil and gas, while only 8.2% energy is produced from cumulative contribution of nuclear, hydroelectric and renewables. This is approximately 5.% lower than the world average contribution which stands at 13.3%. Coal dominates in its share in India, while oil dominates in its contribution to the TPED on global scale. India is essentially a coal economy. It has vast indigenous reserves and stands 4th largest holder of coal reserves in the world. After coal, oil and gas form a significant proportion of primary energy consumption. Oil accounted for 30.3% and 29.5% of India's TPED in 2013 and 2014 respectively, while natural gas contributed to 9.2% in 2012 and fell to 7.8% in 2013 mainly due to a domestic shortage of supplies. Coal was the leading contributor to the TPED of India. But the quality of coal is very poor and has more ash content leading to increased pollution levels. The international community is also exercising extra pressure for climate change mitigation. In the next two decades, the Indian gas market is anticipated to be one of the fastest growing markets in the world.

One harsh result of its meteoric growth is the widening gap between the required energy and that which is being produced. India is unable to meet the demand of energy. India is forced to rely on imports due to severe scarcity in domestic energy resources (Ahn & Graczyk, 2012). It is also evident that demand-supply gap is widening day-by-day and is more apparent in all three primary forms of energy.

Figure 6. Production and consumption of three primary energy sources of India in 2005–13 (in million tonnes oil equivalent)



Source: BP, *BP Statistical Review of World Energy*, 2014, p. 8, Oil; p. 22, Natural Gas; p. 32, Coal.

Figure 6 show the production and consumption of three main sources of primary energy i.e. coal, oil and gas of India from 2005 to 2013. There is huge gap between the production and consumption of coal. Indian power generation companies depend hugely on coal. The transportation sector is completely dependent on oil refinery produces of petrol, diesel, kerosene, aviation turbine fuel etc. Natural gas is slowly gaining importance as the alternative fuel.

2.2 History of Indian oil and natural gas industry

After its independence in 1947, India focused on regaining control over its oil sector which has been dominated by companies from the West. The government believed that effective control of critical industries like petroleum should always rest in Indian hands. The government felt the necessity of developing a domestic, independent and secure petroleum industry. In comparison to the huge demand, India's domestic hydrocarbon reserves are relatively small. India is predominantly dependent on imports. It has become a huge concern for the country's energy security (Ahn & Graczyk, 2012, p. 58). In 2012, India was the world's fourth largest oil consumer and was also the fourth largest importer while the US was the forerunner in oil consumption and Europe was at the top nation in consuming gas (US Energy Information Administration, 2014e).

Table 7. Consumption and import of oil in top 5 oil consuming and importing countries in 2013 (in million tonnes)

Rank	Country	Oil consumption in million tonnes	Country	Oil import in million tonnes
1	US	831.0	Europe	463.8
2	China	507.4	US	384.4
3	Japan	208.9	China	282.6
4	India	175.2	India	190.5
5	Russian Federation	153.1	Japan	178.2

Source: BP, *BP Statistical Review of World Energy*, 2014, p. 8, Oil Consumption; p. 18, Oil Imports.

In the immediate post-independence era of India there were two major oil and gas exploration companies – Oil and Natural Gas Corporation (hereinafter: ONGC) and Oil India Limited (hereinafter: OIL). Founded in mid-1950s, ONGC was initially a commission linked to the MOPNG, which became a public sector corporation in 1994. OIL began as a private company in 1959, and was nationalised in 1983. Essentially, these were India's National Oil Companies (hereinafter: NOCs). In 1956, under the Industrial Policy Resolution, the Oil and Natural Gas Commission and Indian Oil Corporation were created as the upstream and downstream companies respectively for the petroleum sector. The Indian government nationalised the hydrocarbon sector during the 1970s, reaching completion in 1981 (Ahn & Graczyk, 2012, p. 7).

Despite huge imports, oil does not dominate in its contribution to the primary energy demand but still it plays a very vital role. The Indian oil market is now liberalized to the level of retail prices which is linked to international oil prices and with huge price increase the oil import bill is on the raise.

2.3 Natural gas in India

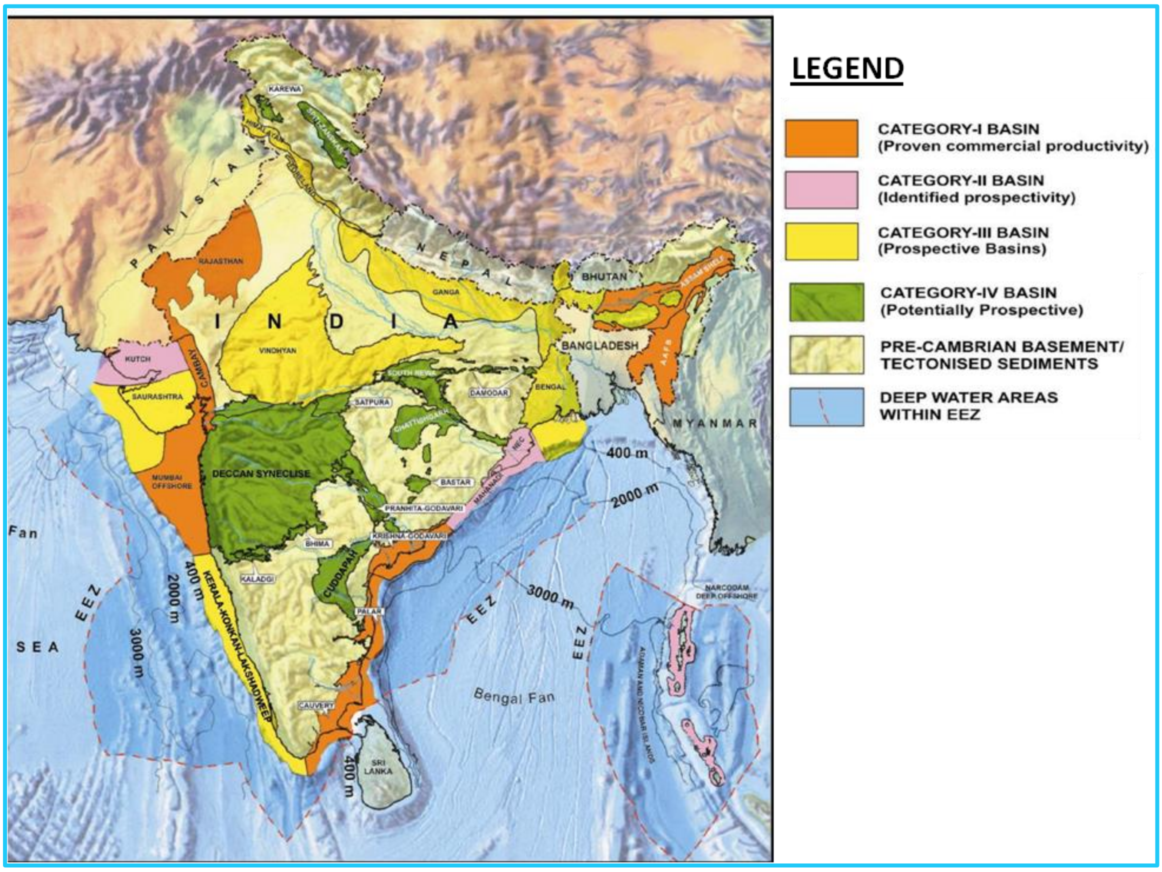
Traditionally, oil was the primary focus of the Indian government's policies. Natural gas began attracting increased attention after the discovery of the off-shore Bombay high gas fields by ONGC where production commenced in 1974. The government realised the need for a dedicated gas distribution network. In 1984 it established a state-owned company, the Gas Authority of India Ltd. in order to handle the gas business as a separate entity. The focus on increasing domestic gas production intensified in the late 1980s as oil production fell drastically and increased awareness on the need of a substitute fuel. In 1986 GAIL India Ltd. (hereinafter: GAIL) laid the foundation set-up for the first large inter-regional pipeline project Hazira–Vijaypur–Jagdishpur (hereinafter: HVJ) which was later commissioned in early 1990s (GAIL India Ltd., 2014). By then, natural gas was viewed as the substitute fuel for oil in power generation (US Energy Information Administration, 2014d). The reform initiatives by Government of India in the hydrocarbons sector are a mix representation of both, a planned approach to economic development and its pitfalls. (Jain & Sen, 2011).

2.3.1 Exploration and Production of natural gas in India

Historically, the exploration and production of gas in India has been carried out by NOCs and very few private companies under joint venture with NOCs or other Public Sector Undertakings (hereinafter: PSU). The map in Figure 7 outlines the concentration of the sedimentary basin, in different colours showing the prospective categories. The sedimentary basins of India both **onland**[7] and **off-shore**[8] cover a total area of about 1.79 million sq. km (Directorate General of Hydrocarbons, Government of India, 2014d). So far 26 basins have been recognized and they have been divided into four categories based on their degree of prospect, namely proven commercial productivity, identified productivity, prospective basins and potentially prospective basins. In **deep waters** the sedimentary area has been estimated to be about 1.35 million sq. km. The total works out to 3.14 million sq. km.

[7] Onland means located on the land.
[8] Off-shore means located at a distant away from the shore on the sea/water.

Figure 7. Prospective oil and gas basin reserves in India



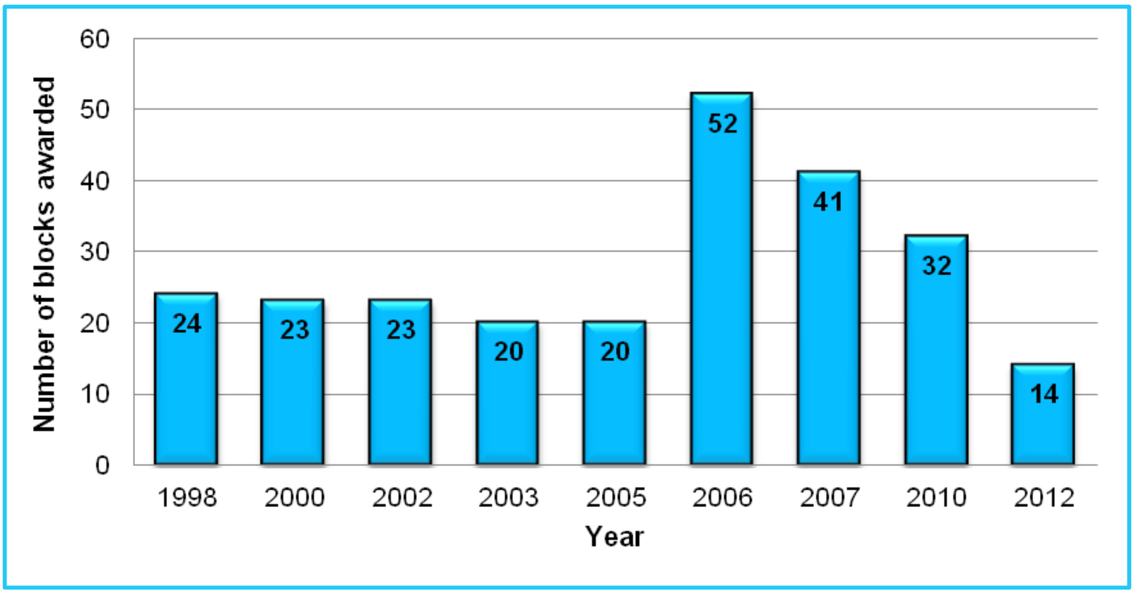
Source: Directorate General of Hydrocarbons, Government of India, *Sedimentary Basins*, 2014d.

Between the post-independence era and the liberalisation in 1991, oil and gas blocks[9] for exploration were then allocated to oil PSUs directly on nomination basis without any auctioning or tendering. There was no competition in oil and gas exploration jobs. The companies were simply nominated by the government based on their expression of interest in fields for oil and gas exploration and were subsequently granted licences for this activity. The private companies could not participate in the exploration jobs directly. They could enter into exploration jobs only through a joint venture with PSUs. The extracted oil and gas were then distributed by the Central government to major consuming and distributing sectors, which lay entirely in the public sector (Ahn & Graczyk, 2012, p. 59). India had different fiscal regimes for oil and gas exploration. An exploration block was awarded to PSU on a royalty-based scheme, without profit sharing or the option of divesting their participating share. This regime was stopped in the late 1990s. After the liberalisation in 1991, the ‘discovered fields’ regime started. Under this regime, private companies formed joint ventures with NOCs and bid for the fields that are auctioned.

[9] An oil or gas exploration block is a large area of land, typically in thousands of square kilometers, that is awarded to oil drilling and exploration companies by a country's government.

In the past fifteen years, there have been significant steps taken in exploring the hydrocarbon potential of the sedimentary basins of India. The unexplored area has come down from 50% in 1995–96 to 15% in 2010. Of the estimated sedimentary area of 3.14 million square kilometres, at present 1.06 million square kilometres area is under active petroleum exploration licenses in 18 basins by national oil companies and private as well as joint venture companies. The credit for this achievement goes to the preliminary speculative surveys carried out by Directorate General of Hydrocarbons (hereinafter: DGH). The DGH is the upstream regulator and is empowered to monitor the country's Exploration and Production (hereinafter: E&P) activities and Coal Bed Methane (hereinafter: CBM) projects and to obtain all data from all lessees/licensees to monitor the government revenues from upstream projects. The responsibility of the DGH is in terms of calling for bids, auctioning, awarding blocks, executing production sharing contracts, monitoring developments etc. (Directorate General of Hydrocarbons, Government of India, 2014b). In 1998, the government of India under suggestions of the DGH launched the New Exploration Licensing Policy (hereinafter: NELP) in order to increase domestic investment from the private sector and more precisely from international private investors in oil and gas fields. (Ministry of Petroleum and Natural Gas, Government of India, 2014a). The DGH was the nodal agency in awarding acreages for exploration under NELP based on the speculative survey. So far nine rounds of NELP bidding have been carried out successfully by the DGH (Directorate General of Hydrocarbons, Government of India, 2014a).

Figure 8. Oil and gas blocks awarded on each round of NELP auctions



Source: Adapted from Directorate General of Hydrocarbons, Government of India, *Chronology of E&P Events in India,* 2014a.

In the nine rounds of NELP auctions spanning 2000–12, Production Sharing Contracts (hereinafter: PSC) for 249 exploration blocks have been signed. The details of the number of blocks awarded under each NELP auction and the corresponding year is shown in

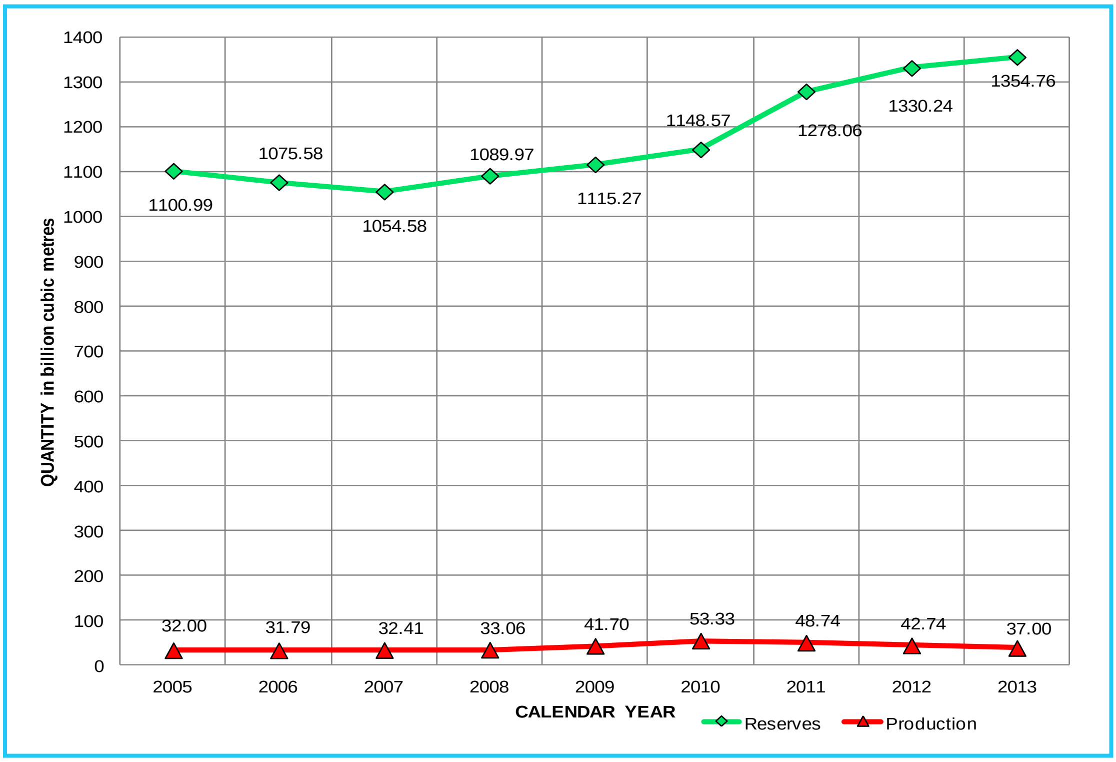
Figure 8. Despite award of more than 249 oil and gas blocks, the explorations from these fields are slow and currently the production of oil and gas from these fields are very low. The Indian Petroleum and natural gas statistics 2012–13 report released by Economic division of Ministry of Petroleum and Natural gas, Government of India (Ministry of Petroleum and Natural Gas, Government of India, 2013a), reveals a very low production of natural gas since 2005 against the estimated reserves as shown in Table 8 and Figure 9.

Table 8. Potential reserves of natural gas and the actual production of India in 2005–13 (in bcm)

Year	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**
Reserves	1100.99	1075.58	1054.58	1089.97	1115.27	1148.57	1278.06	1330.24	1354.76
Production	32.00	31.79	32.41	33.06	41.70	53.33	48.74	42.74	37.00

Source: Adapted from Ministry of Petroleum and Natural Gas, Government of India, *Indian Petroleum & Natural Gas Statistics 2012–13,* 2013a, p. 26, Table II.11; p. 27, Table II.12.

Figure 9. Potential reserves of natural gas and the actual production of India in 2005–13 (in bcm)



Source: Adapted from Table 8.

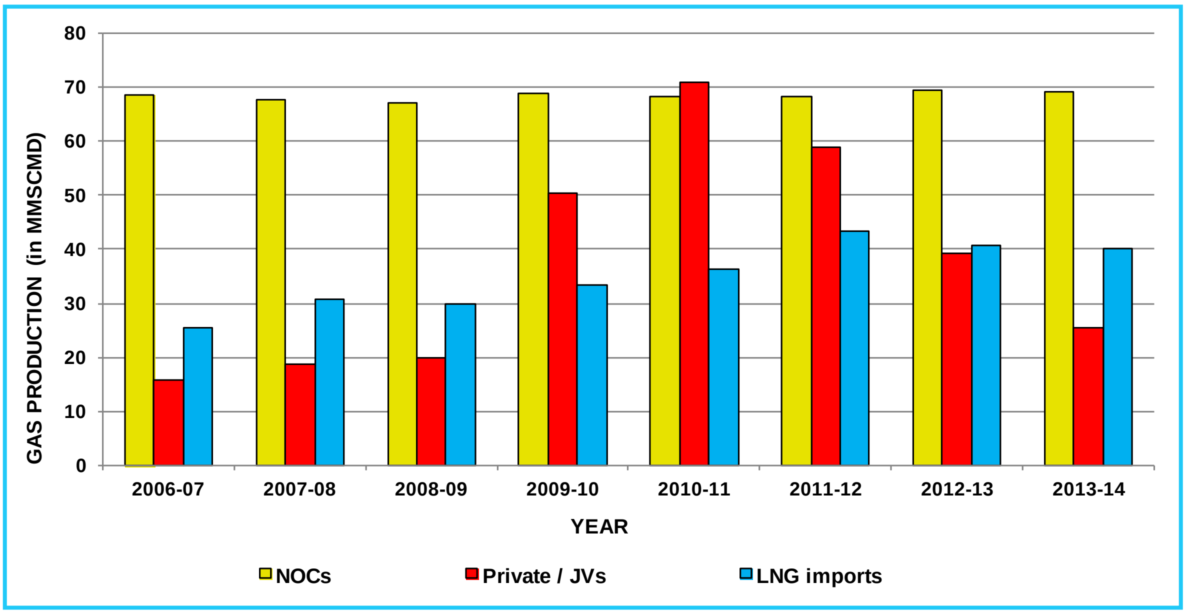
From Table 8 and Figure 9 it is evident that the production levels are too low in comparison to the estimated reserves. The primary reason attributed to such a low performance is the lack of necessary technology and infrastructure. The major technological drawback includes lack of sufficient drilling platforms and the associated infrastructure in the domestic market (Corbeau, 2010). The outsourcing of these platforms is very expensive and requires very high capital investments. This is a major concern for India. Another concern is that even after nine rounds of NELP the foreign investors are still not participating in the auction.

Table 9. Indian average daily production of natural gas in 2006–14 (in MMSCMD[10])

Year[11]	2006–07	2007–08	2008–09	2009–10	2010–11	2011–12	2012–13	2013–14
Average daily domestic production by NOCs	68.51	67.68	67.21	68.77	68.27	68.19	69.61	69.11
Average daily domestic production by private/JVs	15.85	18.57	19.78	50.33	71.04	58.80	39.32	25.56
Average daily domestic production total	84.36	86.25	86.99	119.10	139.31	126.99	108.93	94.67
LNG imports	25.40	30.80	29.70	33.30	36.40	43.50	40.70	40.20

Source: Adapted from Petroleum Planning & Analysis Cell, *Natural Gas Production Current and Historical,* 2014c.

Figure 10. Indian average daily production of natural gas in 2006–14 (in MMSCMD)



Source: Adapted from Petroleum Planning & Analysis Cell, *Natural Gas Production Current and Historical,* 2014c.

[10] MMSCMD stands for million standard cubic metres per day.
[11] Year here represents financial year from the 1st April of the first year to the 31st March of the next year.

Looking specifically at the domestic gas production by NOCs and private, as well as joint venture firms, the daily gas production is very low as detailed in Table 9. Based on the historical and current data maintained by Petroleum Planning and Analysis Cell (hereinafter: PPAC), a central government department under MOPNG, the natural gas produced by NOCs, private and joint ventures as well as the LNG imports on a daily average basis is presented in Table 9 and Figure 10 (Petroleum Planning & Analysis Cell, 2014b). It shows that the historical maximum production achieved was around 140 million standard cubic metres per day (hereinafter: MMSCMD) in 2010–11. From the data it can be concluded that over the past eight years there is no appreciable increase in the gas production by the NOCs. It clearly points out the absence of incentives for improvement among the public sector undertakings.

The gas production from private and joint ventures peaked during 2010–11 due to the increased production in the Krishna-Godavari (hereinafter: KG) basin gas fields. From the Table 9 and Figure 10, it can be seen that the natural gas production increased by approximately 2.5 times in the year 2009-10. From 2011 on the production declined due to various technical reasons. This aspect shall be discussed in section 2.4. Due to an ever increasing population the demand is never fulfilled. The oil companies are not able to extract higher quantum of oil and gas from the domestic reserves. The poor production results are multi-dimensional and ultimately narrow down to the policy regulations which failed to upgrade, or rather reflect the depleting domestic gas production and increasing demand.

2.3.2 Transportation pipeline infrastructure of India

After the first major gas finds in the western offshore in 1970, the use of natural gas as an energy fuel commenced. With the commissioning of the first natural gas pipeline, the HVJ pipeline in the early 1990s, the natural gas use gained further momentum. India is continuously striving for rapid growth in its pipeline infrastructure in order to meet the ever increasing demand of natural gas. As of the 31st of March 2014 India's pipeline network spans 15,340 kilometres (hereinafter: km), with the capacity to carry 395 MMSCMD (Petroleum Planning & Analysis Cell, 2014d). The complete list of natural gas pipelines in India, their lengths, diameter and capacities is placed in Appendix E, while the overall summary is shown in Table 10. The cumulative design capacity of natural gas pipeline network of India is approximately 395 MMSCMD (Table 10) while the maximum gas throughput achieved until today was 140 MMSCMD as presented in Table 9.

GAIL is a notable state owned entity which owns and operates more than 71% of natural gas pipeline network in India (GAIL India Ltd., 2014). Since inception in 1984, GAIL has been the undisputed leader in the marketing, transportation and distribution of Natural Gas in India. It is the leading natural gas company and plays a vital role in natural gas business in India. Currently, GAIL sells around 65 % of Natural Gas sold in India. Of this, 31.3% is to the power sector and 31.5% to the fertilizer sector. Currently, GAIL is supplying around 58 MMSCMD of Natural Gas from domestic sources to customers across India. These customers range from the smallest of companies to mega power and fertilizer plants.

Table 10. Natural gas pipeline network of India in terms of length (in km) and capacity (in MMSCMD)

Network	Owner	Pipeline length (in km)	Design capacity (in MMSCMD)	Current operating quantity (in MMSCMD)	Capacity utilization as on 31.03.2014 (in %)
GAIL INDIA LTD	GAIL	10,841	243.71	58.00	34.33
EAST–WEST PIPE LINE (RGTIL)ǂ	Reliance	1,469	80.00	48.00	60.00
GSPCLǂǂ Network including Spur Lines	GSPCL	1,874	50.00	22.00	44.00
Assam Gas Company (Duliajan to Numaligarh)	AGC	1,000	6.00	4.50	75.00
Dadri–Panipat	IOCL	132	9.50	3.11	32.77
Uran–Trombay	ONGC	24	6.00	-	-
Total		**15,340**	**395.21**	**135.00 (on average)**	**34.00 (on average)**

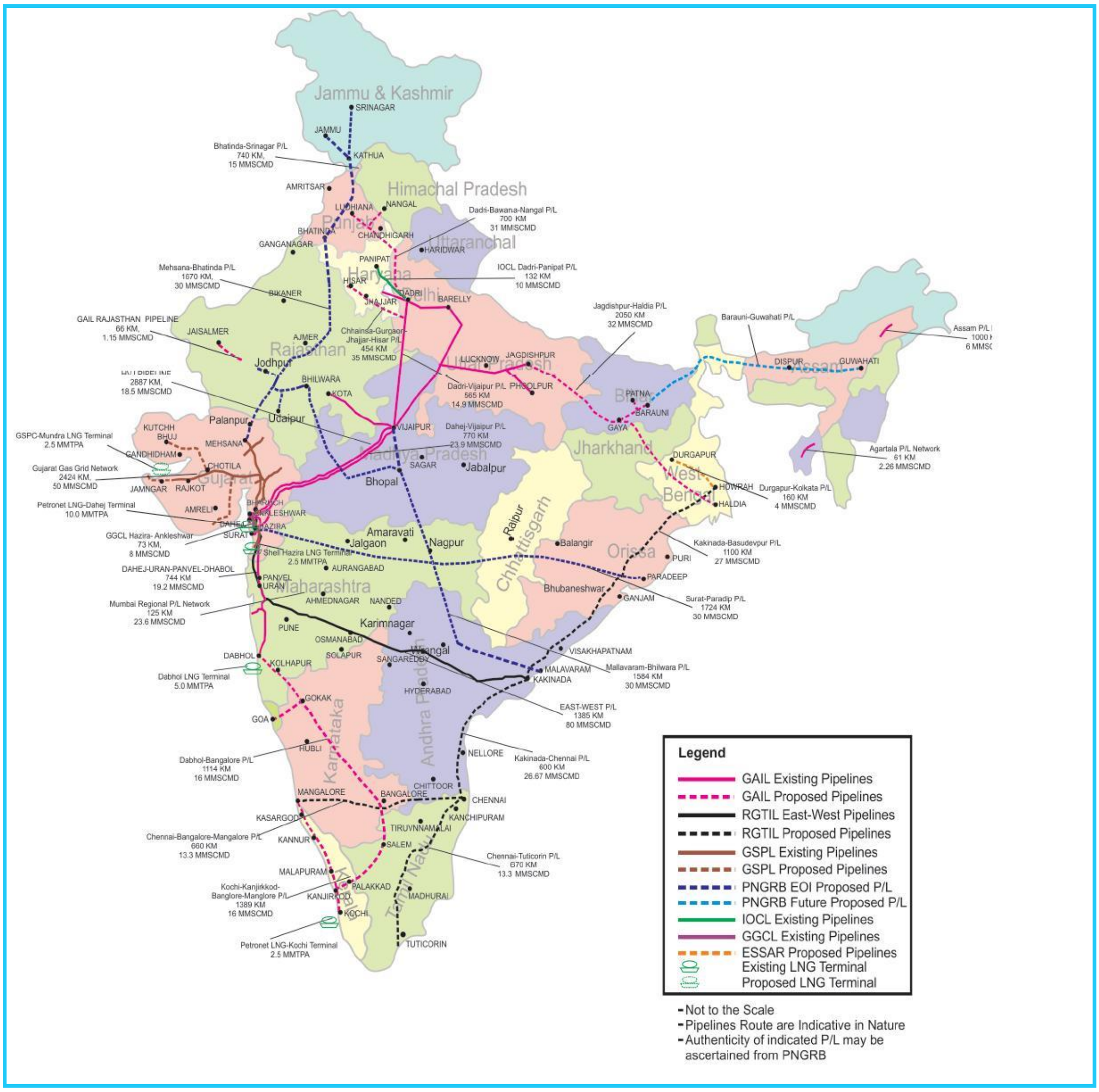
Note: * AGC stands for Assam Oil Company; ** IOCL stands for Indian Oil Corporation Limited, ǂ stands for Reliance Gas Transportation Infrastructure Limited; ǂǂ stands for Gujarat State Petroleum Corporation Limited.

Source: Adapted from Petroleum Planning & Analysis Cell, *Pipelines and CGD Infrastructure*, 2014d.

On average these pipelines cater to approximately 135 MMSCMD which roughly reckons to 34% of capacity utilisation on a national average. Few exceptions are noted in the Table 10 such as in the case of Reliance Gas Transportation Infrastructure Ltd. (RGTIL) and Assam Gas Company (AGC) pipeline. RGTIL’s East–West gas pipeline transports gas from Kakinada (in the state of Andhra Pradesh) to Bharuch (in the state of Gujarat) through the Indian states of Andhra Pradesh, Karnataka, Maharashtra and Gujarat. It has been authorized as a common carrier pipeline (Reliance Gas Transportation Infrastructure Ltd., 2014). The Assam Gas Company Ltd. (AGC) has an underground pipeline that operates with in the Assam state of India serving more than 400 commercial establishments, about 20,000 domestic consumers, more than 300 tea estates and several big industrial consumers in Assam. The Indian Oil Corporation Ltd. (IOCL) owns and operates 132 km long natural gas pipeline from Dadri (in state of Uttar Pradesh) to Panipat (in state of Haryana). This pipeline is interconnected with GAIL’s HVJ pipeline and acts as a common carrier pipeline for transporting natural gas from HVJ pipeline network to IOCL’s Panipat refinery (Indian Oil Corporation Ltd., 2014). The Uran-Trombay gas pipeline is a very small 24 km pipeline of ONGC in Mumbai in state of Maharashtra. These pipelines are dedicated pipelines and are very small in comparison to major network of GAIL. The overall operating capacity of roughly 35% is a very serious concern. The under-utilisation of network is a huge loss in terms of fixed capital investments made. It is a loss of opportunity cost in terms of failing to transport to the maximum capacity. It is also a revenue loss state exchequer in form of taxes and duties not earned.

Another important aspect is the geographical distribution of these natural gas pipelines of India. It has remained uneven (Petroleum & Natural Gas Regulatory Board, 2013, p. 45). Figure 11 shows the natural gas pipeline network of India.

Figure 11. Natural gas pipeline network of India in April 2012



Source: Petroleum & Natural Gas Regulatory Board, *What's New: Indicative Map of Natural Gas Pipelines in India*, 2010.

The states closer to the gas source have the benefits of higher utilization of gas and local development of gas market. The Indian states of Gujarat, Maharashtra and Andhra Pradesh, which are very close to natural gas reserves of South Basin, Bombay high offshore fields and Krishna–Godavari (hereinafter: KG) basin fields respectively are at a benefit. Looking into the Figure 11, it can be clearly evident that the western region of India has a huge pipeline network which also leads in the consumption of natural gas. The distribution of pipeline network remains significantly low in the southern, eastern and central parts of India. To alleviate the uneven distribution the government has initiated slew of measures and has sanctioned new pipelines to ensure access to gas for all prospective industrial locations across the country. The government of India is vehemently pushing for the development of a national grid of natural gas pipeline network to ensure even distribution across the country. The purpose of the grid is to complete gas pipeline connectivity across the nation. The objective is to integrate all the sources and meet the demand of even the last customer. The grid is also being targeted in anticipation of various new supply options in the global market, specifically sourcing of gas through LNG imports and trans-national pipelines from Turkmenistan and Iran.

Table 11 shows the gas pipeline infrastructures that are being completed in the following years, targeting the end of 2017, in terms of the length in km and design capacities in MMSCMD. These pipelines are in the project execution and in pre-commissioning stage as authorized by the regulator Petroleum and Natural Gas Regulatory Board (hereinafter: PNGRB) (2014). PNGRB was created in 2006 as a downstream regulator. The role of PNGRB is further described under section 2.5.1.

Table 11. Natural gas pipelines under execution or to be executed before 2017

Network	**Company**	**Pipeline length (in km)**	**Pipeline design capacity (MMSCMD)**
Kochi–Kottanad–Banglore–Mangalore	GAIL	1,104	16.00
Dhabhol–Banglore (DBPL)	GAIL	1,414	16.00
Surat–Paradip	GAIL	2,112	75.00
Jagdishpur–Haldia	GAIL	1,860	32.00
Mallapuram–Bhilwada	GSPL*	2,042	76.25
Mehsana–Bhatinda	GSPL	2,052	77.11
Bhatinda–Srinagar	GSPL	725	42.00
Kakinada–Srikakulam	APGDC**	391	90.00
Total		**11,700**	**425.00**

Note: * GSPL stands for Gujarat State Petronet Ltd.; ** APGDC stands for Andhra Pradesh Gas Distribution Corporation.

Source: Adapted from Petroleum Planning & Analysis Cell, *Pipelines and CGD Infrastructure*, 2014d.

The gas pipeline network of India is projected to expand to around 28,000 km of pipeline length with a total capacity of around 721 MMSCMD in next 5 to 6 years (Petroleum & Natural Gas Regulatory Board, 2013, pp. 10-11). In the recent central budget approved in July 2014 the government has allocated huge sums of money for the development of the necessary infrastructure for the national gas grid. The present finance minister of India has stated that "we have at present about 15,000 km of gas pipeline systems in the country. In order to complete the gas grid across the country, an additional 15,000 km of pipelines are required. The budget proposes to develop these pipelines using appropriate public-private-partnership models. This will help increase the usage of gas, domestic as well as imported, which in the long-term will be beneficial in reducing dependence on any one energy source. This shall ensure larger and uniform distribution of gas to all regions for better economic and social progress of India" (Kumar, 2014).

2.3.3 Distribution and sale of natural gas

The Indian government liberalised the exploration and production market, while transportation and distribution was regulated and controlled by the government in the very old fashion. The objective is a free and fair market ensuring availability of the hydrocarbon products at nominal price and assuring energy access to all sections of the society. This distributional objective has been pursued mainly through pricing and allocation (Jain & Sen, 2011, p. 11).

In the 1970s, the gas production has just begun and hence the amount of gas produced was very low. The gas prices were fixed by an expert committee. Between 1970 and the mid–1980s, prices were fixed after outcome of the negotiation between large gas users and the corresponding public companies. In 1987 the distributional objectives became explicit, as the government implemented the Administered Pricing Mechanism (hereinafter: APM), resulting in government controlled prices across different consumers. Under APM the prices were fixed based on the cost of production. Some marginal amount is added to production cost which was usually fixed percentage of their investment in the exploration of the well. There was no pre-formulated calculation for fixing the price in any of the said regimes. The majority of gas was produced by NOCs. The price of natural gas was controlled by the Indian government at very low levels since the mid-1980s. Such lucrative low price regime increased the natural gas demand rapidly and by 1990s, there was a deficit in the quantity available.

India had no market mechanism for managing the crisis of demand-supply imbalance (Ebinger & Avasarala, 2013). In the absence of any market mechanism, policymakers decided to introduce an institutional arrangement to control demand-supply imbalance by priority allocation of gas and to better manage the supply deficit. This led to the formation of a Gas Linkage Committee (hereinafter: GLC) in 1991. The government purchased the entire quantity of gas and sold it at subsidised rates to users on the basis of sectoral allocations determined by the committee. This was a regular exercise. The order of priority of allocation was fixed. Fertilizers industries had highest priority followed by power and petrochemicals. Besides these natural gas was also allocated as a part of an anti-pollution initiatives in line with the directives of Supreme Court of India. Notable are the City Gas Distribution (hereinafter: CGD) project in New Delhi and green initiative in Agra-Taj corridor to protect the Taj Mahal, one of the greatest wonder of the world. The natural gas is used in the form of Compressed Natural Gas (hereinafter: CNG) in public transport system such as buses, cars, taxis etc., to bring down the carbon-monoxide, NOx and SOx[12] levels. The miniscule scale industries in Agra-Taj corridor are also supplied with natural gas to drastically reduce the pollution levels in the mammoth process of saving the UNESCO (2014) world heritage site. The natural gas allocations to bring down the pollution levels were further extended to few other major cities like Mumbai. Due to the absence of a formal policy on gas allocation and utilisation, the committee arrived at these decisions on an ad-hoc basis. The PSUs were the main followers of the governmental orders on priority allocation. Hence, the methodology of allocation was never questioned and the government faced no obstacles and had not taken any initiative for developing formal policies and reforms in the natural gas distribution sector.

The majority of administered price mechanism gas was allocated to the power and fertilizer sectors at a low cost, with the objective to keep the prices of power and urea relatively low. The government was effectively subsidising the prices of the inputs and outputs. The input subsidies have created distortions in the choice of the fuel. The objective of constitution of GLC was to better manage the gap between demand and supply which was totally defeated when the committee was forced to allocate more gas in 2008, roughly to the tune of 150 MMSCMD more than was actually available. Based on this assurance many investors started building huge gas based power plants and augmenting the existing power and fertilizer plants. Unfortunately the commitment of the producer turned out to be false. The investments made became idle due to severe gas shortages and some plants had to operate at inefficiently low plant load factors. This incident drew in severe criticism from all quarters of the industry which was pointing on the anomalies in the allocation mechanism and was obviously targeting on the major policy lapses (Ahn & Graczyk, 2012, pp. 67-69).

GLC lost much of relevance following NELP in 1999 and became less significant with the gas allocation discrepancy in 2008. The committee failed to have oversight or administrative control on gas produced by private companies due to lack of any transparency agreements with the private owners and operators. There was no provision for government audits on these private industries. The relinquishment of the role of the committee was more prudent with the decline in production of the APM gas and LNG emerged as an important potential supply source. The huge imbalance between demand

[12] NOx and SOx indicate to the general oxides of nitrogen (NO, NO_2, N_2O_2, etc.) and the general oxides of sulfur (SO_2, SO_3, etc.) when discussing air pollution.

and supply forced the government to develop a new policy for better administrative control over the prices and allocation volumes. In 2008, the government introduced the Gas Utilization Policy for distribution and sale of gas in the market. Further details on this policy are deliberated in section 2.5.2.

2.4 Natural gas demand-supply and need for imports

India does not have trans-national natural gas pipeline. The only form of import is LNG. The sector wise demand of natural gas taken from planning commission documents of eleventh plan as projected for 2007–12 (Ministry of Petroleum and Natural Gas, Government of India, 2006, p. 66) and from twelfth plan as projected for 2012–17 (Planning Commission, Government of India, 2013, p. 176) is detailed in Table 12.

Table 12. Projection of daily natural gas demand by sectors in MMSCMD in the 11th and 12th five year plan

	Gas demand projected under 11th plan 2007–12 (in MMSCMD)					**Gas demand projected under 12th plan 2012–14 (in MMSCMD)**	
Sector / Year	**2007–08**	**2008–09**	**2009–10**	**2010–11**	**2011–12**	**2012–13**	**2013–14**
Power	79.70	91.20	102.70	114.20	126.57	135.00	153.00
Fertilizer	41.02	42.89	55.90	76.26	76.26	55.00	61.00
City gas	12.08	12.93	13.83	14.80	15.83	15.00	19.00
Industrial	15.00	16.05	17.17	18.38	19.66	20.00	20.00
Petrochemicals/ refineries/ internal consumption	25.37	27.15	29.05	31.08	33.25	54.00	61.00
Sponge iron/ Steel	6.00	6.42	6.87	7.35	7.86	7.00	8.00
Total	**179.17**	**196.64**	**225.52**	**262.07**	**279.43**	**286.00**	**322.00**

Source: Ministry of Petroleum and Natural Gas, Government of India, *Report of Working Group on Petroleum and Natural Gas Sector for the XI plan (2007-2012)*, 2006, p. 66, Table 8.11; Planning Commission, Government of India, *Twelfth Five Year Plan (2012-2017) Economic Sectors Volume II*, 2013, p. 176, Table 14.37.

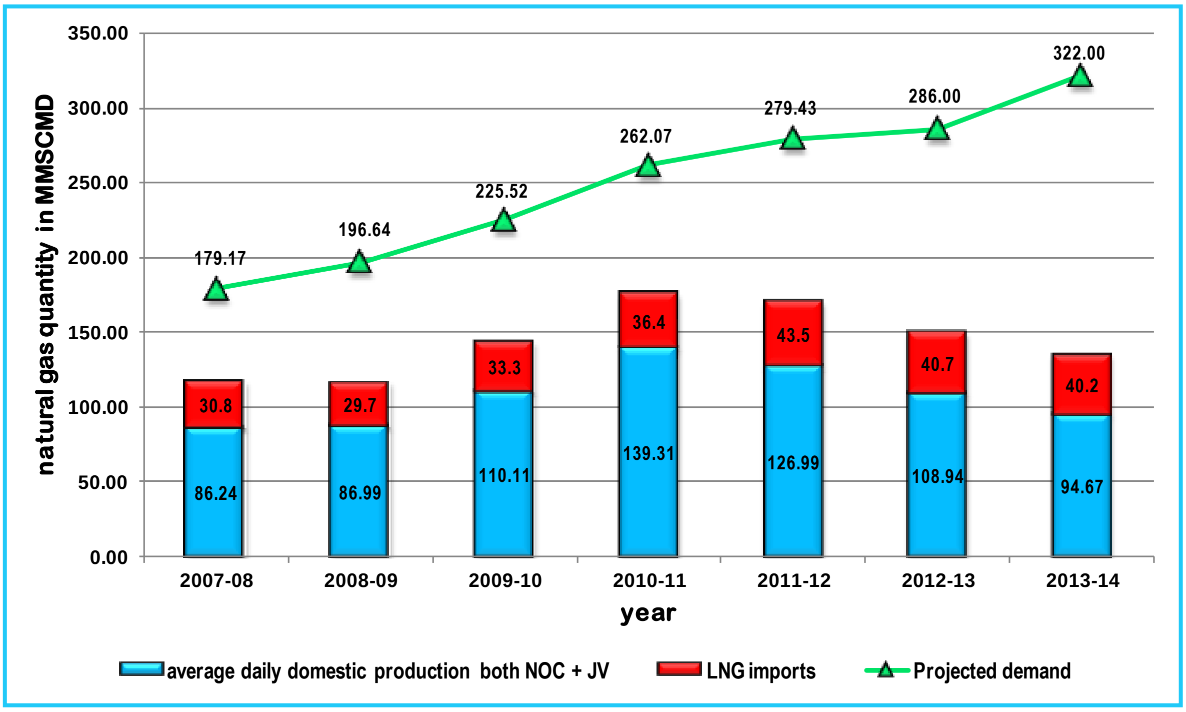
By reproducing the data from Table 9, the daily domestic gas production and the LNG imports and comparing with the projected demand data in Table 12, it is clearly visible that there is a huge gap between the original plan and the actual production output. The deficit is tabulated in Table 13.

Table 13. Average daily domestic production, LNG imports and deficit from 2007–14 (in MMSCMD)

Source	2007–08	2008–09	2009–10	2010–11	2011–12	2012–13	2013–14
Average daily domestic production total	86.25	86.99	119.10	139.31	126.99	108.93	94.67
LNG imports	30.80	29.70	33.30	36.40	43.50	40.70	40.20
Projected demand	179.17	196.64	225.52	262.07	279.43	286.00	322.00
Deficit	**62.13**	**79.95**	**73.12**	**86.36**	**108.94**	**136.36**	**187.13**

Source: Adapted from Petroleum Planning & Analysis Cell, *Natural Gas Production Current and Historical*, 2014c.

Figure 12. Indian's demand-supply natural gas gap in natural gas in 2007–14 (in MMSCMD)



Source: Adapted from Petroleum Planning & Analysis Cell, *Natural Gas Production Current and Historical*, 2014c.

Figure 12 gives a clear picture about the natural gas deficit and the demand-supply imbalance of India. This forecasted demand in the 11th and 12th plan, is based on the expectation of 80–100 MMSCMD from domestic supplies more predominantly from the

Krishna-Godavari basin D6 fields[13] (hereinafter KG D–6). But due to technical problems the project failed to deliver the committed quantity (Ahn & Graczyk, 2012, p. 70). In addition to a substantial reduction of output from KG D–6, the question of availability of overall reserves as originally projected is the growing concern. If the fields turned out to be hostile then India needs to speed-up its exploration activities in the other NELP blocks awarded for better energy security.

Policymakers of India have pursued two options for meeting deficit in natural gas. The first was LNG imports and the second was transnational pipelines. LNG import started in 2004 and since then the imported volume is increasing each year. India joined the global LNG market in March 2004, when Petronet Dahej LNG terminal was commissioned (Balyan, 2013). Looking into the future of import of natural gas through trans-national pipeline the Turkmenistan–Afghanistan–Pakistan–India (hereinafter: TAPI) pipeline project is the pioneer. Initiated in 1995, it has faced and is still facing huge geo-political insurgencies in the countries through which the pipeline was proposed to pass through. Despite the severe set-backs, the project made some progress in May 2012 when the Gas Sales and Purchase Agreement (hereinafter: GSPA) was signed between the India and Turkmenistan. Further discussions on the trans-national pipeline imports of India are covered under section 3.1.2. Stripped of conventional natural gas reserves which are under constant depletion, the government is on the anvil of approving a set of new guidelines that allow investments for exploring and developing natural gas from unconventional resources, such as shale gas, tight oil or gas etc.

2.5 Natural gas policy and regulations

In the absence of a market mechanism, policymakers formed the GLC in 1991 to enable the allocation of gas and to manage the supply deficit. Another reason for initiation of such reforms was the death knell when India defaulted on her loans and appealed for bailout from the International Monetary Fund (IMF) (Global Policy Forum, 2014). IMF bailed out India with a pre-condition that the Indian government initiates further reforms for stability and security of energy economy. This stepping stone that paved the way for India's emergence as a free market economy.

The objective of GLC was to better manage the gap between demand and supply. The committee completely failed in its initiative could not bail out the economy of oil and gas due to heavy subsidies. The prices were being pegged at very low levels in comparison to the global price scale. The reasons cited are primarily politically motivated for simple electoral gains. The government of India imported oil at higher costs and sold at a lower cost. This created a big void in central treasury. Even 1991 liberalization of oil and gas

[13] Krishna-Godavari D6 fields (hereinafter: KG D–6) is the off-shore well of M/s. Reliance Industries. Well is known as Dhirubhai Ambani (D), sixth block in the Krishna River and Godavari River basins in Andhra Pradesh. The site is known for the biggest natural gas reserves in India in 2002.

market failed to attract private investors as they circumspect the governmental initiatives (Singh & Mitra, 2010). The committee could not come up with any innovations in bridging the gap, as the demand continuously increased while the prices were kept low. Due to controlled price regime, the state owned industries ONGC and OIL, had very less incentive to improve the yields in the exploration and production of gas and oil from their fields. The companies' balance sheet reflected very marginal increase in the revenue, in comparison to their huge investments. The government was completely stranded with constant increase of the oil prices on the international market greatly attributed due to geo-political crisis in the Gulf region. With raising demand and very slow exploration and production of hydrocarbon reserves led to a re-liberalisation of the sector in the mid-1990s. In the 1990s, as part of this process the government auctioned-off fields that had been 'discovered' but not fully developed by NOCs. The DGH was set up in 1993 and the NELP was launched in 1998.

The NELP, effectuated in 1999, is a very important turning point in India's oil and gas policy. The NELP was institutionalised mainly to accelerate the exploration and the development of hydrocarbon resources in India to meet the increasing domestic demand. NELP was based on production sharing agreements. It awards exploration blocks through international competitive bidding. The PSUs started competing on equal footing with private and foreign companies under the NELP with the Production Sharing Contract (hereinafter: PSC) became the controlling instrument (Ahn & Graczyk, 2012, p. 41). Till today nine rounds of bidding have been carried out under the NELP and 249 oil and gas blocks were awarded. With the introduction of the NELP auctioning, India's unexplored sedimentary areas decreased from 50% in 1995–96 to 15% in 2010 (Directorate General of Hydrocarbons, Government of India, 2014a). But the growing concern is that NELP has failed to attract international investors and the bidders till today have been predominantly domestic private sector companies.

2.5.1 Key regulators of natural gas market of India

The MOPNG oversees the entire oil and gas sector, ranging from exploration, production, refining, transportation supply, distribution, marketing and pricing. It also oversees import, export and is responsible for implementing reforms for the conservation of petroleum products and natural gas. The MOPNG regulates the allocation of gas under the gas utilization policy and pricing of gas produced by the public sector undertakings through administrative orders. The gas from private and joint ventures under the NELP fields is governed through production sharing contracts The DGH is the upstream regulator empowered to monitor the country's exploration and production activities both in oil and gas as well as coal based methane projects. It is mandated to obtain all data from all lessees/licensees in order to monitor the government revenues from upstream projects. PPAC created in 2002 administers the subsidies on petroleum products such as diesel, kerosene and domestic liquefied petroleum gas (LPG). It analyses trends in the oil and gas market, including prices of domestic as well as import/export petroleum products. The PNGRB was created in 2006 as a downstream regulator. It regulates the refining, processing, storage, transportation, distribution, marketing and sales of petroleum products and natural gas. It is the nodal agency for city gas distribution market of natural gas. However, it has no price setting power, which weakens its authority to regulate the downstream sector.

2.5.2 Gas utilization policy

In 2008, the government introduced the new set of guidelines for distribution and sale of natural gas in the market known as Gas Utilization Policy. The large gap between demand and available supplies prompted the government to develop a policy for better administrative control over prices and volumes to be allocated to end-consumers. The policy refers to a system of prioritised allocation of natural gas among consuming sectors, particularly power and fertilizers. The main objectives include:

- to manage shortages in gas availability.
- to provide gas at subsidised prices to the consuming sectors to keep the final product/service output accessible by all sections of the society.
- to play an integral part in the planning process.

This policy refers to a system of prioritised allocation of gas among consuming sectors. Table 14 shows the current priority list of natural gas allocation in India (Ministry of Petroleum and Natural Gas, Government of India, 2013b).

Table 14. Gas allocation priority list in 2014

Order of priority	
For existing customers	**For green-field customers***
1. Fertilizer producers	1. Fertilizer producers
2. LPG and petrochemicals	2. Petrochemicals
3. Power plants	3. City gas distribution
4. City gas distribution	4. Refineries
5. Refineries	5. Power plants
6. Others	

Note: * green-field investment, the investment in a structure in an area where no previous facilities exist i.e. new set-up.

Source: Adapted from Ministry of Petroleum and Natural Gas, Government of India, *Standing Committee on Petroleum & Natural Gas (2013-14), Fifteenth Lok Sabha, Allocation and Pricing of Gas, Nineteenth Report*, 2013b.

The order of the priority does not imply that the gas is “reserved”. It is simply the sequential order of allocation. If one particular customer could not consume gas due to some operational constraints the next category customer becomes automatically eligible to consume that quantity under additional allocation. The guidelines further elaborate that once the gas demand from existing units has been satisfied, the gas should be utilized in the order prescribed for green-field projects. Green-field projects are new projects which do not have any gas allocation but will receive gas only in excess availability conditions, when existing industries have been supplied to its full requirements.

Table 15. Consumption of natural gas industry wise (in million cubic metres) for 2005–13

Financial year	**Consumption of natural gas industry wise (in million cubic metres)**			
	Power Generation	**Fertiliser**	**City gas distribution**	**Petrochemical**
2005–06	11,878	7,762	1,120	1,175
2006–07	11,963	8,497	40	1,377
2007–08	12,037	9,823	1,324	1,432
2008–09	12,603	9,082	1,535	1,105
2009–10	21,365	13,168	1,838	1,264
2010–11	23,583	10,444	6,551	470
2011–12	18,912	10,406	5,759	576
2012–13	12,849	10,702	3,224	437

Source: Adapted from Ministry of Petroleum and Natural Gas, Government of India, *Indian Petroleum & Natural Gas Statistics 2012–13,* 2013, p. 30, Table III.15.

The gas utilisation policy is a curious and complex system which was introduced as an integral function of the planning system of the government. The policy gave priority to power generators and fertilizer producers to ensure cheaper power and cheaper fertilizers availability to all the sections of the society. But looking into Table 15, it can be observed that since 2005, the natural gas consumption by the power plants was higher compared to fertilizer plants. One noteworthy inference might be the lack of pipeline connectivity to all fertilizer plants and the gas allocations made may have gone unused. This highlights synchronicity problems. The gas utilisation policy could not actually serve the real purpose for which it was drafted. Natural gas has a more imposing requirement in the fertilizers sector which is a direct link with the agricultural sector and farmers. The manufacturing process of fertilizer industries requires a huge re-orientation to use natural gas as a primary input when compared to the power sector. Gas is considered more economical than the fuel regularly used i.e. naphtha[14]. This situation has changed with the increase of APM gas prices to US$ 4.2/MMBtu in May 2010. The price issue is dealt under section 2.6 of this thesis.

[14] Naphtha is a component of natural gas condensate or a distillation product from petroleum, coal tar etc. It is a broad term covering among the lightest and most volatile fractions of the liquid hydrocarbons in petroleum.

Shortcomings of the gas utilization policy: The gas utilisation policy, in practice, negates the right of the NELP producers to sell gas on purely commercial basis. The policy gives priority to fertilizer, LPG and power sector. The negative aspect of the policy is that, the green-field industries like Independent Power Producers (IPP) are placed last on the priority list when the nation is passing through acute power crisis. The policy is not flexible enough to understand the essential requirement of the nation, rather than simply following a framework of guidelines. Despite crippling power crisis, the small domestic industrial customer is allocated gas as part of anti-pollution initiatives following old historical court judgement. The policy did not able to adapt to dynamic changes in the natural gas market. This effect underlies the reason for poor investments by private investors. This limits further upstream investments as the high cost of off-shore exploration cannot be recovered from the priority sectors that are highly price sensitive. The government has not instituted any rehabilitation measures for the dead investments of IPP due to declining production from KG D-6 gas fields. India is still far away from having a fully integrated national gas grid. The southern, eastern and central parts of the country suffer from a lack of pipeline connectivity. A fully developed grid would allow gas-fired power generation units and industrial use to spread throughout the country and provide anchor load for other users like city gas and CNG. Many potential industrial consumers are unable to access the gas due to lack of required last mile pipeline connectivity.

2.6 Pricing of natural gas in India

Corbeau[15] (2010), critically analyses the pricing system of natural gas in India. She expresses that "the pricing system in India is relatively complex due to the existence of a dual pricing resulting in two distinct gas markets. In one market, gas produced by PSUs is allocated to specific customers according to the Gas Utilisation Policy and sold under the APM decided by the government. In the other one, gas was produced by JVs or private companies and sold at prices agreed according to the PSCs." The theory behind administered pricing of the government was to fulfil distributional objectives. The pricing in the Indian energy sector has long been controlled at the input end to keep the prices of final goods at minimum. Over the period of time, the Indian mindset has refused to accept that the energy has become costlier. The people still believe that the government has to shell out their money to ensure cheaper oil and gas. Ultimately it is the tax payers' money which is re-distributed over the entire population in form of subsidies. Such an administered control is not solely for economic reason but for electoral gains. Until recently, the political parties have fought election on assurances of the public provision of essential goods at low prices.

[15] Ms. Anne Sophie Corbeau, is Senior Gas Analyst at International Energy Agency, France having wide knowledge of natural gas business of the world but specially acclaimed as expert in having great knowledge of natural gas business of India.

2.6.1 Indian natural gas price evolution

Historically, government of India has played a very important role in the gas pricing to keep it at low to control the output products.

- From 1959 to 1987, gas prices were fixed by ONGC and OIL both being PSUs fully owned by the government.
- In 1987 the Government of India constituted a group of ministers from relevant energy sectors i.e. power, coal, petroleum and natural gas. They were given special powers to determine the pricing and allocation mechanism for petroleum and natural gas. They were called the Empowered Group of Ministers (hereinafter: EGoM). During the 15 year period from 1987–2002, three committees were successively in place and they decided the gas price which included the producer price and petroleum transportation tariff. The tariffs of natural gas transportation through pipelines were also fixed by the EGoM.
- With the introduction of the NELP in 2002 and the production sharing contract mechanism, the APM system was formally abolished for oil but still continued for gas produced by PSUs. With the market opening and NELP auctions, EGoM was dissolved.
- With raising demand and depleting domestic supplies, the first revolutionary decision by the government of India was taken in 2005 when it was decided by the cabinet committee on economic affairs to increase the price of APM gas based on the recommendation of tariff commission[16]. They also decided on the revising the order of priority of allocation and gave gas based power plants higher priority over fertilizer industries due to acute power crisis.

2.6.2 Current natural gas pricing regime

The research paper by Jain and Sen (2011, pp. 36-38) analyzes the natural gas pricing regimes that exist in India at present.

1. On the basis of analysis of various the government orders of MOPNG, at present India has broadly two pricing regimes for natural gas. One is priced under APM and the other as non-APM or free market gas. The price of APM gas is fixed by the government. Furthermore non-APM or free market gas could also be broadly sub-divided into two categories, namely, imported LNG and domestically produced gas from fields of private as well as joint venture operators. The price of LNG imported is governed by the SPA[17] between the LNG seller and buyer. The pricing of natural gas

[16] The Tariff Commission was established in September 1997.Tariff Commission having a multi dimensional structure of experts who are technical experts, cost and financial analysts, statisticians and economists, provides study based inputs for informed decision making by Government.

[17] SPA stands for Sale and Purchase Agreement, a term very common in LNG business across the globe.

from private and joint venture fields is governed by the provisions of the production sharing contract.

2. Apart from APM and non-APM, a third regime covers NELP gas, under which gas producers can calculate and fix the price of gas themselves. They need to justify the basis for the price and get the approval from the government. This price regime is still evolving. As NELP gas will overtake the production from APM and 'discovered fields', the third pricing regime is the most relevant for India in future.
3. Meanwhile, non-APM gas is also sold to consumers at the price at which transporter of gas buys from producers at landfall point. In this case, it depends whether gas is produced under PSC predating NELP, NELP gas or LNG.

Table 16. Prevailing natural gas pricing regimes in India

Source	Regime	Producer price (US$/MMBtu)
APM Gas	APM	4.20
Panna-Mukta-Tapti fields	Discovered Fields	4.60 to 5.65
Ravva field	Discovered Fields	3.50 to 4.30
Lakshmi and Gauri fields	Discovered Fields	4.60 to 4.75
Hazira field	NELP	4.65
D-6	NELP	4.20
LNG (Term)	Imported Gas	9.00 to 10.50
LNG (Spot Prices)	Imported Gas	12.00 to 17.00

Source: A. Jain and A. Sen, *Natural Gas in India: An analysis of Policy*, 2011, p. 36, Table 17; GAIL India Ltd., *Rate Chart,* 2014.

Multiple gas pricing regimes in India have resulted in gas being sold at different prices. Table 16 shows the producer prices for gas. Besides domestic gas, LNG has become an increasing contributor to the natural gas supply mix of India. LNG prices are determined on international markets depending on the contracts which are a mix of short-term, long-term and spot contracts. In India, short-term and spot market comprises 45% of LNG imports. LNG is, effectively, the swing supplier of gas (Kate, Varro, & Corbeau, 2013).

The price of natural gas fixed by the tariff commission at 4.2 US$/MMBtu was valid until 31st March 2014. In April 2012, the Government of India, constituted a competent committee under the chairmanship of Dr C. Rangarajan, chairman of the Economic Advisory Council to the Prime Minister, which was supposed to look into the production sharing contract mechanism in petroleum industry. The committee submitted its report in mid-2013. The committee suggested a new pricing regime to be implemented from 1st April 2014. The committee has suggested mandating the price of domestically-produced natural gas at an average of international hub prices and cost of imported LNG in place of the existing mechanism of market discovery. The committee suggested to the government that, "by first taking an average of the U.S., Europe and Japanese hub or market price and then averaging it out with the netback price of imported LNG to give the sale price of domestically-produced gas" (Rangarajan, et al., 2013). Based on the formula suggested by the report, the government of India issued orders to double the increase of gas pricing to 8.4 US$/MMBtu from 1st April 2014 However, with election on the table during May 2014, few opposition political parties had filed a public petition, labelling the government's order as anti-poor and appealed to the Supreme court of India seeking for justice. Currently the matter is under judgment. Until the court delivers its judgment in this matter the old pricing regime is still in practice.

3 PERSPECTIVES FOR FUTURE DEVELOPMENTS OF NATURAL GAS IN INDIA

In November 2011, the PNGRB constituted a committee comprised of experts from various industry groups of energy sector in order to give suggestions about the infrastructure required for the development of the natural gas sector in India. The committee submitted a document entitled "Vision–2030: Natural gas infrastructure in India". In line with the document the share of natural gas contribution to the energy mix of India is expected to increase from existing 7.8% of the total primary energy demand in 2013 to 20% in 2025. It is evident that natural gas in India is becoming a substitute fuel for oil. Industries which were dependent on oil are switching to natural gas. The usage of oil is predominantly limited to the transportation sector. With the increase of imports of natural gas in form of LNG, trans-national pipeline and the planned infrastructure development, it is forecasted that the vision of 20% can be achieved at the earliest by 2025 or by 2030. From the Table 15 it is seen that power and fertilizer sectors remain the two biggest consumers of natural gas accounting for more than 75% of India's natural gas consumption. To cater to the demand of natural gas it is necessary for initiatives to be taken by the government, learning from the experiences of developed economies.

3.1 Import of natural gas

As discussed under section 2.3, the gap between natural gas demand and supply is widening. It is reckoned that there was a 187 MMSCMD shortage of natural gas supply in 2013–14. This is due to the huge drop in gas production from KG D–6 basin. In 2008, many industries especially independent power producers have been set-up in anticipation of gas from KG D–6 fields. Originally estimated close to 80 MMSCMD, this field slowly dropped in production and came down to approximately 8.05 MMSCMD in July 2014 (Press Trust of India, 2014). To offset this huge decline in production the owner M/s. Reliance Industries has entered into partnership with the British giant, M/s. BP Plc. for developing new resources in the adjacent areas and also revive the dead wells in order to improve the gas yield with advanced technology. Before identifying the options for bridging India's natural gas demand-supply gap, the consolidated sector-wise demand-supply projections from 2016 to 2030, as detailed in PNGRB vision–2030 document, are tabulated in Table 17 and Table 18 (Petroleum & Natural Gas Regulatory Board, 2013, pp. 28-36).

Table 17. Demand of natural gas by sectors in MMSCMD forecasted for 2016–30

Sector	Demand of natural gas (in MMSCMD)			
	2016–17	2021–22	2026–27	2029–30
Power	158.88	238.88	308.88	353.88
Fertilizer	96.85	107.85	110.05	110.05
City Gas	22.32	46.25	67.96	85.61
Industrial	27.00	37.00	52.06	63.91
Petrochemical/ refineries/ internal consumption	65.01	81.99	103.41	118.85
Sponge Iron / Steel	8.00	10.00	12.19	13.73
Total demand	**378.06**	**516.97**	**654.55**	**746.03**

Source: Petroleum & Natural Gas Regulatory Board, "*Vision 2030" Natural Gas Infrastructure in India*, 2013, p. 28, Table 11 and Table 12.

Table 18. Source-wise supply of natural gas in MMSCMD forecasted for 2016–30

Sources	2016–17		2021–22		2026–27		2029–30		Index: 2030/ 2016
	Volume (in MMSCMD)	Share (in %)	Volume (in MMSCMD)	Share (in %)	Volume (in MMSCMD)	Share (in %)	Volume (in MMSCMD)	Share (in %)	
Domestic sources	156.7	52.3	182.0	45.5	211.0	45.4	230.0	48.5	146.8
LNG imports	143.0	47.7	188.0	47.0	214.0	46.1	214.0	45.1	149.7
Gas imports (cross border pipelines)[18]	0.0	-	30.0	7.5	30.0	6.5	30.0	6.4	-
Total	**299.7**	**100.0**	**400.0**	**100.0**	**464.0**	**100.0**	**474.0**	**100.0**	**158.2**
Deficit	**78.4**	**-**	**117.0**	**-**	**190.5**	**-**	**272.0**	**-**	**-**

Source: Petroleum & Natural Gas Regulatory Board, "*Vision 2030" Natural Gas Infrastructure in India*, 2013, p. 35, Table 17; pp. 36, Table 18.

From Table 18, it is seen that the natural gas demand-supply gap shall increase to 272 MMSCMD in 2029–30. The supply of natural gas is likely to increase in future with the the increase of domestic gas production and imported LNG. However, due to technical

[18] It is assumed that Turkmensitan–Afgahnistan–Pakistan–India (TAPI) pipeline shall be commissioned after 2017.

problems, the expected increase in domestic production at present is significantly lower than their original projections. Out of 249 oil and gas fields awarded under the nine rounds of NELP, the commercial production has been commenced only in 24 blocks (Directorate General of Hydrocarbons, Government of India, 2014b). However, LNG shall be fuel for immediate future until the production from domestic sources increase or imports through trans-national pipeline materialize.

3.1.1 Import of Liquefied Natural Gas (LNG)

Balyan (2013), Managing Director and Chief Executive Officer of M/s. Petronet LNG Ltd. (hereinafter: PLL), recognised as one of the pioneers in LNG business in India, predicts "over the next years, there will be substantial increase in natural gas demand from power, fertilizer and industrial sectors. In view of lack of sufficient indigenous supply options to mitigate the growing demand-supply gap, LNG is bound to play pivotal role".

Table 19. Existing and future LNG terminals of India and their handling capacity in MMTPA+

Terminal name	Owner	Capacity	Remarks and future plans
Existing			
Dahej terminal	PLL	10 MMTPA (36 MMSCMD)	plan for expansion to 15 MMTPA by 2016 and later to 20 MMTPA by 2020
Shell Hazira terminal	Shell and Total	3.6 MMTPA (12.9 MMSCMD)	plan for expansion to 10 MMTPA by 2016-17
Dhabol LNG terminal	RGPPL*	5.0 MMTPA (18 MMSCMD)	operates at 1.2 MMTPA due to process limitations
Kochi terminal	PLL	5.0 MMTPA (18 MMSCMD)	operating under very low capacity due to insufficient downstream pipeline infrastructure.
Proposed			
Gangavarm	PLL	5.0 MMTPA (18 MMSCMD)	Gangavarm in Vizag city of Andhra Pradesh state on the East coast.
Ennore	IOCL	5.0 MMTPA (18 MMSCMD)	Ennore in Chennai city of Tamilnadu state on the East coast
Mundra	Adani-GSPC JV	5.0 MMTPA (18 MMSCMD)	Mundra in Gujarat state on the Western coast
Under progress			
Kakinada FSRU**	APGDC	-	FSRU in Kakinada port of Andhra Pradesh state on Eastern coast

Note: + stands for million tonnes per annum (hereinafter: MMTPA); * RGPPL stands for Ratnagiri Gas Power Private Ltd.; ** FSRU stands for Floating Surface Re-gasification Unit.

Source: A. K. Balyan, *Meeting Demand Challenges of an Emerging LNG Market: India*, 2013, p. 6, Table 4.

Presently, India is 6th largest LNG importer. Ongoing development of required infrastructure such as LNG regasification terminals and natural gas pipeline in the country is further strengthening the development of LNG market in India. The construction of a LNG terminal requires huge investments and time. Several companies are contemplating to set up LNG plants in India. Concluding from Table 19, India's current firm LNG re-gasification capacity is 13.60 million tonnes per annum (hereinafter: MMTPA) i.e. 10 MMTPA at Dahej and 3.60 MMTPA at Shell's terminal at Hazira, both in the state of Gujarat. An additional capacity of 1.2 MMTPA from Dhabol terminal in Maharashtra augments the Re-gasified LNG (RLNG) basket only for 6 months out of a year. The major setback is that it doesn't operate throughout the year because of rough Arabian Sea during the monsoon season and the lack of breakwater facilities, besides facing heavy financial debt. Due to process bottlenecks the terminal does not even operate to its full design capacity of 5.0 MMTPA. The government is trying out various options to bail this project out for better times. In future, the Dahej terminal's expansion shall take place, increasing its capacity to 15.0 MMTPA by 2015–16. Shell's Hazira terminal is also likely to be expanded to 10.0 MMTPA by 2016–17. PLL has recently added another 5.0 MMTPA terminal in Kochi in the state of Kerala in August 2013. All four regasification facilities are on the western coast of India. The best economical option is to import the LNG from the west, from countries such as Qatar, but imports become expensive when imported from the eastern countries such as Australia, Indonesia etc. This drawback will be eliminated in the near future when Indian Oil Corporation Ltd. (IOCL) sets up its 5.0 MMTPA at Ennore in Chennai and PLL sets up its 3rd LNG terminal at Gangavaram in Visahakpatnam, both these terminals coming up on the eastern coast targeted by 2017–18. As a stop-gap arrangement, which will bridge the gap between demand and supply of natural gas, certain short term and ready-made LNG terminal infrastructure projects are also on the way. One such project on the Eastern coast is planned by the state government of Andhra Pradesh. It had initiated the project of Floating Surface Re-gasification terminal (FSRU) in the Kakinada Port, where the plan is to outsource the pre-fabricated terminal to re-gasify the LNG. This terminal is expected to commence its operation by late 2015.

LNG is India is being imported through a mix of long term, short term and spot basis contracts. India currently has the following long term contract agreements between:

1. PLL and RasGas, Qatar for 7.5 MMTPA (Petronet LNG Ltd, 2013).
2. PLL and Mobil Australia Resources Limited for 1.44 MMTPA from Gorgon Project, Australia (Petronet LNG Ltd., 2013).
3. GAIL and Chenniere Energy, US for supply of for 3.5 MMTPA LNG over 20 years with Sabine Pass Liquefaction, LLC, a subsidiary of Cheniere Energy Partners, L.P., USA (GAIL India Ltd., 2014).
4. GAIL and US Dominion Cove Point (2.3 MMTPA) (GAIL India Ltd., 2014).
5. GAIL and Gazprom, Russsia for 2.5 MMTPA (GAIL India Ltd., 2014).

Of the five agreements listed above, the 1st and 2nd are currently active while the long term agreements of GAIL with suppliers are expected to commence during 2018–20. LNG is also imported into India under various contracts between the Indian buyers and global suppliers on medium and short term basis. In the recent years we have also witnessed a huge spot purchase by Indian energy players. A spot market is very lucrative business during the summer when India is faced with acute power crisis. In the future, India will play a key role in the global LNG market due to its depleting domestic resources. The LNG suppliers across the globe are witnessing that the LNG trading is picking up fast in India and that it shall continue to accelerate at rapid pace in next 10–15 years. It is extremely important that India prepares itself for signing successful long term agreements and that it develops the necessary infrastructure for taking in the supplies without wasting time. The world is keenly monitoring the natural gas needs of India. Russia, North America, Africa and Australia have already started expanding their liquefaction[19] terminals with an eye on Indian imports (Kate, Varro, & Corbeau, 2013).

Indian companies must look at diversifying their portfolio in terms of source and pricing. In terms of future perspective of LNG imports by India following points needs to be addressed by the government (Balyan, 2013):

- The pricing of LNG is very important if natural gas is considered as a substitute fuel. Natural gas will face serious competition from coal if the price is not competitive, as India holds the fourth largest coal reserves in the world. Natural gas has the benefit of being a cleaner, greener fuel, while Indian coal suffers from poor calorific value and high ash content forming a huge threat to the government's anti-pollution initiatives. The government plays a very critical role in deciding between reducing the emissions and the energy access at lowest possible price. Higher fuel costs will increase the price of energy produced. This shall create a deficit in treasury, if the electricity prices are continued to be subsidised.
- Currently the fertilizer sector uses the cheap domestic gas as its raw material. LNG can be used in manufacturing of fertilizers if the cost of LNG is nearly comparable to domestic gas prices. Imported LNG has to be cheaper for fertilizer industries, when compared to the direct import of fertilizers.
- Another bottleneck will be the LNG re-gasification capacity and downstream transportation infrastructure. For more LNG imports as per the future long term agreements, rapid development of re-gasification terminals and downstream pipeline infrastructure is very important.

From the Table 5, it is seen that in 2013 the far-eastern countries like Japan (119 bcm), South Korea (54.2 bcm) and other Asia-Pacific countries (40.4 bcm) had accounted for more than 60% of LNG imports of the world. Recently China is planning huge imports of

[19] Liquefaction is the process of converting gas to liquids and in this case natural gas to LNG at −162°C and 4 psi.

LNG and has therefore started the investments and initiatives on a war-footing. India faces stiff competition from these markets and government has to move quickly. A holistic approach to review pricing of all energy sources needs to be undertaken for creating an investment environment for sustainable growth. The reforms in taxation, excise duties, import policies need a faster review by the government. India should also have to look at few strategic decisions like upstream participation in integrated liquefaction projects around the world (Kate, Varro, & Corbeau, 2013).

3.1.2 Import of natural gas through trans-national pipelines

New LNG terminals will be coming up in another 2–3 years, on the eastern, as well as the western side of the Indian peninsula. The government is also pushing vehemently to increase domestic production of gas from awarded NELP acreages. The natural gas import through pipeline is also a very economical option considering the huge volumes it can handle. From Table 5, it can be seen that the volume of the natural gas being imported through pipelines is higher compared to LNG imported through carrier vessels. The pipeline imports of the US in 2013 stands at 78.9 bcm from Canada. Germany imported 95.8 bcm, Italy around 57.6 bcm and the UK around 41.6 bcm in 2013 from Russia. Realizing this, the Indian government started discussions in early 1990s with its neighbouring countries for trans-national pipelines. Two pipeline projects were part of the dialogue with neighbouring nations for a very long time. The first one was the Turkmenistan–Afghanistan–Pakistan–India (TAPI) pipeline from Turkmenistan and the second one was Iran–Pakistan–India (IPI) pipeline from Iran. The third pipeline was from Myanmar lost its momentum since inception (Corbeau, 2010, pp. 35-36). From Table 4 and Appendix B it is evident that Turkmenistan and Iran have huge gas reserves which can meet the demand for another 280.3 and 202.8 years respectively.

The Indian government started the initiative for gas supplies through trans-national pipeline with Turkmenistan and Afghanistan way-back in 1995. This was before the Afghan war and the US intervention in Afghanistan. Turkmenistan has huge gas potential. This 1800 km long pipeline would be designed to carry up to 33 bcm per year of which India would share 14 bcm per year, equivalent to 38 MMSCMD. The proposed pipeline originating from Turkmenistan shall be routed through the countries of Afghanistan and Pakistan before ending in India, catering all consumers along its route. The project has not moved ahead for 17 years. But in May 2012, GSPA was signed between the state owned entity GAIL and Turkmengaz. This was the flagship movement in India’s foreign policy reforms (2012). The project has strong backing from the US government who currently holds more strategic control over Afghanistan and has very good defence trade ties with Pakistan. Contrarily, from the Indian perspective as remarked by Ebinger (2011) “TAPI remain on the backburner as the security situation in Afghanistan and Pakistan deteriorated and Indo-Pakistani relations continue to flounder”.

The draft gas pipeline framework agreement signed between the governments of Turkmenistan, Afghanistan, Pakistan and India addresses these security concerns and Afghanistan has pledged to resolve them. The recent press release by MOPNG, the Government of India states that the interested partners have planned an international consortium specifically for its operation. The construction cost was estimated at US$ 7.6 billion in 2008. As per news release, the pipeline is expected to become operational in 2018 (Ministry of Petroleum and Natural Gas, Government of India, 2014b).

Another pipeline to suffer such insurgency is the Iran–Pakistan–India (hereinafter: IPI) pipeline. In the geopolitical scramble the IPI pipeline has suffered the worst. Conceived initially as a trade link between Iran and India, the pipeline has to merely cross Pakistan on its route. However Pakistan was never a participant in the initial dialogue. Various books and media news narrate the obstacles put forth by Pakistan in transit fees, pipeline security threats etc. It is speculated that there is a silent political pressure from the US, which was backing for Turkmenistan gas pipeline to South Asia. Remarked commonly as “peace pipeline”, this pipeline has very ancient historical roots. The feasibility of this pipeline has been discussed in an article entitled “Persian Pipeline” by Malik Aftab Ahmed Khan, an army engineer from Pakistan in mid-1950s. The article discuss about a pipeline from Iran to India through Pakistan and the security threat en route in Baluchistan province.[20] The Persian pipeline idea was once again rechristened in 1989 by Mr. Pachauri, the Nobel Peace prize winner and current Chairperson of Intergovernmental Panel on Climate Change (IPCC), who was at that time the Director-General of the Energy Research Institute of India. He held talks with Mr. Ardakeni, the then deputy foreign minister of Iran. The pipeline was formally launched in mid-1990s (Ebinger, 2011). Several discussions on the modus-operandi of the pipeline were held between the three nations. India withdrew from the dialogue after the terror attack in Mumbai on the 26th of November 2008. But Pakistan was quick to cash in on the opportunity and to sign the agreement with Iran for the part of the pipeline up to their border targeting to commission by 2015 (International Gas Union, 2009).

Despite all the potential for a deal on a long-planned pipeline from Iran to India (the IPI pipeline), geo-political events, huge cross-border barriers and uncertainties have so far put-off the IPI project. Today security threats pose a severe problem for all pipelines crossing through these insurgent nations. Europe is also a victim of such insurgencies, for example in Ukraine which lies en route in the Russian Gazprom pipeline. It is an undeniable fact that the South Asian regional rivalries hinder the promotion any cross-border permanent infrastructure investments. Another important aspect is that the discussions for these trans-national pipelines are on the desk for a longer period of time than they would have been if the actual pipeline had been built. The major question is the continued availability of reserves even today, as per the country’s original commitment some 20 years ago.

[20] Baluchistan is the sub-divisional province of Pakistan. The province was administered by a Chief Commissioner appointed by the Federal Government.

Eventhough the reserves have been re-evaluated upward, the reluctance of the erstwhile Indian government is mainly because of geo-political, geo-strategic and geo-economic factors, which have made these projects remain as pipeline dream. These trans-national pipelines may not bring in cheap gas, but would ensure huge volumes of gas reliably over a longer duration of time (Singh, 2008). These pipelines must be seen as opportunities by the governments for better economic and strategic ties among the neighbours breaking all the barriers of the communal and political tangle.

3.2 New sources of natural gas

3.2.1 Shale gas

Shales are a type of sedimentary rocks. They serve as the source for hydrocarbons migrating into permeable reservoirs and act as seals for trapping oil and gas in underlying sediments (Boyer, Clark, Joechen, Lewis, & Miller, 2011). Shale gas reservoirs are called **shale plays**. For decades, oil and gas industry generally regarded them as nuisances to be tolerated during the drilling of reservoirs targeting oil and gas. To define **shale gas** is that gas that remains tightly trapped in shale formations and contains primarily methane. Geologists and scientists backed their research which revealed that specific type of shale called organic-rich **black shale** are a potential sources of hydrocarbons and also serve as reservoirs for oil and gas. This is formed when shale rock has been subjected to heat and pressure millions of years ago at depths ranging from 5000 to 15000 feet. Shale gas is another form of un-conventional gas. Initially to drill for shale gas was estimated to be a very expensive investment. But over the past decade, the combination of horizontal drilling[21] and hydraulic fracturing[22] has allowed access to large volumes of shale gas that were previously uneconomical to produce. The US is the pioneer in shale gas exploration and the shale gas production has rejuvenated the natural gas industry of the US. The potential emergence of shale oil presents both major strategic opportunities and challenges for the oil and gas industry and for governments worldwide. Many countries are currently in the fray in exploring their shale resources. Notable countries developing their shale gas resources are Argentina, Australia, China, India, Mexico and Poland. Researchers, scientists, policymakers etc., interested in the shale gas development in their area are closely analysing the success of shale gas exploration the US. It shall increase the energy independence of many countries and could also influence the dynamics of geopolitics and reduces the influence of Organization of the Petroleum Exporting Countries (hereinafter: OPEC). Despite the technological advancement in extracting the shale gas, there are several potential environmental concerns. The detail on shale gas in India is discussed under section 3.3, while the shale gas development across the world and in particular the US is placed in Appendices J and K.

[21] A type of drilling in the horizontal direction guided by accurate control measures.
[22] Hydraulic fracturing is a technique in which rock is fractured by a hydraulically pressurized liquid. It is also commonly called fracking.

3.2.2 Gas hydrates

Gas hydrates are crystalline, ice-like substances composed of gas molecules such as methane, ethane, propane, etc., being held in a cage-like ice structure. Also called Methane hydrates, they are naturally occurring un-conventional sources of hydrocarbon, formed from a combination of water and one or more hydrocarbon or non-hydrocarbon gases. In physical appearance, gas hydrates resemble packed snow or ice. Technically called "gas clathrates"[23] they are stable only under specific pressure-temperature conditions. Gas hydrates occur in two discrete geological situations. One are marine shelf sediments[24] and second are on-shore Polar Regions beneath permafrost[25]. Gas hydrates are deducted seismically. Research and development are trying to determine the process of utilisation of these resources for a sustainable future of natural gas. The data released by the USEIA projects that "global estimates place the gas volume (primarily methane) resident in oceanic natural gas hydrate deposits in the range of 30000 to 49,100,000 trillion cubic feet (hereinafter: tcf), and in continental natural gas hydrate deposits in the range of 5,000 to 12,000,000 tcf. Comparatively, current worldwide natural gas resources are about 13,000 tcf and natural gas reserves are about 5,000 tcf" (1998).

India's quest for energy has made it focus on the methane hydrates. With this objective the Indian government launched the National Gas Hydrate Program (hereinafter: NGHP) in 1997. The various projects under this programme are constantly reviewed by a steering committee set up by the MOPNG. The program is technically co-ordinated by the DGH. The NGHP consists of technical committee formed by a consortium of national exploration and production companies (both ONGC and GAIL) together with national research institutions namely, National Institute of Oceanography, National Institute of Ocean Technology and National Geophysical Research Institute. The government of India had sanctioned an amount of 35 million US$ up to March 2012 (Directorate General of Hydrocarbons, Government of India, 2014c). Currently research and development is being carried out in two areas in Indian waters, one along East Coast and other on West Coast. Originally targeting mid-2015 for the commercial production of methane from gas hydrate, the programme is presented with serious of challenges. The main challenges are (Collett, et al., 2008):

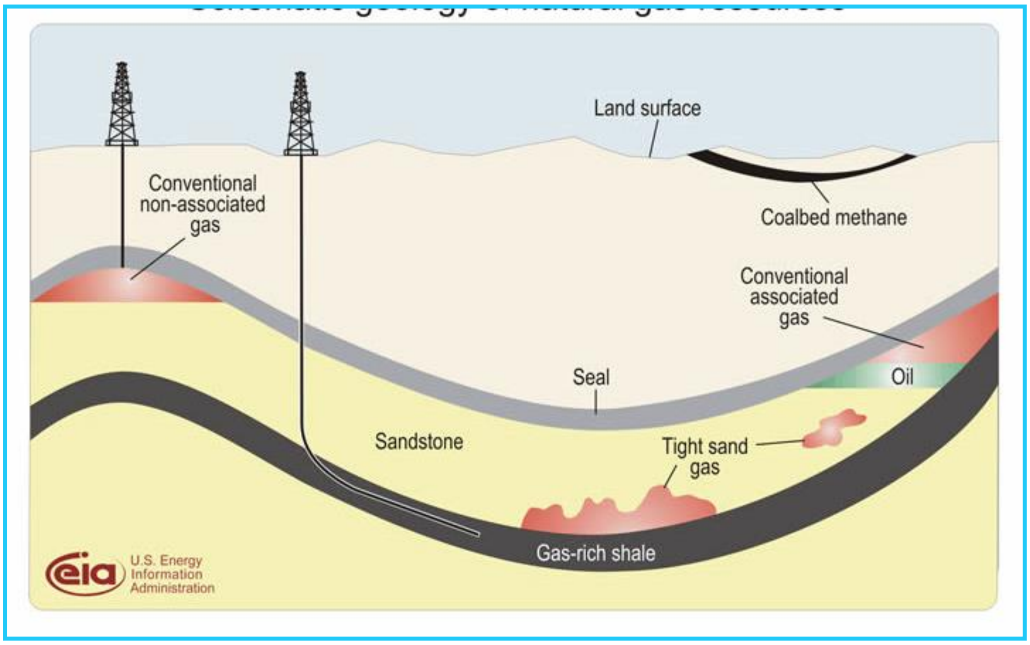
1. absence of representative deepwater gas hydrates field anywhere in the world,
2. gas production rate. The earlier incident of very low gas production during testing of Mallik[26] well in Canada, which, in the permafrost area could not sustain more than 7 days of production,

[23] Clathrates are substances in which molecules of one compound are completely "caged" within the crystal structure of another. Gas hydrates are one type of clathrate.
[24] Marine life sediments is an underwater landmass.
[25] In geology, permafrost is soil at or below the freezing point of water 0°C.
[26] Mallik Gas Hydrate Production Research Well (Mallik test well) is located in the Beaufort Sea, Canada. It is the first dedicated scientific and technical research site investigating permafrost gas hydrates.

3. large amount of water is expected to be produced along with the dissociation of hydrates which needs to be managed.
4. reservoir subsidence[27] and other environmental hazards.

Despite huge road blocks, the scientists and researchers in the project are committed to the task. Realizing the need of the hour, the co-ordinator, DGH had signed various memoranda of understanding with Japan Oil, Gas, Metal Corporation JOGMEC, Gas Hydrate R&D[28] Organisation (GHDO) of the Korea Institute of Geology, Mining and Materials (KIGAM) and the US Department of Energy (USDOE) (Directorate General of Hydrocarbons, Government of India, 2014c). To conclude, earth's vast deposits of natural gas hydrates hold the future of the world's natural gas needs. The detailed knowledge of the gas hydrates is scant. The best possible solution is that global community of scientists and researchers in this project have to come together and work in tandem.

Figure 13. Schematic geology of natural gas resources



Source: US Energy Information Administration, *Today in Energy: The Geology of Natural Gas Resources*, 2011.

3.2.3 Coal based methane

Methane is the predominating hydrocarbon of natural gas and is the main constituent for the calorific value[29] of the natural gas. It is a common perception that methane is closely related to petroleum products, but is occurs in association with coal also. Coal Based Methane (CBM) is an eco-friendly unconventional form of natural gas stored in coal seams

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[27] Shifting of the earth's surface below the existing datum of sea-level.
[28] R&D stands for Research and Development (hereinafter: R&D).
[29] The amount of energy available in a item in general. In case of natural gas, it is the amount of heat produced by the complete combustion of a fuel.

generated during the process of coalification[30]. It is simply the methane recovery from un-mined coal seams before mining of coal. CBM is recovered from un-mined coal seams for two primary reasons (US Environmental Protection Agency, 2009):

- as a safety practice to drain the methane case from the coal bed before the mining of coal. It is necessary to drain the methane gas to reduce the risk of explosion.
- utilizing this gas for commercial purpose by proper tapping technique mitigates methane emissions to the atmosphere. Methane can be used for energy production before mining of coal.

CBM exploration and exploitation prevents the methane emissions from open cast coal mines to freely enter into the atmosphere. Besides utilizing it for the commercial production of energy, controlling carbon emissions can earn huge carbon credits. Moreover, extracting methane from coal bed prior to mining of coal through degassing of the coal seams is the best economical method of boosting coal production, besides maintaining safe methane levels in working mines.

In the world commercial production of CBM is a proven technology. In July 1997 India formulated the policy for exploration and production of methane gas from coal bed. Being the 4th largest holder of coal reserves in the world, the commercial recovery of CBM in India is significantly very high.

Table 20. CBM resources and exploration in India as in 2013

Details of CBM project	Results
Prognosticated[31] CBM resources	92 tcf
Established CBM resources	8.92 tcf
Total available coal bearing area	26000 sq. km
Exploration initiated	17000 sq. km
Blocks awarded	33 nos
Commercial production of CBM gas	0.23 MMSCMD

Note: * tcf stands for trillion cubic feet; ** sq. km stands for square kilometres

Source: Petroleum Planning & Analysis Cell, *Ready Reckoner: Snapshot of India's Oil & Gas data*, 2014, p. 5, Table 6.

Four rounds of bidding for CBM exploration blocks have been carried by the DGH under NELP and 33 blocks have been awarded (Table 20). However, only five blocks are currently producing gas of approximately 0.23 MMSCMD (Petroleum Planning &

[30] Geological formation of coal by gradual heating and compression of organic matter.
[31] It is the term used technically in CBM predicting the remaining residual gas after which it shall cease to exist.

Analysis Cell, 2014a). The progress is very slow and output is very low compared to huge volumes of coal in India. Taking this into the view, the government of India has allocated considerable funds for CBM projects in the recent budget of 2014 and it was pledged that production and exploitation of CBM will be accelerated. The US is the pioneer today in commercial production of gas from CBM. Table 21 shows the production of natural gas from coal bed in the US.

Table 21. Statistics of CBM production in the USA from 2008–12

Source	2008	2009	2010	2011	2012
Production from coal bed wells (in tcf*)	2.02	2.01	1.92	1.78	1.54
Total production of natural gas (in tcf)	20.15	20.62	21.32	22.90	24.06
Contribution of CBM for overall share of natural gas production from all sources (in %)	10.03	9.74	8.99	7.76	6.39

Note: * tcf – trillion cubic feet

Source: US Energy Information Administration, *Natural Gas: US Coal Bed Methane Production*, 2014.

From Table 21 it is seen that approximately 6.4 % of natural gas produced in the US is produced through CBM. This percentage was higher in 2008, but slowly the beds are getting degasified. Further exploitation of coal beds are in the process. However, major concentration is towards shale gas resources. India is currently experiencing a huge energy scarcity and has to therefore push the CBM projects at a more rapid pace as it has huge amount of coal reserves standing as the fourth largest holder of coal reserves.

3.3 Shale gas perspective for India

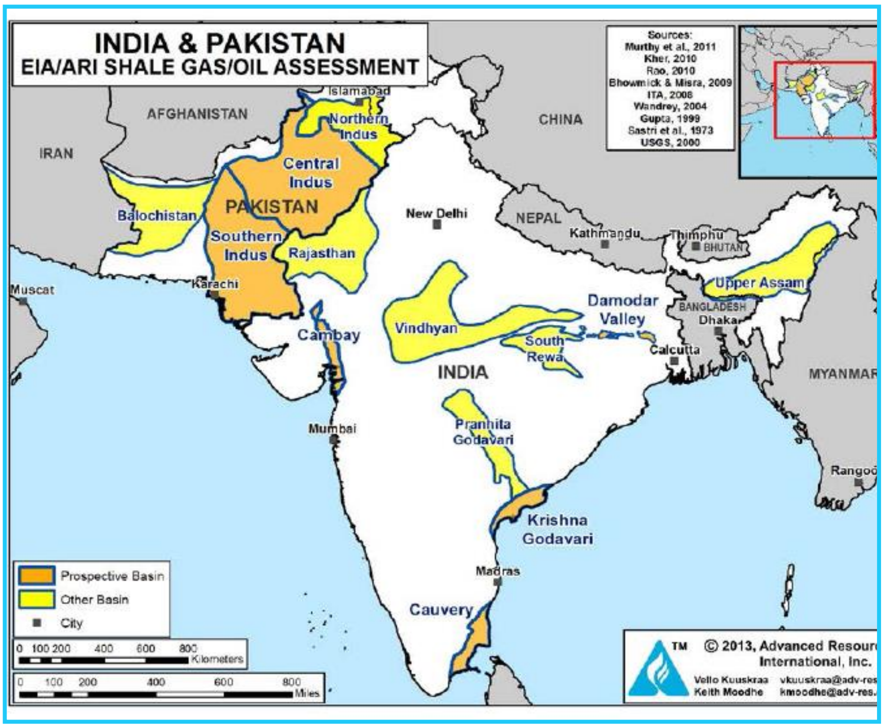
With the advent of improved technology shale gas extraction is no longer an improbable venture. The reserve accretion, production and development of shale gas from one basin to another around the world are rapidly increasing. India also appears to have a large resource of prolific matured shale distributed in different onshore sedimentary basins such as Cambay, Krishna-Godavari, Cauvery and Damodar valley (Sunjay, 2012). In the report prepared by M/s. Advanced Resources International Inc, for the USEIA (2013b, p. XXIV), four priority basins were assessed and reported, namely, Cambay, Krishna-Godavari, Cauvery and Damodar Valley. India holds 584 tcf of shale gas reserves in place but only 96 tcf is technically recoverable as shown in Table 22. In its country analysis by USEIA on India (2014b), it has been stated that many companies are interested in shale gas exploration projects in India, but the government has not unveiled any shale gas and oil policy.

Table 22. Size of assessed shale gas resources of India at basin and formation levels

Basin	Formation	Risked gas-in-place (tcf)	Technically recoverable (tcf)
Cambay	Cambay Shale	146	30
Krishna-Godavari	Permian-Triassic	381	57
Cauvery	Sattapadi-Andimadam	30	5
Damodar valley	Barren Measure	27	4
	Total	**584**	**96**

Source: US Energy Information Administration, *Report on Technically Recoverable Shale Oil and Shale Gas Resources: An Assessment of 137 Shale Formations in 41 Countries Outside the United States*, 2013, p. Attachment A.4,Table A-4.

Figure 14. Geographical map of India showing the prospective shale gas basins



Source: US Energy Information Administration, *Report on Technically Recoverable Shale Oil and Shale Gas Resources: An Assessment of 137 Shale Foermations in 41 Countries Outside the United States*, 2013, Figure XXIV-1.

The geographical map of India showing the shale basins in Figure 14 is reproduced from the report to understand the isolated nature of the basin. To quote from the report, “ONGC drilled and completed India’s first shale gas well, RNSG-1, northwest of Calcutta in West Bengal. The well was drilled to a depth of 2,000 meters and reportedly had gas shows at the base of the Permian-age[32] Barren Measure Shale” (US Energy Information Administration, 2013b). In Cambay basin, two wells have been drilled and found to have

[32] The Permian-age is the geological period which represents the period million years ago.

modest reserves of Black Shale. USEIA report cites that many of the basins are mostly isolated in nature and geological nature of the shale is highly thick which would make it technically not recoverable. Moreover archives of geological data are not available with government of India and speculative surveys could not be made accurately.

The shale gas prospects in the Cambay basin in Gujarat and the Assam-Arakan basin in north-eastern India are only speculations while the MOPNG has not released any official figures on shale gas exploration and production. DGH also has not called for any expression of interest options for shale gas development. The annual report on hydrocarbon exploration and production activities of India by DGH (2013, pp. 66-68), states that it has initiated systematic approach for shale oil and gas exploitation. In this direction memorandum of understanding has been signed between MOPNG and Department of State, United States of America, on 6th November 2010. As per the understanding both the partners shall co-operate in areas of assessment of shale gas resources in India, technical studies, consultations in regulatory framework and investment promotion. DGH has submitted a draft policy for shale oil and gas exploration in India to MOPNG for necessary vetting in July 2012. Under research and development pilot studies the state owned entity M/s. ONGC has drilled four wells in Damodar valley by hydro-fracturing. On 25th January 2011, one of the well has flowed in surges and it was pioneer event in India from the Barren Measures shales. ONGC is constantly pursuing its shale gas research and has joined hands with M/s. Conoco Phillips, USA for cooperation in exploration and development of shale gas resources in India.

The future of shale gas exploration in India lies in the policy formulation by the government on shale gas. India does not have necessary technology for the shale gas exploration and it is dependent on foreign investors. India has to adopt pro-investment policies for foreign investors like tax credits, easy of entry for business, strong support for research and development through regular allocation of funds in annual budgets etc. India has very high population density, so exploration of shale gas by hydraulic fracturing will be a big challenge. India is already faces water scarcity hence the requirement of huge quantities of fresh water for hydraulic fracturing will be difficult unless alternative methods such as sea-water desalination projects are conceived in parallel. As an important lesson from the US, the Indian government has to back its state owned entities like ONGC, OIL, GAIL for the research and development of shale gas, by giving concessions for the research work. To summarize, Indian government is going to play an important role for exploitation of this unconventional energy for better energy security of the country provided it develops a broad outline of the policy that may include (Sunjay, 2012):

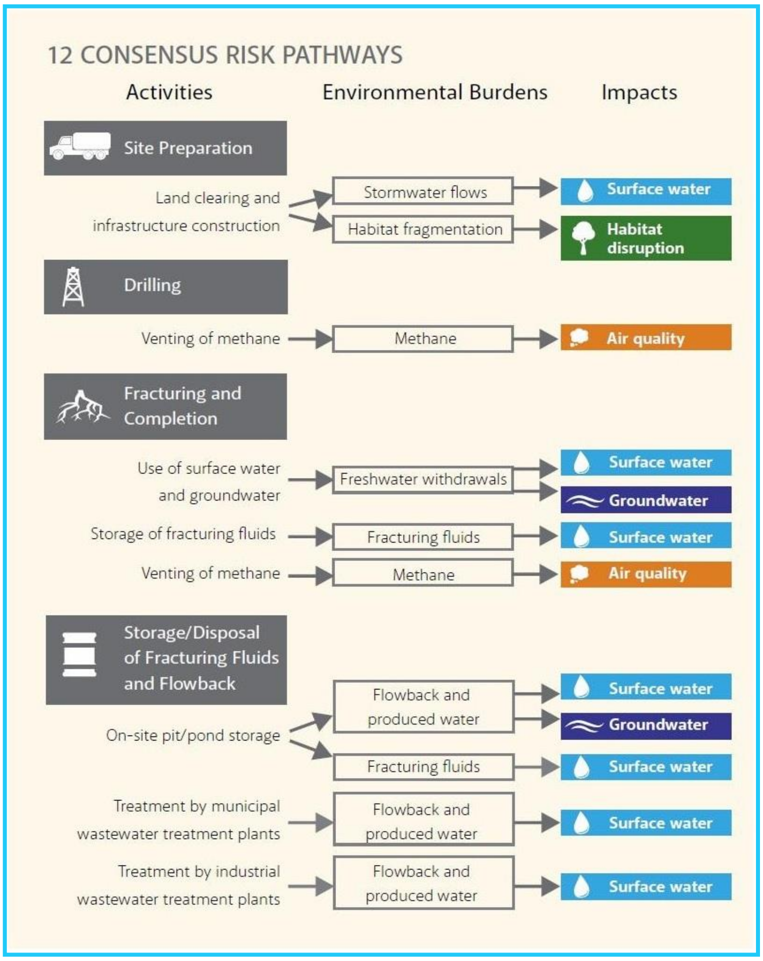
- generation of near accurate geological data of prospective basins and areas as the areas are isolated,
- estimation of shale gas resources,
- carving out of exclusive shale gas blocks,

- bringing in necessary policies and reforms to make sure that shale gas as another producible hydrocarbon exclusively for bidding and exploration.

3.3.1 Environmental impacts of shale energy

The availability and the utilization of advanced technology have clearly upheld the US shale gas development over other countries, leading to the shale gas revolution in the US. Advance drilling technologies and production strategies like horizontal drilling, hydraulic fracturing and large availability of fresh water have accelerated the production of oil and gas from numerous unconventional fields across the US notable are the shale gas plays. To commence a development project needs environmental clearances. The clearances are not easily obtained, especially in countries like India having huge population density. Usually, there is huge upheaval from environmentalists and other social activists because of the anticipated negative environmental impacts the project may create. This is more prominent in hydrocarbon projects like coal, oil and gas.

Figure 15. Showing the activities associated with shale gas exploration and the environmental burden and likely impacts



Source: A. Krupnick, H. Gordon and S. Olmstead, *RFF Report: Pathways to Dialogue: What the Expers say about the Environmental Risks of Shale Gas Development*, 2013, p. 54, Figure 7.

Krupnick, Gordon and Olmstead (2013) identified the priority environmental risks related to natural gas exploration and development from shale plays based on a survey. The suvey aimed to identify the pathways to dialogue between the energy leaders and environmentalists. The objective of the survey was to understand the environmental risks of shale gas development. The survey was conducted among experts from government, industry, universities and non-governmental organizations. The survey results had identified twelve consensus risk pathways. Figure 15 details the activities associated with the shale gas exploration and its environmental burdens and the likely impacts. Shale gas exploration has huge impacts on water. It requires huge volumes of water for hydraulic facturing on the input side while huge volumes of effluent water is released as discharge during the process. Vengosh, Nathaniel, Jackson and Darrah (2013, pp. 863-866) senior environmental researchers from Nicholas School of Environment, Duke University, USA, discuss on the possible environmental consequence due to increased shale gas exploration by the US. The three possible major impacts on water quality due to shale gas exploration and hydraulic fracturing are identified as:

1. shallow groundwater contamination whereby discharged effluent water will slowly contaminate the drinking water wells and is a major health hazard for the livelihood in that area.
2. possible hydraulic pathways between deep and shallow formations, in which a big fractured pathway is created between deep bed and shallow water bed due to impact of hydraulic fracturing directly connecting the deep and shallow formations and contaminating the ground water in the shallow zone.
3. disposal of produced and flowback[33] waters associated with high salinity, toxicity, radioactive particles etc., which is hazardous to health of living beings.

The huge quantities of effluent water released during the shale gas exploration are the biggest environmental challenge to shale gas exploration. Countries like India, which have a huge populations and acute water scarcity will have greater difficulty in sourcing huge quantities of water for hydraulic fracturing. Handling as well as treating the effluent flowback discharge water from the wells, to prevent the inhabitants around the area from being affected will be a biggest challenge.

In his article the noted geologists from Russia, Adhushkin and Yudin (2000, pp. 4-7) analyzes the various seismic impacts of oil and gas exploration during the process of hydraulic fracturing. He explains that hydraulic fracturing can induce earthquakes in the

[33] A flowback is a process in which water and other fluids used in hydraulic fracturing flows in the reverse direction from the well to the surface due to pressure difference. The water and other fluids include mixture of associated hydrocarbon elements at a higher pressure which may be hazardous for living beings if discharged freely on the surface. The purpose of the flowback is to safely treat the water getting devoid of all its effluents.

order of 1–3 on the Ritcher[34] scale. The European Union parliament has also released a study report on the impacts of shale gas and shale oil extraction on the environment and on human health (Lechtenbohmer, et al., 2011) and the key findings are that:

- several chemicals used in hydraulic fracturing flowback to the surface along with gas and water which is highly hazardous to the inhabitants around the exploration area,
- air pollutants emission from heavy drill rig equipments, carbon emissions during shale gas processing, chemicals evaporating from effluent settlement ponds, emission in case of blowouts are constant threats to atmosphere,
- huge water demand and high volumes of flowback effluent water,
- area prone to mild tremors due to hydraulic fracturing,
- some organic rich black shales in the US are found to have uranium contents in the range of 0.0016–0.002%. These radioactive emissions are potential occupational safety hazards.

The impacts discussed above demonstrate that a number of serious risks associated with shale gas extraction endangering human lives. The risks associated with shale gas exploration cannot be weighed on a scale from more or less threatening and therefore cannot be neglected. Presently, there is no accurate analytical data available on shale gas extraction threats in comparison to oil and gas exploration, with the most renowned example of oil spillage in the Gulf of Mexico. Eventhough the nature of the risk, probability and its impact is not quantitatively or qualitatively analysed, it is not guaranteed that threats from shale gas are less serious compared to oil and gas exploration by conventional methods. The accelerated technological development in shale gas extraction and production must also bring in innovative measures to mitigate the challenges posed by the process of exploration.

3.3.2 Economic impacts of shale energy

A common goal of an economic enquiry is to ensure that the activity is economically efficient. The economists and the market are often quite interested in analyzing the economic impact of any activity involved in producing a good or service, whether the activity has delivered the desired output levels. The discussions on the experience of the US in exploration of shale gas, has so far not addressed the economic impacts it has created. With improved technology it is quite feasible to extract shale gas. It is clear that from the need of horizontal drilling and hydraulic fracturing for shale gas exploration, the cost of producing gas from shale plays are more expensive in comparison to the cost of extraction from conventional deposits. The shale gas market is still in the infancy stage, and as such there is no authentic data available on the long-term production characteristics

[34] Richter scale assigns a magnitude number to quantify the energy released by an earthquake. It is a logarithmic scale representing the earth quake.

and economic performance of shale gas wells even for the highest efficient Marcellus shale[35] plays.

In the process of the drilling for oil or gas, the technical process is not only the commercial activity. Considine, Watson and Blumsack (2010, pp. 8-10) explains that shale gas exploration and production is associated with planned set of activities which have significant economic impacts. The drilling and production requires manpower for multiple activities. Before commencement of drilling the concerned land has to be legally obtained either as lease or acquisition. The legal and regulatory work such as leasing of land, verifying the land owners' documents and other legal activities needs professional manpower. People are required to identify the lease properties, write leases and conduct related legal and regulatory work. Seismic survey needs technical manpower. Once a prospective site is identified, site preparation and drilling services needs labour and services for local activities. After confirming the availability of shale deposits in considerable quantities huge infrastructure such as well-head equipments, downstream piping, early processing and despatch stations are further added which further stimulates local business activities. When the well began to commercially produce, the company has to pay royalties to landowners and local governments are benefitted by the taxes paid by the company. With the establishment of permanent infrastructure of processing plants, the local area gets developed with community services such as health care, education, public transport etc. There is huge expenditure associated with each stage of production of oil and gas from the well rig. Besides the direct economic impacts, there are many indirect economic impacts. In developing the lease agreements with the land owners, the drilling companies outsource the services of land management companies of the local area who is much aware of the geo-political situation prevalent there. These indirect impacts drive more employment opportunities in the area. The wages earned by locally employed inhabitants increase the household income of the area which are the induced impacts of shale gas economics. The total impact is the sum of direct, indirect and induced spending which is the valuable economic impact on the society resulting from setting up of shale gas exploration projects which is very huge.

Once the project is established, the production initially increases, reaches maturity and further decline due to various technical and geological factors. Without any further investments, it would be difficult to sustain the yield and maintain efficiency in the production. The decreased production co-relates to decreased revenues from the project. The decreased production may sometimes have a legal tangle, in case the supplier could not fulfil the agreed gas quantity to the buyer. The supplier may have to pay huge compensation when the committed quantity is not being met, due to sharp decline in the well producing rates. Usually the oil and gas business has huge profit margins if reliable supplies are ensured, but contrarily will have adverse effects in case of failure to meet the

[35] The Marcellus Shale is an organic- rich sedimentary rock formation in the Appalachian Basin that is estimated to contain significant quantities of natural gas.

committed quantity. As the productivity from the wells decline, the investors have to invest further to remove bottlenecks in the process or by drilling extra. Hefley et al. (2011, pp. 45-65) agrees to the fact drilling a bit extra and hydraulic fracturing may increase productivity in technical terms. The studies were done to analyze the economic implication part-wise for each process in the value chain of shale gas exploration. Hefley and team reckoned the revenue contribution of each process in the value chain by citing several mathematical calculations and various examples. The final summary break-up is tabulated below:

Table 23. The share of estimated cost of shale gas exploration in the value chain (in %)

Process in the value chain	Estimated cost (in %)
Acquisition and leasing	28.64
Permitting i.e. obtaining local statutory permits	0.13
Site preparation	5.23
Vertical drilling	8.67
Horizontal drilling	15.88
Fracturing	32.67
Completion	2.61
Production to gathering	6.17
Total	**100.00**

Source: W. E. Hefley et al., *The Economic Impact of the Value Chain of a Marcellus Shale Well,* 2011, p. 65, Table 12.

From the Table 23 it can be inferred that vertical drilling, horizontal drilling and hydraulic fracturing contributes to roughly 55% of the total expenditure planned. The drilling and hydraulic fracturing is the most expensive and capital intensive of the value chain.

The US is the pioneer and only country in the world currently to produce huge volumes of natural gas from shale plays. In the executive summary of BP Statistical Review of World Energy, Bob Dudley, the executive chairman of M/s. BP Plc. states “driven by massive investment in shale and other tight formations, the US saw the world’s largest increase in oil and gas production last year, offsetting the numerous disruptions seen elsewhere” (BP, 2014, p. 1).

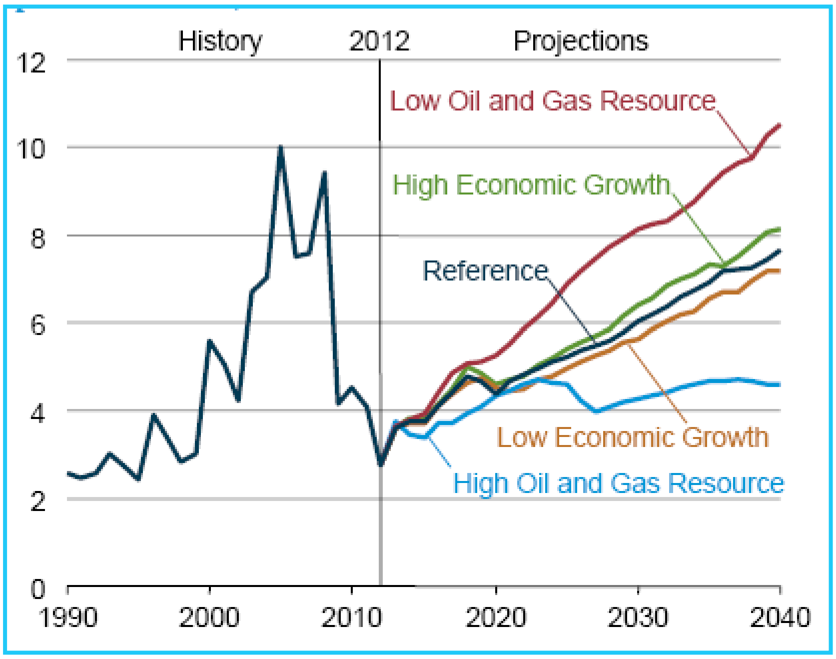
Table 24. Prices of natural gas in the US Henry hub index prices

Year	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Price in US$/MMBtu	5.85	8.79	6.76	6.95	8.85	3.89	4.39	4.01	2.76	3.71

Source: BP, *BP Statistical Review of World Energy*, 2014, p. 27, Table Prices.

In the US, prices were constantly increasing since 2004 up to 2008. In 2009 the prices collapsed to US$ 3.89/MMBtu. Two most important factors seen in price rise and sudden drop in 2009 was the financial crisis that occurred in 2008. But since 2009 there was no substantiate increase in the price of natural gas. Contrarily in 2012, the prices fell to record low of 2.76 US$/MMBtu due to over production specifically from shale gas reserves. The market experts attribute the low prices to overproduction of natural gas from shale plays.

Figure 16. Forecasted average prices of natural gas in the US (Henry hub) price projection from 2014 to 2040



Source: US Energy Information Administration, *Annual Energy Outlook 2014 with Projections to 2040*, 2014a, p. MT-41.

Further as per the independent statistical report by the USEIA, the prices of natural gas in US shall not double even up to 2040 as can be seen from Figure 16 (US Energy Information Administration, 2014a, pp. MT-41). The natural gas prices depend on many factors, including macroeconomic growth rates and expected rates of resource recovery from natural gas wells. Higher rates of economic growth lead to increased consumption of natural gas. From the Figure 16, it can be seen that in the high economic growth case, higher levels of consumption result in more rapid increases both in depletion of natural gas resources and in the cost of developing new production, pushing natural gas prices higher. The converse is true in the low economic growth case.

The various factors working against favourable shale gas economics are increasing production costs, declining production, huge fluctuations in gas prices across the nation, overproduction issues etc. With drop in output during regular production phase, more investments and revenue are needed to improve yields by advanced technology. All of these conditions are inter-related to each another and affect the overall profitability of shale gas activities. Due to heavy competition, the wholesale gas prices in the market drop and it has become difficult for producers of shale gas to achieve profits consistently in comparison to other conventional gas producers. This is very difficult for other nations like Europe, India as they do not have the technological advantage which played the major role in shale gas revolution in the US. On the other hand, the US should focus to invent technology that can produce shale gas cheaper.

3.4 Role of natural gas in sustainable energy future of India

A strong and sustainable energy sector is crucial to maintain the vibrancy of the Indian economy. This is also essential to the prosperity of the global economy. Most climate scientists believe that the increasing concentration of carbon-dioxide is quite an unexpected experiment being carried with the earth atmosphere. The biggest climate change challenge is to use all available energy resources in the most efficient way. Natural gas, a cleaner burning fuel than coal and oil, offers solutions to the world's economic and environmental challenges in a secure and sustainable way. Geologists all over the world believe that the reserves of gas in conventional reservoirs will last enough to meet more than 60 years of demand at today's consumption rates.

PNGRB's natural gas visionary document for 2030 (Petroleum & Natural Gas Regulatory Board, 2013, p. 12), points out that the growth of the natural gas sector in India in the past, as well as the present is very modest. Due to scarce conventional domestic resources and a lack of technological partnership to extract gas from non-conventional sources like shale plays, India's future lies on imported gas both in the form of LNG and through trans-national pipelines. India has unveiled all its plans for building the necessary infrastructure for import of LNG and the subsequent downstream pipeline network which shall be in place in another 5 to 6 years. It is hoped that natural gas shall be fuel for the future of energy security and shall contribute to 20% of the total primary energy demand by 2030. Besides imports, sustainable future of natural gas includes two dimensions, namely:

- the contribution of natural gas towards energy demand sustainably i.e. for longer time
- ensuring sustainable production of natural gas from the existing and new reserves .i.e. in terms of technological improvements.

3.4.1 Natural gas contribution to energy demand on sustainable basis

The government of India is much more concerned about the energy security of the country. In 2004, the prime minister directed the Planning Commission to form an expert committee to draft an energy policy. The objective of the committee was to formulate an integrated energy policy that shall cover all energy sources, addresses energy consumption and production, energy security, access and availability. Moreover the policy has to address on efficient production of energy linked with sustainable development (2006). Set-up in 2004, the committee submitted their first draft report in August 2006 which was approved by the cabinet in December 2008. The Integrated Energy Policy (IEP) is the first comprehensive energy policy by the Indian government and oversees all energy sectors including natural gas business.

India's largest natural gas processing, transportation and distribution company, GAIL, in its annual sustainability report 2012–13 (GAIL India Ltd., 2013, pp. 34-35) has released a list of suggested sustainable measures for natural gas business for India that have potential for natural gas being acclaimed as the fuel of the future. The measures include:

- Sourcing gas supplies that meet the requirements of quality, quantity and cost. This plays an important role towards sustained natural gas business.
- Strategic increase of the investments in the oil and gas exploration and production in India and internationally. In case India can access cheap natural gas overseas under long-term (25–30 years) arrangements, it should consider setting up captive fertiliser and/or gas liquefaction facilities in such countries where the natural gas is cheaper. This would essentially augment energy availability for India.
- LNG is considered as the purest form of fuel or gas. Securing long term contract agreements from diversified sources shall mitigate geo-political and pricing risks.
- LNG formed by process of liquefaction of natural gas is devoid of all forms of impurities like carbon-dioxide, Nitrogen etc. It is friendlier to the atmosphere.
- The US federal government also enabled greater public-private partnership in unconventional gas R&D, coordinating basic and applied research as well as accelerating technology transfer in the industry (Burwen & Flegal, 2013). Besides broader business strategic interests, public-private partnership is very much essential for government to be well abreast with recent trends in gas industry and reform the polices based on existing market priorities.

3.4.2 Sustainable production of natural gas from the reserves

India does not have enough domestic natural gas resources. Moreover, the productions from these reserves are very low. From Table 9 it can be seen that less than 3% of the gas is produced from the proven resources, while the global average is around 5.5%. The shortcomings have been analysed earlier. The primary reason attributing to low production is lack of availability of suitable technology in sufficient quantities to boost production on sustainable basis.

The opening of exploration of oil and gas market shall bring in foreign investments which will benefit in technological development and shall augment domestic supplies. However, government has to devise policies that are attractive and conducive for foreign investments. Lessons can be taken from the US on the attractive schemes of tax concessions, more transparency etc. Like the United States, India need to develop strategies to achieve energy security, economic development and environmental sustainability simultaneously (Luthra, 2014). India has to include natural gas resource assessments in their dialogue with the US, under US-India strategic co-operation. India has to learn from the US experience in shale gas research, development and extraction. Strategic tie-up with US multinational giants already having a strong foothold in the shale gas business is the need of the hour. Such strategic initiatives could contribute to a greater extent to explore more domestic reserves of natural gas for sustainable development and better energy security. Natural gas can also help integrate additional renewable generation into the grid, as gas turbines can cycle down and cycle up quickly as needed. In the US the public-private partnership play a vital role in funding strategic R&D programmes in case of limited allocation of money from the government. Apart from economic aspects, technology holds the forte for the sustenance of natural gas reserves.

CONCLUSION

It is estimated that India will become the world's largest country around 2028, surpassing China, with a population of 1.45 billion. India's population is expected to grow and while China's population is expected to decrease (United Nations News Centre, 2013). This statement is of great concern for every citizen of the country, however it must constantly echo in the minds of policy makers and energy leaders. As of today India's thirst for energy is not quenched. India's future plans needs to align quickly and accelerate faster to match with the increasing demand of energy. All forms of conventional and non-conventional energy sources will play an important role in this energy trilemma, however natural gas will play a pivotal role in solving this. The perspectives for future of natural gas in India shall depend on identifying and trouble-shooting various obstacles.

Energy security: India need to target energy security by achieving self-reliance through increased domestic production and investment in equity oil and gas fields abroad. Natural gas plays a very important role in providing energy security for India. The share of natural gas will increase from 7–20% by the year 2030, looking into the various gas sourcing plans and the associated infrastructure development. Considering the demand, the natural gas production from domestic sources will not be sufficient to meet the energy requirements of India and therefore has to depend on imports. India has to strive constantly reduce its import dependency for hydrocarbons, oil and gas. The government of India has already constituted a competent committee of experts under the Chairmanship of Dr. Vijay Kelkar, noted economist and former chairman of the Finance Commission of India, to study, analyze and report the measures to be adopted in order to reduce the burden of imports (Kelkar, 2013). The committee had made a series of recommendations for improving the licensing and auctioning of policies of the prospective oil and gas basins, and their production sharing contract agreements. India has to focus on its hydrocarbon security through the intensification of exploration efforts and it has to fully cover unexplored basins to enhance oil and gas productivity, but in a time bound manner. Agreements with natural gas rich nations for a longer term are the immediate need of the hour.

Technology: There is less natural gas production from domestic sources as there are available reserves. The constant drop in production from KG–D6 fields has come as a huge blow for many gas based power plants across the nation. The owner has entered into international partnerships to improve the yield and to sustain the KG basin wells. India lacks suitable technology domestically for the exploration and production in adversity. India currently also lacks technology for the extraction of gas from non-conventional reserves such as shale gas, CBM etc. The R&D programmes needs to be strengthened for sustained production from the reserves. Foreign collaborations and R&D partnerships are the need of the hour. Policy makers must be open to all sorts of suggestions from experts in order to initiate suitable reforms for attracting better competition from domestic and international companies. Another option are better public-private partnership programmes in research and development of these natural reserves.

New age explorations: Natural gas exploration from non-conventional sources has been kept in the back-burner by the government. For better energy security the government has to bring in reforms to tap all the available resources of energy conventional, non-conventional and renewables. Since 2012, **the shale gas exploration and production** policy is still in the draft phase. The yield from CBM acreages is less than 0.23 MMSCMD. More monetary allocations are required for these projects without anticipating on any immediate Return-On-Investment. The government has to push the reforms pertaining to E&P of these reserves more strenuously. The success of shale gas and CBM projects depends on quick and early access of these resources for commercial use. India's research and development program in shale gas and CBM are in infancy state and is mal-nutritioned. Every drop of oil and gas needs to be accessed. Shale gas exploration will have huge hurdle due to India's dense population and water scarcity. But with improved technology and R&D these issues has to be resolved to make the project successful.

Infrastructure: India's **pipeline and gas transportation infrastructure** is a step in the right direction, with the government planning to build the national grid and allocating sufficient funds in the recent federal budget in 2014. The pipeline capacity will be doubled to 30,000 km within another 3 to 4 years. The regulator PNGRB has taken pro-active measures in calling interested participants by Expression of Interest (EOI) initiatives in developing the trunk pipelines for cross-country transportation and city-gas distribution network to deliver to the customers. But the energy security of India is better achieved if these pipelines operate at 100% capacity otherwise they represent a loss of opportunity cost.

Policies: Another reason is lack of foreign investments and their involvements in Indian E&P acreages. Due to policy and regulatory challenges, India may lose on foreign investment, especially in areas like deep water E&P, Shale gas, CGD, fuel retailing, etc, despite being an attractive market in terms of demand potential. A stable and consistent regulatory environment and need-based intervention from state is required in order to attract investment (Rangarajan, et al., 2013). The government of India has to adopt **foreign investor friendly policies**. The government can learn from the US's experience in the 1970s during their deepest oil crisis. The government has to initiate a slew of measures such as tax reforms, government concessions and support for research and development programmes related to shale gas, gas hydrates, coal bed methane etc. A long-term fiscal policy to attract required investments especially international investors in hydrocarbon sector has to be formulated. Things cannot be achieved if government moves at a slow pace.

LNG sourcing: India has the requisite long term and short term agreements in place for **sourcing future LNG**. But the cost of LNG is very high compared to domestic gas which is pegged at 4.2 US$/MMBtu, which is still in discussion for upward revision. LNG in India is priced at US$ 9–17 per MMBtu, depending on the various sources. This imported gas is quite costly for power and fertiliser industries without government subsidies. Another idea can be drawn from Warsaw where LNG is being used to power the buses used in public transportation around the capital (Gazprom, 2012a). This LNG fuelled transport sector is a new promising olive branch which shall compliment the already existing CNG network of India. Both LNG and CNG have the same chemical components but under different pressure and temperature conditions. The liquefaction process of LNG also involves removal of unwanted gases, acids, water, and heavy hydrocarbons, thereby ensuring pure fuel and enhanced life for the engines of the vehicles. Indian's CNG market should target personal vehicles like car, auto, taxi etc., while LNG shall target the heavy duty vehicles like buses, trucks, earthmovers etc. Similar capacity of tanks can hold more LNG in comparison to CNG, giving more flexibility in storage for longer period of use. Poland is the first in Europe to introduce LNG in public transportation. On a longer run LNG is economical than petrol and diesel, while the domestic gas currently used in CNG can be better utilized to cut the subsidy burden of the government. India can take a leaf from this book for sustainable future enhancing the oxygen content in the atmosphere of most crowded cities.

Trans-national pipelines: The trans-national pipelines **TAPI** and **IPI** have to reach the Indian border, setting aside geo-political, geo-strategic and geo-economical hindrances. The neighbouring nations must come together for better, more secure, affordable energy for future generations. If the opportunity is not utilised, then all these nations will be common losers in the "economic-war".

Sustainability: Meeting global energy demand means producing more, and more efficiently in an environmental friendly and energy **sustainable** manner. As global demand for energy soars, oil and gas fields are getting more and more complex to produce. Oil fields and drilling rigs are highly hazardous to the environment. Besides effective and efficient operational priority it is extremely important not to jeopardize the safety of people, both working and living around the area and to mitigate environmental risks. Over the past decades exploration and production of oil and gas hydrocarbon has been viewed as the most technologically innovative field in comparison to rocket science. New innovations have reshaped the industry. India needs to enhance quality of life of its citizens by progressively improving product and service standards adhering to cleaner and greener initiatives. Natural gas will be a vital player in this game. The government has to quickly create a policy framework to develop the hydrocarbon sector as a globally competitive industry, which could be compared to the best in the world, through technology upgrade and capacity building in all facets of the industry. It also has to develop energy import policy and exercise all options for the import of cheaper natural gas by long term agreements with gas majors across the world. India needs a clear and distinct plan with attainable results. The plan shall stand as a guarantee for reliable energy access to the customer at an economical cost.

While these effects will form the foundation for India’s strong growth in the decades to come, India’s growth drivers will increasingly have to come from domestic sources. It has to develop regulatory and legislative framework for providing oil and gas security for the country. The government has to formulate adequate measures in order to boost the domestic production of natural gas. For a long-term natural gas potential, India needs to continue making progress on its domestic reforms agenda, encourage investments and unlock supply constraints while adhering to technological consolidation. The promise is to be a more secure, less volatile world, and a cleaner and less costly one. The policy pertaining to natural gas must be robust and updated and be in tandem with ongoing changes across the globe. In conclusion, this thesis only touched on the topic of natural gas business of India, based on the current market scenario and known conditions. The potential for further research in this area is great and opens a completely new set of questions related to policies and reforms of the government in the years to come.

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APPENDICES

LIST OF APPENDICES

Appendix A: List of commonly used abbreviations

APM	Administered Pricing Mechanism
CBM	Coal Bed Methane
CGD	City Gas Distribution
CNG	Compressed Natural Gas
DGH	Directorate General of Hydrocarbons
E&P	Exploration and Production
EU	European Union
GAIL	GAIL India Limited
GLC	Gas Linkage Committeee
GSPL	Gujarat State Petronet Limited
GSPCL	Gujarat State Petroleum Corporation Limited
IOCL	Indian Oil Corporation Limited
KG	Krishna-Godavari
LNG	Liquefied Natural Gas
MMSCMD	Million Standard Cubic Metres per Day
MMTPA	Million Tonnes Per Annum
MOPNG	Ministry of Petroleum and Natural Gas
NELP	New Exploration Licensing Policy
NOC	National Oil Companies
ONGC	Oil and Natural Gas Corporation
OIL	Oil India Limited
PLL	Petronet LNG Limited
PNGRB	Petroleum and Natural Gas Regulatory Board
PPAC	Petroleum Planning and Analysis Cell
PSC	Production Sharing Contract
TPED	Total Primary Energy Demand
UN	United Nations
UNESCO	United Nations Educational, Scientific and Cultural Organisation
UK	United Kingdom
US	United States
USEIA	United States Energy Information Administration
MMBtu	Million British thermal units
mtoe	million tonnes oil equivalent
bcm	billion cubic metres
tcm	trillion cubic metres
tcf	trillion cubic feet

Appendix B: Primary energy consumption of countries and regions of the world in 2009–13 in million tonnes oil equivalent

Countries / Year Regions	2009	2010	2011	2012	2013	Index: 2013/ 2012	Share in 2013 (in %)
	Energy Consumption in million tonnes oil equivalent						
US	2205.9	2284.9	2265.4	2208.0	**2265.8**	**102.6**	17.8
Canada	311.5	315.6	328.1	326.9	**332.9**	**101.8**	2.6
Mexico	173.0	177.9	186.2	188.5	**188.0**	**99.7**	1.5
Total North America	**2690.4**	**2778.4**	**2779.7**	**2723.4**	**2786.7**	**102.3**	**21.9**
Argentina	75.8	78.1	79.8	82.2	**84.5**	**102.9**	0.7
Brazil	235.2	257.4	269.3	276.0	**284.0**	**102.9**	2.2
Chile	30.9	30.0	32.6	34.0	**34.6**	**101.8**	0.3
Colombia	31.8	33.0	35.7	36.8	**38.0**	**103.1**	0.3
Ecuador	11.5	12.8	13.6	14.3	**14.7**	**102.4**	0.1
Peru	16.6	18.9	20.6	21.6	**21.8**	**100.8**	0.2
Trinidad & Tobago	21.7	22.8	22.5	21.7	**22.0**	**101.3**	0.2
Venezuela	82.9	75.8	77.7	79.9	**82.9**	**103.7**	0.7
Other S. & Cent. America	85.7	87.6	88.7	90.3	**91.0**	**100.7**	0.7
Total South & Cent. America	**592.0**	**616.4**	**640.5**	**656.9**	**673.5**	**102.5**	**5.3**
Austria	34.7	36.0	33.7	35.4	**34.0**	**96.1**	0.3
Azerbaijan	10.9	10.7	11.9	12.3	**12.7**	**103.4**	0.1
Belarus	23.9	25.4	25.2	25.2	**25.3**	**100.2**	0.2
Belgium	62.6	66.8	63.8	60.3	**61.7**	**102.4**	0.5
Bulgaria	17.1	17.8	19.1	18.1	**17.1**	**94.6**	0.1
Czech Republic	42.0	43.8	43.2	42.4	**41.9**	**98.8**	0.3
Denmark	18.5	19.5	18.5	17.2	**18.1**	**105.0**	0.1
Finland	27.0	29.2	27.2	26.5	**26.1**	**98.6**	0.2
France	244.9	253.3	245.0	245.3	**248.4**	**101.3**	2.0
Germany	307.8	322.5	307.5	317.1	**325.0**	**102.5**	2.6
Greece	33.4	31.4	30.7	29.3	**27.2**	**93.1**	0.2
Hungary	25.2	25.0	22.6	22.0	**20.4**	**92.8**	0.2
Republic of Ireland	14.4	14.4	13.3	13.2	**13.3**	**101.4**	0.1
Italy	167.9	173.2	169.5	163.2	**158.8**	**97.3**	1.2
Kazakhstan	50.8	50.8	56.7	60.9	**62.0**	**101.9**	0.5
Lithuania	7.8	5.9	6.1	6.1	**5.7**	**92.5**	0.1
Netherlands	91.8	96.1	91.5	88.4	**86.8**	**98.2**	0.7
Norway	43.9	42.1	43.2	47.9	**45.0**	**93.8**	0.4
Poland	92.1	99.5	99.8	98.7	**99.9**	**101.2**	0.8
Portugal	24.0	25.1	23.8	22.2	**23.8**	**107.0**	0.2
Romania	33.9	34.3	35.4	34.3	**33.0**	**96.4**	0.3
Russian Federation	647.8	674.1	695.9	699.3	**699.0**	**100.0**	5.5
Slovakia	16.0	17.0	16.5	16.0	**16.6**	**103.6**	0.1
Spain	143.9	144.7	142.4	141.1	**133.7**	**94.7**	1.1
Sweden	48.1	51.8	50.9	54.0	**51.0**	**94.5**	0.4
Switzerland	29.7	29.0	27.5	29.1	**30.2**	**103.6**	0.2
Turkey	103.7	110.4	117.6	122.7	**122.8**	**100.1**	1.0
Turkmenistan	23.1	26.1	27.0	29.9	**26.3**	**88.1**	0.2
Ukraine	112.9	120.9	125.8	122.7	**117.5**	**95.7**	0.9
United Kingdom	203.9	209.2	196.3	201.6	**200.0**	**99.2**	1.6
Uzbekistan	46.7	48.0	51.1	48.9	**47.8**	**97.7**	0.4
Other Europe & Eurasia	88.6	94.5	93.5	91.4	**94.3**	**103.2**	0.7
Total Europe & Eurasia	**2839.1**	**2948.8**	**2932.3**	**2942.6**	**2925.3**	**99.4**	**23.0**

(table continues)

(continued)

Countries / Year Regions	2009	2010	2011	2012	2013	Index: 2013/ 2012	Share in 2013 (in %)
	Energy Consumption in million tonnes oil equivalent						
Iran	227.0	227.4	237.6	238.8	**243.9**	**102.1**	1.9
Israel	23.1	23.4	24.0	24.8	**24.2**	**97.9**	0.2
Kuwait	31.5	34.7	35.7	38.0	**37.8**	**99.6**	0.3
Qatar	24.0	24.9	28.6	29.1	**31.8**	**109.2**	0.2
Saudi Arabia	186.4	203.1	208.1	220.6	**227.7**	**103.2**	1.8
United Arab Emirates	80.9	84.9	89.2	93.3	**97.1**	**104.1**	0.8
Other Middle East	106.7	116.1	113.9	119.9	**122.9**	**102.5**	1.0
Total Middle East	**679.7**	**714.4**	**737.1**	**764.4**	**785.3**	**102.7**	**6.2**
Algeria	39.6	38.6	40.7	44.8	**46.6**	**104.2**	0.4
Egypt	77.0	81.6	83.0	87.6	**86.8**	**99.1**	0.7
South Africa	123.6	125.1	123.0	122.6	**122.4**	**99.9**	1.0
Other Africa	132.1	144.2	140.0	147.5	**152.3**	**103.3**	1.2
Total Africa	**372.4**	**389.4**	**386.7**	**402.4**	**408.1**	**101.4**	**3.2**
Australia	123.1	122.8	124.1	118.0	**116.0**	**98.3**	0.9
Bangladesh	21.4	23.3	24.7	26.0	**26.7**	**102.7**	0.2
China	2104.3	2339.6	2544.8	2731.1	**2852.4**	**104.4**	22.4
China Hong Kong SAR	26.5	27.6	28.3	27.2	**27.9**	**102.7**	0.2
India	483.8	510.2	534.6	573.3	**595.0**	**103.8**	4.7
Indonesia	134.5	150.0	159.8	161.0	**168.7**	**104.8**	1.3
Japan	477.5	506.8	481.2	478.0	**474.0**	**99.2**	3.7
Malaysia	71.5	77.5	76.6	80.2	**81.1**	**101.1**	0.6
New Zealand	19.1	19.7	19.6	19.7	**19.8**	**100.8**	0.2
Pakistan	67.0	68.0	68.1	69.1	**69.6**	**100.7**	0.5
Philippines	27.8	28.1	29.2	30.4	**31.8**	**104.5**	0.2
Singapore	64.5	70.6	73.7	74.1	**75.7**	**102.1**	0.6
South Korea	237.4	254.6	267.8	270.9	**271.3**	**100.1**	2.1
Taiwan	104.1	109.7	109.5	109.2	**110.9**	**101.6**	0.9
Thailand	97.2	102.7	107.1	115.3	**115.6**	**100.3**	0.9
Vietnam	42.6	44.2	48.9	52.5	**54.4**	**103.6**	0.4
Other Asia Pacific	49.9	52.8	57.2	57.6	**60.7**	**105.4**	0.5
Total Asia Pacific	**4152.3**	**4508.2**	**4755.1**	**4993.5**	**5151.5**	**103.2**	**40.5**
Total World	**11325.9**	**11955.6**	**12231.5**	**12483.2**	**12730.4**	**102.0**	**100.0**
of which: OECD	5398.3	5598.2	5535.8	5484.4	**5533.1**	**100.9**	43.5
Non-OECD	5927.5	6357.3	6695.7	6998.9	**7197.3**	**102.8**	56.5
European Union	1691.2	1752.8	1691.2	1685.5	**1675.9**	**99.4**	13.2

Note:
In this review, primary energy comprises commercially-traded fuels oil, natural gas, coal, nuclear energy, hydroelectricity and modern renewables used to generate electricity.
Counties with share of less than 0.1% is not shown in the table.

Source: BP, *BP Statistical Review of World Energy*, 2014, p. 40.

Appendix C: Oil and gas production of the regions and countries of the world in 2012 and 2013

Countries / Regions	Oil Production				Gas Production			
	Volume in million tonnes		Index: 2013/ 2012	Share in 2013 (in %)	Volume in million tonnes oil equivalent		Index: 2013/ 2012	Share in 2013 (in %)
Year	2012	2013			2012	2013		
US	394.1	**446.2**	113.2	10.8	620.8	**627.2**	101.0	20.6
Canada	182.6	**193.0**	105.7	4.7	140.4	**139.3**	99.2	4.6
Mexico	143.9	**141.8**	98.6	3.4	51.2	**51.0**	99.6	1.7
Total North America	**720.6**	**781.1**	108.4	**18.9**	**812.4**	**817.5**	100.6	26.9
Argentina	31.1	**30.5**	98.2	0.7	34.0	**32.0**	94.2	1.1
Bolivia	--	--	--	--	16.5	**18.8**	114.1	0.6
Brazil	112.2	**109.9**	98.0	2.7	17.3	**19.2**	110.6	0.6
Colombia	49.9	**52.9**	106.1	1.3	10.8	**11.4**	105.5	0.4
Ecuador	27.1	**28.2**	104.2	0.7	--	**--**	--	--
Peru	4.8	**4.6**	95.7	0.1	10.7	**11.0**	102.8	0.4
Trinidad & Tobago	6.0	**5.9**	98.5	0.1	38.5	**38.6**	100.3	1.3
Venezuela	136.6	**135.1**	98.9	3.3	26.5	**25.6**	96.5	0.8
Other South. & Central America	7.1	**7.3**	102.7	0.2	2.6	**2.3**	86.4	0.1
Total South & Central America	**374.7**	**374.4**	99.9	**9.1**	**156.8**	**158.7**	101.2	5.2
Azerbaijan	45.7	**46.2**	101.0	1.1	14.0	**14.5**	103.6	0.5
Denmark	10.0	**8.7**	87.0	0.2	5.2	**4.4**	84.2	0.1
Germany	--	--	--	--	8.1	**7.4**	90.9	0.2
Italy	5.4	**5.6**	103.0	0.1	7.1	**6.4**	89.9	0.2
Kazakhstan	81.2	**83.8**	103.3	2.0	16.5	**16.6**	100.5	0.5
Netherlands	--	--	--	--	57.5	**61.8**	107.6	2.0
Norway	87.2	**83.2**	95.3	2.0	103.3	**97.9**	94.8	3.2
Poland	--	--	--	--	3.8	**3.8**	98.3	0.1
Romania	4.0	**4.1**	103.7	0.1	9.8	**9.9**	100.3	0.3
Russian Federation	526.2	**531.4**	101.0	12.9	533.1	**544.3**	102.1	17.9
Turkmenistan	11.0	**11.4**	103.8	0.3	56.1	**56.1**	100.1	1.8
Ukraine	--	--	--	--	16.7	**17.3**	103.7	0.6
United Kingdom	44.6	**40.6**	91.2	1.0	35.0	**32.8**	93.8	1.1
Uzbekistan	3.2	**2.9**	92.6	0.1	51.2	**49.7**	97.0	1.6
Other Europe & Eurasia	19.2	**19.6**	102.1	0.5	7.8	**6.7**	85.9	0.2
Total Europe & Eurasia	**837.7**	**837.5**	100.0	**20.3**	**925.3**	**929.6**	100.5	30.6
Bahrain	--	--	--	--	12.4	**14.2**	114.8	0.5
Iran	177.1	**166.1**	93.8	4.0	149.1	**149.9**	100.6	4.9
Iraq	152.5	**153.2**	100.5	3.7	0.6	**0.6**	95.4	0.1
Kuwait	153.7	**151.3**	98.4	3.7	14.0	**14.0**	100.5	0.5
Oman	45.0	**46.1**	102.4	1.1	27.0	**27.8**	103.0	0.9
Qatar	83.3	**84.2**	101.1	2.0	135.7	**142.7**	105.1	4.7
Saudi Arabia	549.8	**542.3**	98.6	13.1	89.4	**92.7**	103.7	3.0
Syria	8.5	**2.8**	32.6	0.1	4.8	**4.0**	84.6	0.1
United Arab Emirates	154.7	**165.7**	107.1	4.0	48.9	**50.4**	103.0	1.7
Yemen	8.3	**7.4**	88.3	0.2	6.8	**9.3**	136.1	0.3
Other Middle East	9.0	**10.2**	113.2	0.2	2.4	**5.9**	247.8	0.2
Total Middle East	**1342.1**	**1329.3**	99.0	**32.2**	**490.9**	**511.4**	104.2	16.8

(table continues)

(continued)

Countries / Regions	Oil Production					Gas Production			
	Volume in million tonnes		Index: 2013/ 2012	Share in 2013 (in %)		Volume in million tonnes oil equivalent		Index: 2013/ 2012	Share in 2013 (in %)
Year	**2012**	**2013**				**2012**	**2013**		
Algeria	67.2	**68.9**	102.5	1.7		73.4	**70.7**	96.4	2.3
Angola	86.9	**87.4**	100.6	2.1		--	--	--	--
Chad	5.3	**5.0**	93.4	0.1		--	--	--	--
Rep. of Congo (Brazzaville)	15.0	**14.5**	96.8	0.4		--	--	--	--
Egypt	34.7	**34.5**	99.5	0.8		54.8	**50.5**	92.1	1.7
Equatorial Guinea	14.9	**14.6**	97.9	0.4		--	--	--	--
Gabon	12.3	**11.8**	96.5	0.3		--	--	--	--
Libya	71.1	**46.5**	65.4	1.1		11.0	**10.8**	98.2	0.4
Nigeria	116.2	**111.3**	95.7	2.7		39.0	**32.5**	83.3	1.1
South Sudan	1.5	**4.9**	318.5	0.1		--	--	--	--
Sudan	5.1	**6.0**	118.0	0.1		--	--	--	--
Tunisia	3.2	**3.0**	92.6	0.1		--	--	--	--
Other Africa	11.6	**10.4**	89.8	0.3		16.6	**19.4**	116.8	0.6
Total Africa	**445.0**	**418.6**	94.1	**10.1**		**194.7**	**183.9**	94.4	6.0
Australia	21.6	**17.9**	83.0	0.4		39.0	**38.6**	98.8	1.3
Bangladesh	--	--	--	--		19.0	**19.7**	103.9	0.6
Brunei	7.8	**6.6**	84.5	0.2		11.3	**11.0**	97.1	0.4
China	207.5	**208.1**	100.3	5.0		96.4	**105.3**	109.2	3.5
India	42.0	**42.0**	99.8	1.0		36.3	**30.3**	83.5	1.0
Indonesia	44.6	**42.7**	95.7	1.0		64.0	**63.4**	99.1	2.1
Malaysia	30.3	**29.6**	97.6	0.7		59.8	**62.1**	103.9	2.0
Myanmar	--	--	--	--		11.5	**11.8**	102.8	0.4
Pakistan	--	--	--	--		37.1	**34.7**	93.5	1.1
Thailand	16.4	**16.6**	101.5	0.4		37.3	**37.6**	100.9	1.2
Vietnam	17.0	**17.0**	100.1	0.4		8.4	**8.8**	104.2	0.3
Other Asia Pacific	12.5	**11.4**	91.2	0.3		16.4	**16.9**	103.0	0.6
Total Asia Pacific	**399.8**	**392.0**	98.0	**9.5**		**436.4**	**440.1**	100.8	14.5
Total World	**4119.8**	**4132.9**	**100.3**	**100.0**		**3016.6**	**3041.3**	**100.8**	**100.0**
of which: OECD	903.1	**951.0**	105.3	23.0		1087.0	**1088.4**	100.1	35.8
Non-OECD	3216.7	**3181.9**	98.9	77.0		1929.6	**1952.9**	101.2	64.2
OPEC	1776.3	**1740.1**	98.0	42.1		--	--	--	--
European Union	72.9	68.4	93.9	1.70		133.1	132.1	99.2	4.3
Note: -- means data not available									

Source: Adapted from BP, *BP Statistical Review of World Energy*, 2014, p. 8 for oil and p. 22 for gas.

Appendix D: Proved reserves of natural gas of countries at the end of years 1993, 2003, 2012 and 2013 in tcm and the production at end of 2013 and the R/P ratio

Countries and Regions	Natural Gas: Proved reserves in trillion cubic metres				Production at end 2013 in tcm	Share of world total (in %)	R/P ratio
	at end 1993	at end 2003	at end 2012	at end 2013			
US	4.6	5.4	8.7	9.3	0.688	5.0	13.6
Canada	2.2	1.6	2.0	2.0	0.155	1.1	13.1
Mexico	2.0	0.4	0.4	0.3	0.057	0.2	6.1
Total North America	**8.8**	**7.4**	**11.1**	**11.7**	**0.899**	**6.3**	**13.0**
Argentina	0.5	0.6	0.3	0.3	0.036	0.2	8.9
Bolivia	0.1	0.8	0.3	0.3	0.021	0.2	15.2
Brazil	0.1	0.2	0.5	0.5	0.021	0.2	21.2
Colombia	0.2	0.1	0.2	0.2	0.013	0.1	12.8
Peru	0.3	0.2	0.4	0.4	0.012	0.2	35.7
Trinidad & Tobago	0.2	0.5	0.4	0.4	0.043	0.2	8.2
Venezuela	3.7	4.2	5.6	5.6	0.028	3.0	*
Other S. & Cent. America	0.2	0.1	0.1	0.1	0.003	w	24.9
Total S. & Cent. America	**5.4**	**6.8**	**7.7**	**7.7**	**0.176**	**4.1**	**43.5**
Azerbaijan	n/a	0.9	0.9	0.9	0.016	0.5	54.3
Denmark	0.1	0.1	0.0	0.0	0.005	w	7.0
Germany	0.2	0.2	0.1	0.0	0.008	w	5.9
Italy	0.3	0.1	0.1	0.1	0.007	w	7.3
Kazakhstan	n/a	1.3	1.5	1.5	0.018	0.8	82.5
Netherlands	1.7	1.4	0.9	0.9	0.069	0.5	12.4
Norway	1.4	2.5	2.1	2.0	0.109	1.1	18.8
Poland	0.2	0.1	0.1	0.1	0.004	0.1	27.5
Romania	0.4	0.3	0.1	0.1	0.011	0.1	10.6
Russian Federation	n/a	30.4	31.0	31.3	0.605	16.8	51.7
Turkmenistan	n/a	2.3	17.5	17.5	0.062	9.4	*
Ukraine	n/a	0.7	0.6	0.6	0.019	0.3	33.4
United Kingdom	0.6	0.9	0.2	0.2	0.036	0.1	6.7
Uzbekistan	n/a	1.2	1.1	1.1	0.055	0.6	19.7
Other Europe & Eurasia	35.6	0.4	0.3	0.2	0.007	0.1	33.4
Total Europe & Eurasia	**40.5**	**42.7**	**56.5**	**56.6**	**1.033**	**30.5**	**54.8**
Bahrain	0.2	0.1	0.2	0.2	0.016	0.1	12.1
Iran	20.7	27.6	33.6	33.8	0.167	18.2	*
Iraq	3.1	3.2	3.6	3.6	0.001	1.9	*
Kuwait	1.5	1.6	1.8	1.8	0.016	1.0	*
Oman	0.2	1.0	0.9	0.9	0.031	0.5	30.7
Qatar	7.1	25.3	24.9	24.7	0.159	13.3	*
Saudi Arabia	5.2	6.8	8.2	8.2	0.103	4.4	79.9
Syria	0.2	0.3	0.3	0.3	0.004	0.2	63.9
United Arab Emirates	5.8	6.0	6.1	6.1	0.056	3.3	*
Yemen	0.4	0.5	0.5	0.5	0.010	0.3	46.3
Other Middle East	0.0	0.1	0.2	0.2	0.007	0.1	35.3
Total Middle East	**44.4**	**72.4**	**80.3**	**80.3**	**0.568**	**43.2**	*****
Algeria	3.7	4.5	4.5	4.5	0.079	2.4	57.3
Egypt	0.6	1.7	2.0	1.8	0.056	1.0	32.9
Libya	1.3	1.5	1.5	1.5	0.012	0.8	*
Nigeria	3.7	5.1	5.1	5.1	0.036	2.7	*
Other Africa	0.7	1.0	1.2	1.2	0.022	0.7	56.9
Total Africa	**10.0**	**13.9**	**14.4**	**14.2**	**0.204**	**7.6**	**69.5**

(table continues)

(continued)

Countries and Regions	Natural Gas: Proved reserves in trillion cubic metres				Production at end 2013 in tcm	Share of world total (in %)	R/P ratio
	at end 1993	at end 2003	at end 2012	at end 2013			
Australia	1.0	2.4	3.8	3.7	0.043	2.0	85.8
Bangladesh	0.3	0.4	0.3	0.3	0.022	0.1	12.6
Brunei	0.4	0.3	0.3	0.3	0.012	0.2	23.6
China	1.7	1.3	3.3	3.3	0.117	1.8	28.0
India	0.7	0.9	1.3	1.4	0.034	0.7	40.2
Indonesia	1.8	2.6	2.9	2.9	0.070	1.6	41.6
Malaysia	1.8	2.5	1.1	1.1	0.069	0.6	15.8
Myanmar	0.3	0.4	0.3	0.3	0.013	0.2	21.6
Pakistan	0.7	0.8	0.6	0.6	0.039	0.3	16.7
Papua New Guinea	^	^	0.2	0.2	n/a	0.1	*
Thailand	0.2	0.4	0.3	0.3	0.042	0.2	6.8
Vietnam	0.1	0.2	0.6	0.6	0.010	0.3	63.3
Other Asia Pacific	0.3	0.5	0.3	0.3	0.019	0.2	17.5
Total Asia Pacific	**9.3**	**12.7**	**15.2**	**15.2**	**0.489**	**8.2**	**31.1**
Total World	**118.4**	**155.7**	**185.3**	**185.7**	**3.370**	**100.0**	**55.1**
of which: OECD	14.6	15.3	18.7	19.2	1.200	10.3	16.0
Non-OECD	103.8	140.4	166.6	166.5	2.170	89.7	76.7
European Union	3.7	3.2	1.6	1.6	0.147	0.8	10.7
Former Soviet Union	35.3	36.9	52.8	52.9	0.776	28.5	68.2
Notes:							
* More than 100 years.							
^ Less than 0.05							
w Less than 0.05%.							
n/a not available.							
Notes: Proved reserves of oil - Generally taken to be those quantities that geological and engineering information indicates with reasonable certainty can be recovered in the future from known reservoirs under existing economic and operating conditions.							
Reserves-to-production (R/P) ratio - If the reserves remaining at the end of any year are divided by the production in that year, the result is the length of time that those remaining reserves would last if production were to continue at that rate.							

Source: BP, *BP Statistical Review of World Energy*, 2014, p. 20.

Appendix E: Natural gas pipeline network of India in terms of their length (in km) and capacity (in MMSCMD)

NETWORK/REGION	Owner	Length (in km)	Design Capacity (in MMSCMD)	Average Flow in 2013-14 (in MMSCMD)	Capacity Utilisation as on 31.03.2014 (in %)	Pipeline Size (in inch)
HVJ- GREP -DVPL & Spur	GAIL	4435	57.30	42.90	80.98	36
DVPL-GREP Upgradation (DVPL-2 & VDPL)	GAIL	1112	54.00	15.33	28.39	48
CHHAINSA- JHAJJAR -HISSAR P/L	GAIL	262	5.00	0.68	15.00	36/16
DAHEJ-URAN-PANVEL P/L	GAIL	873	20.00	8.92	44.82	30/18
DADRI BAWANA NANGAL P/L,	GAIL	803	11.00	2.40	0.00	36/30/ 24/18
DHABHOL -BANGLORE-PIPELINE	GAIL	1004	16.00	0.97	6.09	4–36
KOCHI-Koottanad-Banglore-Mangalore (Phase-1)	GAIL	41	6.00	0.31	5.21	4–16
GAIL ASSAM (Lakwa) Pipeline	GAIL	8	2.50	0.55	22.00	24
GAIL TRIPURA (Agartala) Pipeline	GAIL	61	2.26	1.46	64.40	12
GAIL AHMEDABAD	GAIL	144	3.00	0.38	13.00	12
GAIL RAJASTHAN (Focus Energy)	GAIL	154	2.350	1.09	46.50	12
GAIL BHARUCH , VADODARA	GAIL	670	15.40	2.25	14.60	24 ,16
GAIL MUMBAI Pipeline	GAIL	129	24.00	22.90	95.40	26
GAIL KG BASIN Pipeline	GAIL	877	16.00	6.00	37.40	18
GAIL CAUVERY BASIN	GAIL	268	9.00	3.57	41.22	18
EAST- WEST PIPE LINE (RGTIL)	Reliance	1469	80.00	48.00	60.00	48
GSPCL Network including Spur Lines	GSPCL	1874	50.00	22.00	44.00	Assorted
Assam Gas Company (Duliajan to Numaligarh)	AGC	1000	6.00	4.50	75.00	16
Dadri -Panipat	IOCL	132	9.50	3.11	32.80	30/10
Uran Trombay	ONGC	24	6.00	--	--	--
Total		**15340**	**395.21**	**187.33**	**--**	**--**

Note:
HVJ stands for Hazira–Vijaipur–Jagadishpur pipeline
DVPL stands for Dahej–Vijaipur pipeline
GREP stands for Gas Rehabilitation Expansion Project
VDPL stands for Vijaipur–Dadri pipeline

Source: Adapted from Petroleum Planning & Analysis Cell, *Pipelines and CGD Infrastructure*, 2014d.

Appendix F: Natural gas pipeline import prices of selected countries in 2006–13 in US$/MMBtu

Countries / Year	2006	2007	2008	2009	2010	2011	2012	2013
Austria	7.79	7.94	11.91	8.35	..	..	..	12.95
Belgium	..	6.26	10.70	4.99	6.59	9.44	9.44	10.46
Czech Republic	..	7.89	11.57	8.67	8.74	11.14	13.22	12.1
France	..	..	..	..	..	..	11.57	11.75
Greece	..	8.28	..	8.31	9.90	11.17	13.66	13.13
Hungary	8.13	7.57	11.97	9.68	9.62	11.12	12.12	11.96
Ireland	..	..	8.19	6.08	6.36	7.67	8.75	9.80
Italy	..	..	..	9.05	8.66	10.72	12.82	12.33
Netherland	..	..	..	..	..	11.33	..	11.57
Portugal	7.43	7.80	10.92	..	8.52	11.48	12.74	12.38
Slovak Republic	7.84	7.84	11.66	..	9.47	10.80	11.18	9.32
Spain	..	7.25	..	7.41	7.49	9.54	10.78	10.59
Sweden	8.39	8.06	12.16	8.49	9.25	12.70	12.79	12.15
United Kingdom	7.48	5.18	9.17	4.90	4.70	7.00	7.95	8.36
Other EU member states	7.35	7.10	10.52	7.52	7.59	9.94	10.88	10.84
US	..	6.95	9.84	4.52	4.79	5.47	4.12	6.58

Note: .. stands for data not-available

Source: International Energy Agency, *IEA Statistics Natural Gas Information 2014 with 2013 data*, 2014b, p. III.12, Table 8.

Appendix G: LNG import prices imports of selected countries in 2006–13 in US$/MMBtu

Countries / Year	2006	2007	2008	2009	2010	2011	2012	2013
Italy	..	..	..	7.86	8.87	11.73	12.96	12.17
Portugal	4.86	4.93	6.15	7.34	7.12	8.81	8.51	9.02
Spain	6.36	6.58	9.22	6.70	7.14	9.08	10.14	10.23
United Kingdom	8.14	6.37	9.21	4.43	5.55	8.57	8.36	9.43
Other EU member states	6.47	6.45	9.18	6.24	6.85	9.45	10.26	10.60
Japan	7.18	7.80	12.64	9.23	11.02	14.73	16.75	16.02
Korea	9.22	10.06	14.15	10.50	10.17	12.67	14.77	14.96
US	..	6.70	8.40	4.06	4.38	4.01	2.72	3.66

Note: .. stands for data not-available

Source: International Energy Agency, *IEA Statistics Natural Gas Information 2014 with 2013 data*, 2014b, p. III.16, Table 10.

Appendix H: Natural gas prices for the industry in the years in 2006–13 in US$/MWh[36]

Countries / Year	2006	2007	2008	2009	2010	2011	2012	2013
Canada	23.39	18.58	30.29	14.84	13.77	15.42	11.90	13.72
Chile	..	..	..	..	..	..	..	..
Mexico	29.51	29.84	37.24	..	..	..	..	..
US	25.97	25.26	31.93	17.59	17.83	16.89	12.83	15.39
Australia	..	..	..	..	..	..	..	..
Israel	..	..	..	..	..	..	..	..
Japan	34.52	39.04	..	48.62	54.57	70.39	77.01	..
Korea	42.46	47.36	42.95	41.23	52.47	60.11	64.79	78.68
New Zealand	20.85	23.93	20.60	20.06	20.50	22.32	22.81	24.01
Austria	..	..	..	..	..	..	47.89	48.84
Belgium	..	..	49.98	43.90	32.32	37.82	37.08	39.89
Czech Republic	34.59	33.68	52.80	45.41	45.62	50.77	48.82	47.33
Denmark	..	..	..	64.67		..	..	..
Estonia	..	..	38.69	33.72	36.45	39.64	45.61	47.15
Finland	21.33	23.03	32.01	28.61	30.13	45.16	45.75	47.50
France	35.44	35.61	52.22	37.75	41.67	51.48	51.14	51.83
Germany	45.1	49.53	57.21	47.76	45.08	50.25	44.63	49.89
Greece	..	37.95	55.26	37.93	44.50	55.96	66.76	60.99
Hungary	38.79	50.23	64.75	52.57	36.75	43.56	47.85	45.62
Ireland	40.06	..	52.99	41.57	37.06	43.88	45.58	51.74
Italy	39.05	42.23	55.59	47.95	41.63	..	..	..
Luxembourg	..	..	31.52	29.99	42.07	50.09	49.56	53.53
Netherlands	..	39.11	45.98	42.37	34.44	38.52	38.62	41.48
Norway	..	..	..	..	..	..	..	..
Poland	25.3	32.25	45.72	37.21	39.10	42.51	43.96	42.27
Portugal	34.31	36.86	47.11	41.62	40.29	50.15	52.70	55.71
Slovak Republic	32.59	36.14	53.52	44.43	45.96	50.18	52.53	49.34
Slovenia	..	..	56.36	49.09	51.61	58.30	64.38	57.89
Spain	30.52	32.70	41.84	37.30	33.57	37.69	43.97	45.12
Sweden	..	51.49	65.86	48.95	56.01	67.65	63.32	63.80
Switzerland	41.93	49.58	64.09	60.56	56.92	72.50	71.71	72.24
Turkey	30.33	37.91	49.26	40.21	35.02	33.78	41.15	..
United Kingdom	32.98	28.63	38.38	30.96	28.27	35.53	38.45	41.89

Source: International Energy Agency, *IEA Statistics Natural Gas Information 2014 with 2013 data*, 2014b, p. III.29, Table 18.

[36] Energy prices in US dollars per Mega Watt hour (MWh).

Appendix I: Natural gas prices for the domestic households in 2006–13 in US$/MWh

Countries / Year	2006	2007	2008	2009	2010	2011	2012	2013
Canada	41.41	41.57	43.43	34.22	37.04	37.12	34.36	33.81
Chile	76.80	85.84	117.79	95.91	118.03	137.87	125.01	111.94
Mexico	53.50	54.30	38.51	36.88	39.45	36.57	30.36	34.24
US	45.41	43.05	45.87	40.04	36.95	36.41	35.52	34.05
Australia	..	..	..	..	..	..	..	..
Israel	..	..	..	..	..	..	..	..
Japan	106.53	106.35	..	135.43	142.13	165.61	169.64	..
Korea	54.99	61.28	54.51	49.76	56.36	65.03	69.18	75.80
New Zealand	63.87	84.37	96.13	73.96	86.05	102.42	107.71	116.72
Asutria	67.50	80.53	88.07	89.61	81.39	93.05	90.34	92.88
Belgium	..	..	96.05	77.87	75.03	94.90	91.45	88.08
Czech Republic	46.74	49.66	72.99	70.08	68.55	82.89	87.63	83.95
Denmark	..	..	..	114.41	124.62	141.00	123.09	129.98
Estonua	..	..	52.13	52.69	51.45	60.21	65.79	66.33
Finalnd	30.29	32.98	44.76	40.79	42.69	62.13	62.51	65.34
France	60.78	67.56	79.14	72.93	74.32	86.71	83.76	89.64
Germany	79.37	89.20	103.83	97.02	84.26	92.57	90.32	94.61
Greece	..	86.00	104.40	89.57	93.26	107.98	128.05	151.50
Hungary	25.66	52.92	64.38	61.64	55.50	63.62	60.43	57.51
Ireland	78.85	94.53	88.90	87.45	73.87	80.59	86.75	96.98
Italy	70.54	87.38	99.11	91.10	94.94	..	..	..
Luxembourg	48.04	..	73.84	61.30	57.80	74.04	74.62	78.88
Netherlands	77.36	88.67	106.61	99.97	86.09	96.77	98.70	103.68
Norway	..	..	..	..	..	..	..	..
Poland	47.67	59.20	80.25	68.94	66.46	72.69	70.64	68.05
Prortugal	87.56	92.42	91.68	82.51	81.01	93.75	102.28	117.47
Slovak Republic	47.61	56.49	67.55	67.09	60.51	68.85	68.39	70.64
Slovenia	..	..	91.17	86.75	82.78	98.76	98.49	91.38
Spain	65.08	74.62	88.29	79.61	73.87	89.20	101.90	108.22
Sweden	..	124.83	141.85	125.80	136.71	163.55	156.89	162.77
Switzerland	65.81	75.68	94.02	88.27	87.35	107.43	106.77	108.36
Turkey	35.72	44.67	56.68	48.92	45.27	42.33	50.24	..
United Kingdom	50.80	56.42	61.52	59.13	56.59	67.35	72.17	76.67

Source: International Energy Agency, *IEA Statistics Natural Gas Information 2014 with 2013 data*, 2014b, p. III.30, Table 19.

Appendix J: Shale gas prospects in countries other than the US

Shale gas experienced an extraordinary boom in the United States in the past decade. The shale gas in the US is discussed in detail under Appendix H. The exemplary increase in natural gas production from shale reserves has spurred increasing interests across the world. Many countries are currently in the fray in exploring their shale resources. Notable countries developing their shale gas resources are Argentina, Australia, China, India, Mexico and Poland. Researchers, scientists, policymakers etc., interested in the shale gas development in their area are closely analysing the success of shale gas exploration the US. A technical report in the US Energy Information Administration (USEIA) website brings out data on the technically recoverable shale oil and gas resources after an assessment of 137 shale formations in 41 countries outside the US. The report covers the countries that demonstrate some level of relatively near-term promise and that have a sufficient amount of geologic data for a resource assessment. This report puts that technically recoverable shale gas unproved resources outside the US as 6521 tcf while the proved resources are only the US reckoned as 97 tcf and unproved resources in the US estimated as 567 tcf (US Energy Information Administration, 2013b, pp. 2-3). The report also lists the top ten countries with technically recoverable shale gas reserves which shown in below (US Energy Information Administration, 2013b, p. 9).

Estimated unproved shale gas resources as on year ending 2013 in tcf

Rank	Country	Shale gas (tcf)	Rank	Country	Shale gas (tcf)
1	China	1115	-	Poland	148
2	Argentina	802	-	France	137
3	Algeria	707	-	Ukraine	128
4	USA	665	-	Libya	122
5	Canada	573	-	Pakistan	105
6	Mexico	545	-	Egypt	100
7	Australia	437	-	India	96
8	South Africa	390	-	Paraguay	75
9	Russia	285	-	Colombia	55
10	Brazil	245	-	Indonesia	46

Source: US Energy Information Administration, *Report on Technically Recoverable Shale Oil and Shale Gas Resources: An Assessment of 137 Shale Formations in 41 Countries Outside the United States*, 2013b. p. 6 and 7, Table 3.

Looking into above table, it is seen China leads the race having 1115 tcf of shale gas resources followed by Argentina and Algeria. The top-ten list does not include any country from Europe. Poland and France leads the shale gas resources in Europe. The Chatham house report (Stevens, 2012, pp. 9-12), narrating the prospects of shale gas outside the US express that, the experience of the US shall definitely help a nation to develop shale gas prospects, but it has to be interpolated and adapted to the practical situation of the nation on the ground. It is very difficult to say, a country copying the US model of shale gas can really be successful. Europe reacted very slowly to the shale gas boom due to environmental concerns. EU was not very keen in fossil fuels, as it has imposed strict carbon-di-oxide norms in its third energy directives. It has set up a vision of 20% reduction in carbon emissions by 2020 compared to the levels of 1990. Despite having higher shale gas resources in Europe, France has banned hydraulic fracturing. Bulgaria and the Czech Republic have joined to the list. Germany has not issued any ban, but also has not issued permits for hydraulic fracturing. Research and development still continue in Germany. Even though UK has authorized hydraulic fracturing, it has burdened the companies with strong regulations. Eventhough EU has not banned the hydraulic fracturing, its parliamentary meeting frequently call for formulating a robust regulatory framework. Many European nations are divided in opinion of shale gas exploration. Poland having the highest shale gas resources in Europe, is very keen to develop the gas fields as it is importing huge gas from Russia. Ukraine predicted to have 128 tcf of shale gas resources is striving hard to get ahead in their research and development. The government of Ukraine is moving at a rapid pace, sole reason cited was to avoid any further gas battles with their major supplier Russia (Dreyer & Stang, 2013, p. 3).

China is the third largest consumer of natural gas in the world after the US and Russia. China is estimated to hold the largest technically recoverable reserves of shale gas in the world, nearly twice as much as the US. But the shale industry in China has struggled to get off the ground. Most projects are still in the exploration phase. In many cases the formations that hold gas are deeper than in North America and more expensive to reach. There were many technical challenges compared to the US. These challenges led the government of China to revise their visionary production target for 2020 by half. With increasing consumption and insufficient domestic resources and slow progress in shale gas development, as a quick heal China is building of more LNG re-gasification terminals along its coastline to satisfy its energy needs (Orcutt, 2014). Algeria having the higher shale gas reserves compared to the US is trying in partnership with various global exploration companies for shale gas drilling and production. Recent governmental reports state that it had eased on the policy regulations for shale gas investments by foreign industries. When considering the market implications of abundant shale resources, it is important to understand the criteria technically recoverable resource and an economically recoverable resource. Key positive above-the-ground advantages in the US and Canada that may not apply in other locations include private ownership of subsurface rights that provide a strong incentive for development; availability of many independent operators and supporting contractors with critical expertise and suitable drilling rigs and, pre-existing gathering and pipeline infrastructure; and the availability of water resources for use in hydraulic fracturing. The four primary advantageous factors that the US and Canada had were as geology, regulation, industry and research.

Appendix K: Shale gas in the US

Shale gas has revolutionized the energy basket of the US. The U.S. Energy Information Administration Annual Energy Outlook 2014 report (2014a, pp. MT-23) projects that natural gas production in the US shall increase by 56% from 24.06 trillion cubic feet in 2012 to 37.54 trillion cubic feet in 2040. The forecasted increase is based on the projected shale gas production which shall grow from 9.7 tcf in 2012 to 19.8 trillion cubic feet in 2040. Shale gas production is the largest contributor contributing to about 40% in 2012 and shall increase to 53% in 2040. In 2000, the US was importing huge quantities of natural gas. Canada was the primary supplier to the US natural gas requirements. Anticipating shortage of gas supplies from Canada, the US energy leaders invested in natural gas markets outside America. They also started constructing LNG regasification terminals along the coast, expecting future business to gasify LNG imported from other nations.

Deeply analyzing the origins of shale gas development in the US, Soeder (2012) recalls that the first commercial American gas well was hand-dug into Devonian-age shale in Fredonia, NY by William Hart in 1821. But until 1970s, serious studies and researches on shale gas did not begin in the United States. The 1973 energy crisis due to war in the middle-east followed by series of oil shocks due to revolutions in Iran and Iraq and their disputes greatly pressurized the US policy makers to think for energy security of the nation. In 1975, the Eastern Gas Shales Project (EGSP) was initiated by the Energy Research and Development Administration, a predecessor agency to the current U.S. Department of Energy. Taking the clue from the ancient reins, the administration started the assessment of Devonian-age shales in the Appalachian Basin and similar rock units in the Michigan and Illinois basins to identify organic-rich shales and their potential for commercial production of gas. EGSP was the pioneer of shale gas revolution in the US. The project ended in 1992, however the pilot studies made, their reports and high technology research and development in the field of horizontal drilling, safe fracturing techniques are referred besides being decades older. EGSP was the first to identify the Marcellus shale which was earlier referred as black shale in olden times. The Marcellus Shale is an organic- rich sedimentary rock formation in the Appalachian Basin that is estimated to contain significant quantities of natural gas.

The reason for such a high boom of shale gas in the US has been reviewed retrospectively by Wang and Krupnick (2013). There are said to be number of factors that converged for shale gas boom in the US, but the primary reason identified was the technology innovation. The adopting of laboratory research to the actual field took a longer time in the US, but it resulted in huge production of shale gas in cost-effective manner. It has been deliberated that the key technological developments occurred due to strong research and development backed by the government. Many technologies such as horizontal drilling, three-dimensional (3D) seismic imaging etc., were actually developed for oil industry to increase the oil yield. These technologies proved a huge turning point for shale gas development in the US. One another reason attributed by Wang and Krupnick was the government's policy in promotion of research and development programs by providing huge tax concessions. This was applicable for both government and private investments involved in developing unconventional resources for energy security of the country. Besides these, high natural gas prices in the year 2000 and declining production form conventional sources, prompted government to move faster in development of unconventional sources of energy. The major natural gas policies adopted by the US for shale gas development include tax concessions, huge government funding for R&D programs of unconventional energy sources and the policies targeting restructuring of the natural gas market such as gradual de-regulation of well-head natural gas prices, open access to inters-state natural gas pipelines.

Shale gas has definitely revolutionized the energy hopes of the US. Shale gas is produced in abundance in the US. The question arises on the future plan of the US. In an article in the Gazprom's monthly newsletter blue fuel (2014, pp. 14-17), capturing the abstracts from the lecture of Dr. Seyed Mohammad Hossein Adeli, Secretary General of Gas Exporting Countries Forum (GECF), at the Moscow State Institute of International Relations, the speaker discusses the future plan of the US. The US energy leaders already started building natural gas liquefaction terminals either by building new along the coast or converting the earlier gasification terminals to liquefaction process. The primary importer of the gas will be China. It has been stated that already three terminals on the coast has signed a dedicated agreement for gas transportation to China. China which is forecasted to have the world largest reserves of shale gas as discussed in previous section, still produces very less. It is said to be because of lack of adequate technology at economical cost. The biggest advantage the US had been the technological competency and availability at cheap cost. Moreover the US energy leaders and exploration companies targeted the wet gas which is gas with oil mixture. This associated gas was cheaper in comparison to the cost of oil produced. The investments were made in those shale plays which had both shale oil and shale gas. Many developed nations also cannot exploit their shale resources in economical way. Besides attributed to the primary technology insufficiency, there are myriad of other factors such as geological complexity of shale plays of the country, population density and fresh water required for fracturing etc., Shale revolution outside the US is less likely to happen.