Chapter 1

Introduction

1.1 Background

It is an important fact that the Energy is needed for improving the quality of life, economic growth and also to increase opportunities for development. There is a relationship between use of energy and economic growth as energy is considered to be one of the very important driving forces of economic growth in all economies. The different sources of energy are Petroleum, Coal, Hydroelectricity, Natural Gas, Nuclear and Renewable Energy. Dependence of any sector on energy clearly signifies that there is an obvious link between energy consumption and the overall economic growth rate measured by the GDP (Gross Domestic Product).

During 1993 – 2013, India experienced an average annual growth rate of 6.85% in real GDP and this has led to its comparison with other countries. As per World Bank data, India has proven itself as one of the fastest growing economies in the world. There is a considerable increase in demand for energy in India owing to its high levels of economic growth, growing population and urbanization.

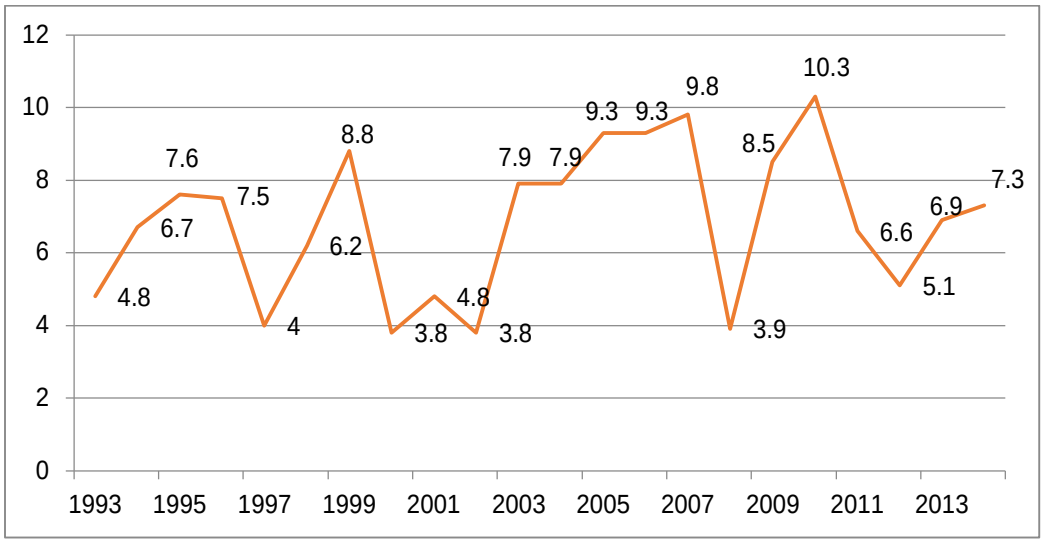

Fig. 1.1 Annual GDP Growth Rate of India (%) – World Development Indicators

The Indian economy has also experienced quite significant structural shifts in its composition as it has transitioned from agriculture to industry. In early 1990s the value added (as a % of GDP) from the agriculture sector averaged about 29%, while today it constitutes nearly18% of Indian GDP – *(http:// data.worldbank.org)*. Notably, in recent times, there has been a significant growth in the service sector as well. As a result of industrialization and growth in service sector, new employment opportunities have been created in cities which have resulted in migration of population from rural areas to urban areas in every part of the country. Present urbanization in India is around 35% and increasing at the rate 2.4% every year. The increasing concentration of population in cities has resulted in an increasing demand of energy consumption, as energy is an important input into various activities like manufacturing, transportation, construction and other service sector.

Increased economic growth and demographic trends have put pressure on the demand for energy in India. However, one of the major concerns regarding the use of energy is that India is dependent on conventional forms of energies such as coal and petroleum products. As there has been no major success in tapping renewable energy, it is expected that the vast majority of increased energy demand shall be met by fossil fuels. This will have significant implications not only on emission of more carbon dioxide (CO2) and resulting environmental degradation, but it will also impact imbalances in India's balance of payments (BOPs) by generating a huge oil import bill. .

India is the world's fourth largest energy consumer. It imports a substantial portion of its energy i.e. around 80 per cent of its oil, 25 per cent of its gas, and around 25 per cent of its coal. As the Indian economy continues to grow, its energy consumption will also increase, especially as the growth of its manufacturing sector catches up with services and agriculture sectors. Prime Minister's 'Make in India Program' will also provide a great thrust in making India a manufacturing hub. However, as the domestic resource production is

facing various challenges, general expectation has been that Indian energy imports will continue to grow and energy security concerns will intensify in coming days.

Energy security is a component of national security and it will continue to remain a prime concern of countries. Based on present trend, India is on its course to become a global energy player and will drive the world energy demand in the next couple of decades. The increase in supply-demand gap is inevitable and will lead to an increase in import dependency for fossil fuels for India which makes it essential to strengthen energy import infrastructure for ensuring availability of sufficient energy in the country. The fall in commodity prices presents a unique opportunity to reinforce its energy security. In this direction, Government has already taken certain initiatives and policies to increase production of oil and natural gas such as new gas pricing formula, development of national gas grid infrastructure, reassessment of hydrocarbon potential, etc. It is important that India increases the intensity of its efforts so as to meet time bound targets and reap significant benefits in the long run.

1.2 World & Indian energy scenario

1.2.1 World's energy scenario:

Growing population, increased urbanization and industrialization are some of the key factors that have resulted into increase in the consumption of primary energy year after year. The total world's primary energy consumption in 2014 stood at 12928.4 Million Ton of Oil Equivalent (MTOE) which was an increment of 0.9 % over 2013. The leading energy consuming nations are China – 2972.1 MTOE, U.S- 2298.7 MTOE, Russia – 681.9 MTOE. The energy basket is constituted of the fuels like Oil, Natural Gas, Coal, Nuclear Energy, Hydro Electricity and Renewable energy sources.

The consumption of these fuels at global level is shown below in MTOE:

Table-1.1 Global Energy Consumption

(BP statistic- review of world energy-2015)

S.NO.	**Fuel**	**Consumption**
1	Oil	4211.1
2	Natural Gas	3065.5
3	Coal	3881.8
4	Nuclear Energy	574.0
5	Hydro Electricity	879.0
7	Renewables	316.9
8	**Total**	**12928.4**

The total world primary energy consumption 12928.4 MTOE in percentage is shown as below -

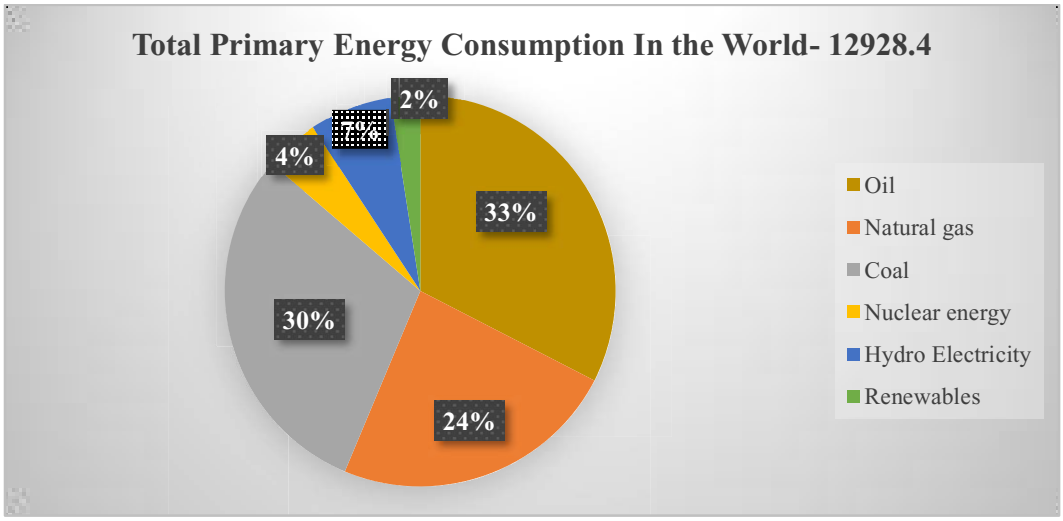

Fig-1.2 Global Energy Consumption percentage sector-wise

(BP statistic- review of world energy-2015)

Country wise energy consumption is shown in figure-1.3:

China, U.S., Russia and India accounts for 51% of total primary energy consumption in the world wherein, India is the fourth largest primary energy consuming country.

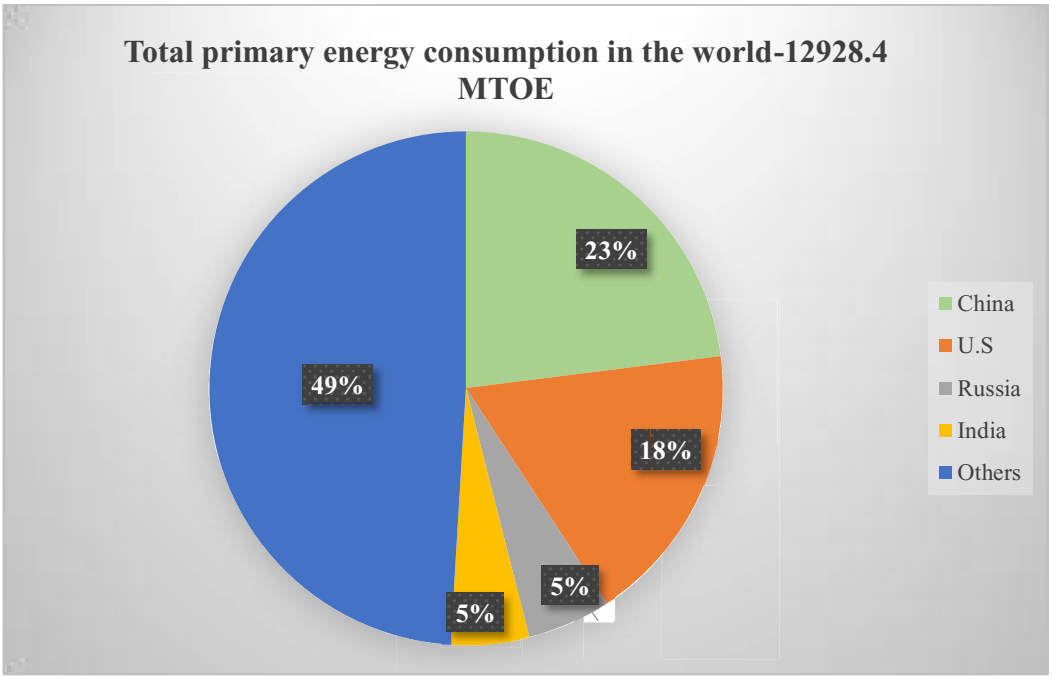

Fig-1.3 Global Energy Consumption percentage country-wise

(BP statistic- review of world energy-2015)

1.2.2 Indian energy scenario:

India consumes 637.8 MTOE of primary energy, which is approximately 4.93% re is projected to increase in the coming future.

The consumption by various fuels in Indian Energy basket of India is shown below in MTOE:

Table-1.2 Indian Energy Consumption

S.NO.	Fuel	Consumption
1	Oil	180.7
2	Natural Gas	45.6
3	Coal	360.2
4	Nuclear Energy	7.8
5	Hydro Electricity	29.6
7	Renewables	13.9
8	**Total**	**637.8**

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(BP statistic- review of world energy-2015)

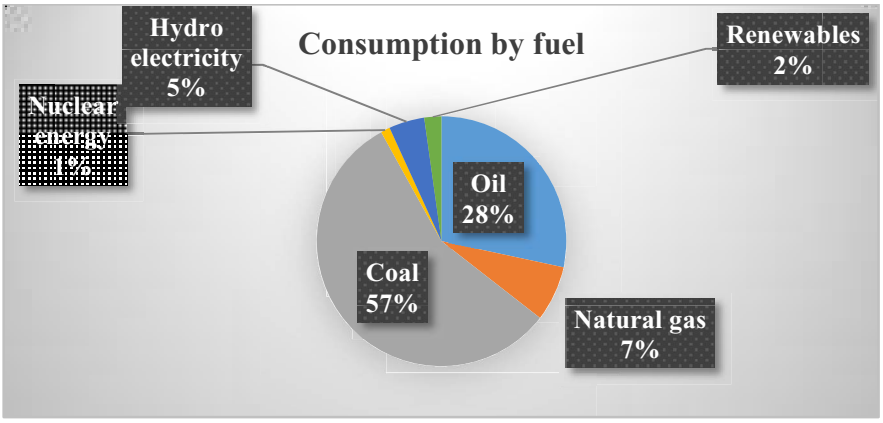

Fig-1.4 Indian Energy Consumption percentage sector-wise

(BP statistic- review of world energy-2015)

The share of natural gas is 7

MTOE. Natural gas is consumed in various sectors in India like Power, Fertilizer,

City Gas Distribution, and other Industries etc. Increase in energy demand is driven by economic growth but this is expected to be compensated by significant improvements in energy intensity. The amount of energy used per unit of GDP. As per BP Energy Outlook 2035, there shall be rapid improvements in energy intensity (gross domestic product) – means that energy demands grows far less quickly than global GDP: 34% compared with 107%.

The energy intensity of the global economy is projected to decline by 2.1% p.a. over the forecast period. Energy intensity in the developed economies of the OECD group declines at a faster rate than in the past 20 years and the growing importance of China means the continuing declines in China's energy intensity have a bigger impact on the global trend. The energy intensity of other major non-OECD economies, including India and Africa, is projected to continue falling even as they go through the industrialization phase of their economic development. By 2035, India's energy intensity of GDP is nearly 40% lower than today's level.

1.3 World scenario of Natural gas

At the end of year 2014, the total proved reserves of natural gas in the world were 187.1 Trillion Cubic Meters (TCM). The proved reserves of natural gas have increased by 63.7% from 1994 to 2014 which is shown in next figure. Iran has the largest proved reserves of 34 TCM, followed by Russia and Qatar having proved reserves of 32.6 and 24.5 TCM respectively.

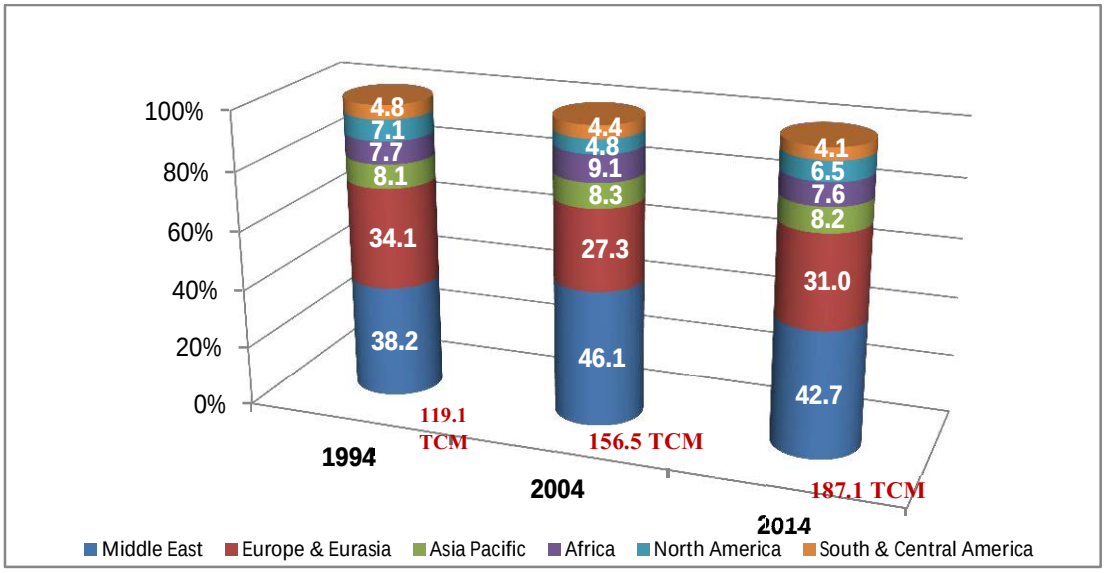

Fig-1.5 Distribution of proved reserves in 1994, 2004, 2014 (%)

(BP statistic- review of world energy-2015)

The world's production of natural gas is about 3460.6 Billion Cubic Meters (BCM) per year .U.S. is the leading country in the world with the production of 728.3 BCM of natural gas followed by Russia – 578.7 BCM and Qatar – 177.2 BCM. The percentage share in Natural Gas production is as shown below:

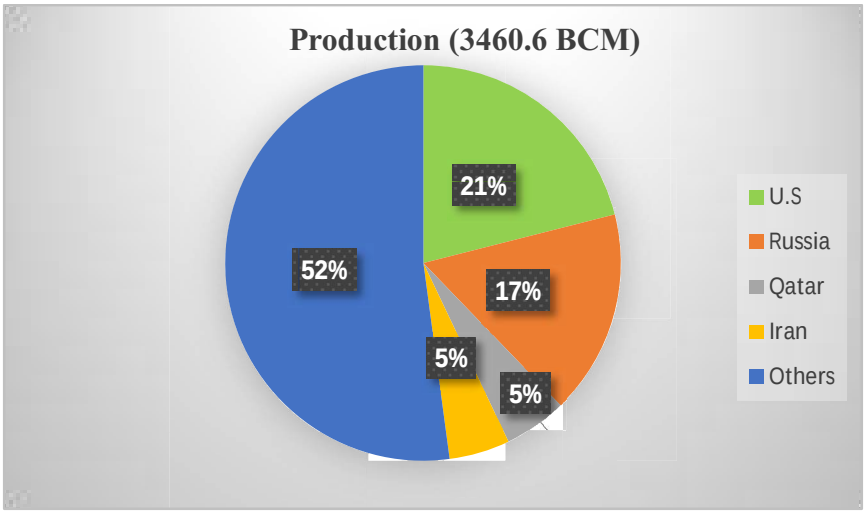

Fig-1.6 Global Natural Gas Production (%)

(BP statistic- review of world energy-2015)

U.S is also ahead of all the countries in terms of natural gas consumption The global consumption of natural gas is 3393 BCM with U.S consuming 759.4 BCM of natural gas followed by Russia -409.2 BCM and China -185.5 BCM. The natural gas consumption share amongst countries has been depicted below:

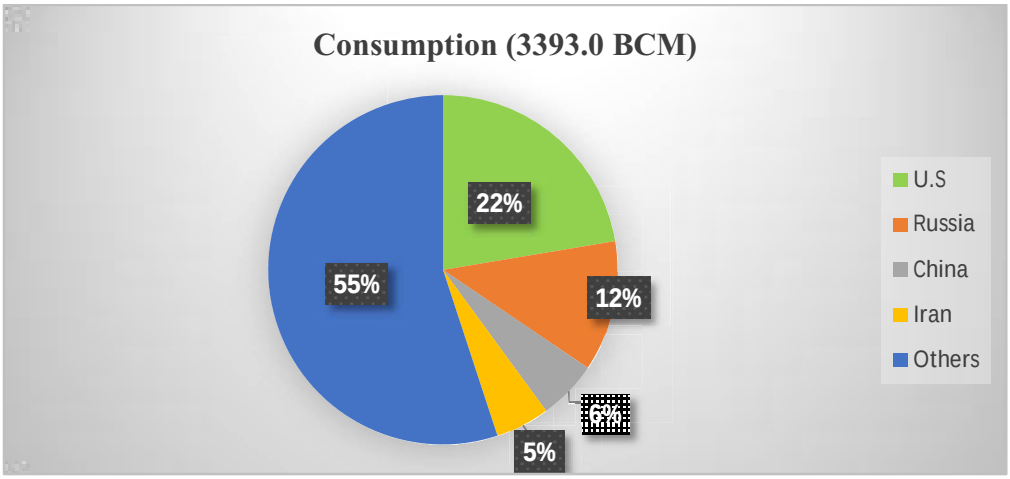

Fig-1.7 Global Natural Gas Consumption (%)

(BP statistic- review of world energy-2015)

Natural gas is transported mainly by interstate pipelines in gaseous form or by LNG tankers in liquefied form. In the world there are more than 35 liquefaction facilities and more than 110 re-gasification facilities.

There are many gas distribution companies present all around the world which transport gas within the country boundaries as well as across the country boundaries. Apart from these companies, there are other city gas distribution companies that mainly distribute gas within the city boundary limits to households and industries in the form on Piped Natural Gas (PNG), and Compressed Natural Gas (CNG) for transportation purpose. Some of these City Gas Distribution (CGD) companies have natural gas storage facilities and while some of them take the service of another company having natural gas storage facility. There are many types of natural gas storage facilities adopted by the

companies like Underground Gas Storage, LNG tanks, Gas bullets, Line Pack etc., are being used for gas storage.

1.4 Indian scenario of natural gas:

The total proved reserves of natural gas in India are as follows:

Table-1.3 Total proved reserves of natural gas in India

Year	Total proved reserves (TCM)
At the end of 1994	0.7
At the end of 2004	0.9
At the end of 2013	1.4
At the end of 2014	1.4

(Source: BP statistic- review of world energy-2015)

The demand of natural gas in India is increasing day by day. The current demand in fiscal 2014-2015 is around 276 mmscmd which is likely to go beyond 500 mmscmd by the year ending 2022 which is further expected to go beyond 700 mmscmd by the year ending 2030. The factor driving this growth in natural gas demand is increased use of natural gas in various sectors like City Gas Distribution, fertilizer, power, LPG/petrochemicals etc.

With PNGRB and Ministry of Petroleum & Natural Gas aiming to cover more than 300 cities and Prime Minister's mission of 1 Crore PNG connection in 5 years, CGD offers vast opportunities in various business segments. Recently Government of India has decided to provide 100 percent requirement of natural gas for compressed natural gas (CNG) and domestic gas (PNG) through the domestic gas which is much cheaper than the imported RLNG. Further for the encouragement of CNG and domestic PNG, government has also decided to

provide 10 percent extra gas to meet growth requirement and fluctuating demand of city gas distribution. The above steps have been taken so as to supply gas to more domestic consumers and to promote CNG based public transport.

In terms of percentage, energy consumption in India is depicted in the pie chart given below:

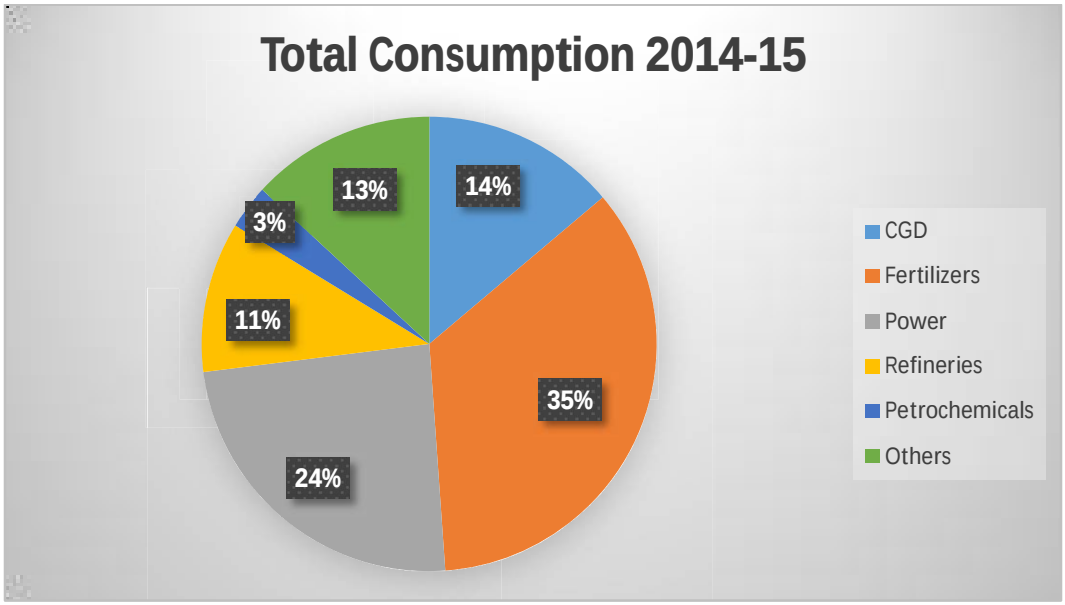

Fig-1.8 Energy consumption in India (%)

(BP statistic- review of world energy-2015)

As evident from the above chart, out of total consumption of natural gas in India, CGD accounts for 14 percent consumption of Natural Gas and this is expected to further increase in the coming times.

Table-1.4 Production and consumption of natural gas in India

Year	Natural Gas Production		Consumption in BCM	
	BCM	MMSCMD*	BCM	MMSCMD*
2004	29.2	80.01	31.9	87.41
2005	29.6	81.10	35.7	97.82
2006	29.3	80.28	37.3	102.20
2007	30.1	82.47	40.3	110.42
2008	30.5	83.57	41.5	113.71
2009	39.2	107.41	52.4	143.58
2010	50.8	139.19	62.7	171.80
2011	46.1	126.31	63.5	173.99
2012	40.3	110.42	59.2	162.21
2013	33.7	92.34	51.4	140.84
2014	31.7	86.86	50.6	138.64

*Source: BP statistic- review of world energy-2015 (*1BCM / YEAR = 2.74 MMSCMD)*

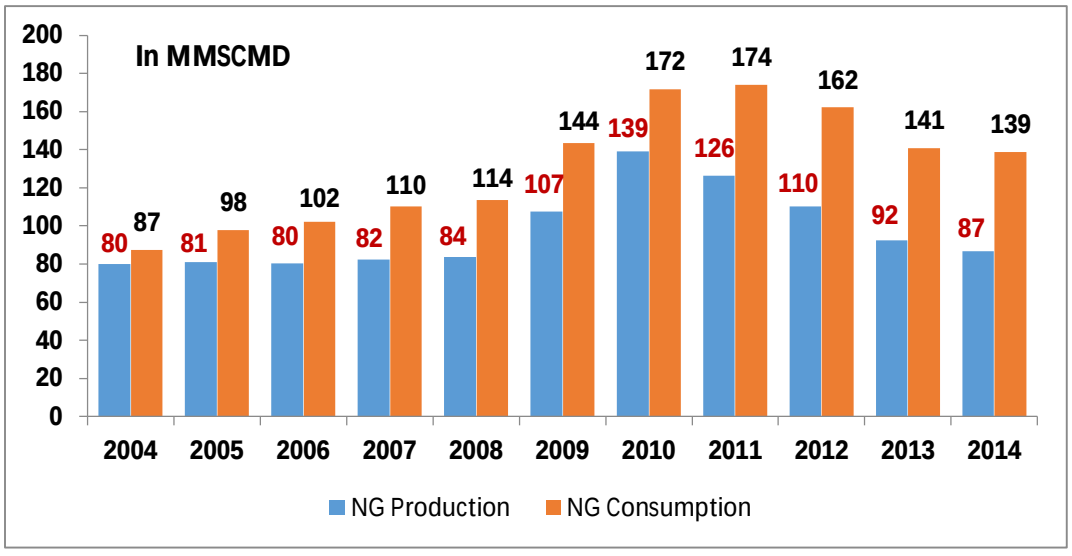

Fig-1.9 Natural Gas Production & Consumption Comparison

(Source: BP statistic- review of world energy-2015)

1.5 City Gas Distribution

City Gas Distribution involves distribution of Compressed Natural Gas (CNG) to transport segment and Piped Natural Gas (PNG) to households, industries and commercial segments.

1.5.1 CNG (Compressed Natural Gas)

Compressed natural gas is a mixture of hydrocarbons mainly methane. It is used in automobiles as a fuel in compressed form. The gas is compressed to a pressure of around 200 to 250 kg/cm^2 so as to enhance the on board storage capacity of the vehicle. CNG is considered as a Green fuel as compared to Petrol and Diesel which emits harmful gases that contribute to pollution.

1.5.1.1 Benefits

- **Green Fuel:** CNG is also known as green fuel as it is free from components like lead, sulphur, benzene and other corrosive and harmful compounds.
- **Operational Cost**: The operational cost of vehicles running on CNG is relatively cheap as compared to vehicles running on other fuels like petrol, diesel etc.
- **Increases life of oils:** When CNG is used as a fuel in an automobile then it increases the life of lubrication oil used in the automotive as CNG do not contaminate the crankcase oil.
- **Safety:** CNG auto ignition temperature is around 540 degrees centigrade and a narrow range of 5% to 15% inflammability, hence it is less likely to auto ignite on hot surfaces.
- CNG is in gaseous form hence it mixes with air easily and in even proportions.

One of the major concern in today's scenario, especially in the context of global warming and greenhouse effect, is the emission of various pollutants from

different fuels and their adverse effect on the environment. Efforts are made all across the world to increase the use of cleaner fuels.

Different types of air pollutants that adversely affect the environment and which are given utmost consideration while selecting the fuel for vehicles are:

- Oxides of Sulfur (SOx)
- Oxides of Nitrogen (NOx)
- Lead (Pb)
- Carbon Monoxide (CO)
- Particulate Matter (PM)
- Hydrocarbons (HC)

1.5.1.2 Detail of pollutants

- **Oxides of sulfur (SOx):**

Sulfur oxides originates from the sulfur content which is present in the fuel, when sulfur is burned it produces SOx, to control SOx sulfur content should be minimized in the fuel. It is a colorless, non-flammable gas and it produces respiratory problems. Also, oxidation of SOx produces Sulfuric acid which then produces acid rain, thus it is imperative that SOx level should remain as low as possible. Coal fired power plants are most responsible for SOx emissions. Bharat Stage 4 (BS 4) diesel has 50 parts per million (ppm) of sulfur content, whereas BS 3 diesel has 350 ppm of sulfur. As per BS4 petrol should not exceed 50 ppm and as per BS 3 the petrol should not exceed the sulfur content of 150 ppm. Natural gas has relatively very low amount of sulfur content. (Sweet gas has less than 4 ppm of hydrogen sulfide).

- **Oxides of nitrogen (NOx):**

It is reddish brown in color and when combusted under high pressure and temperature it emits nitrogen dioxide. Nitrogen oxides contribute in the formation of ground level Ozone and acid rain. The concentration of NOx in diesel exhaust varies in the range of 50 – 1000 ppm. In BS4 for diesel it varies from 0.25 – 0.39 g/km (for light duty vehicles) and for petrol it varies from 0.08 – 0.11 g/km for BS4. And for BS3 it ranges from 0.15-0.21 g/km. For CNG the emission of NOx is approx. 16 ppm which is approximately three times lesser than that of diesel car.

- **Lead (Pb):**

It is a heavy metal, and it causes harm to nervous and reproductive system. Over the time it accumulates in tissues and bones. It is unwanted beyond a certain limit.

- **Carbon Monoxide (CO):**

It is produced when there is incomplete burning of fuels. It is a colorless, odorless and a toxic gas. It can reach the blood stream and can cause reduction in the flow of oxygen in the blood. In BS4 for light duty diesel vehicles it is limited to 0.5 – 0.74 g/km and in BS3 its range is between 0.64 - 0.95–g/km. For gasoline vehicles the emission standard of CO is in between 1- 2.27 g/km as per BS 4 standard. In CNG combustion CO is emitted in very low or negligible quantity. It typically ranges from 20 – 80 % lower than the gasoline combustion.

- **Particulate matter (PM):**

These are very small liquid or solid particles suspended in soot or smoke, in higher concentration it may lead to heart diseases and lung cancer. In BS4 for diesel vehicles its range is limited to 0.025 – 0.06 g/km.

- **Hydrocarbons (HC):**

It results from the incomplete combustion of fuels and its reaction with sunlight causes smog and ground level ozone formation. It must be negligible as per the BS 4 norms for light diesel engines, but for gasoline engines the range which is permitted is 0.1 – 0.16 g/km. The below table details comparative pollution load contributed by the emissions of CNG bus vs. Diesel bus. As evident from the table, in a Diesel bus the level of highly toxic NOx and PM emissions are much higher.

Table-1.5 Pollution load comparison CNG vs Diesel

Vehicle Type	Kms Running	Pollution Load, TPD			
		CO	**NOx**	**HC**	**PM**
City Bus (CNG)	10.53	9.55	21.60	5.79	0.09
City Bus (Diesel)	11.03	6.23	21.73	1.61	1.65

(Source: http://cpcb.nic.in/Delhi.pdf)

There has been a significant reduction in air pollution in India since 1991, and with the new norms being formed by the government it is likely to reduce down more. Till now four emission standards are formed in India with the reference to Euro standards.

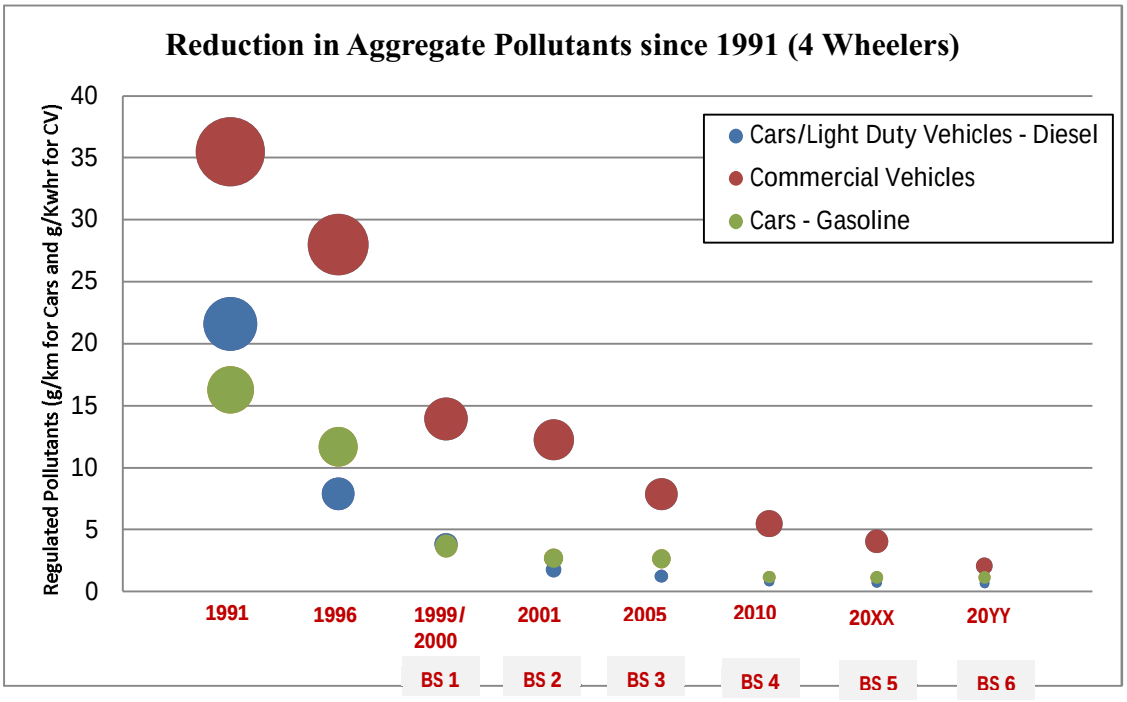

Fig-1.10 Reduction of aggregate pollutants since 1991 (4 wheelers)

(Source: - http://www.siamindia.com/technical-regulation.aspx?mpgid=31&pgidtrail=33)

It may be observed from the above figure that there is a significant reduction in air pollution since 1991. It would be pertinent to mention here that as BS 5 and BS 6 norms will come in the future, Indian refineries must be equipped with advanced technologies so that it can reduce the pollutants contained within the fuel. Meanwhile, except Jamnagar refinery in India other refineries may not adapt to these upcoming standards in immediate future. Thus alternative fuels like CNG which emits much lower pollutants than Diesel and Gasoline will gain more attention and increase their market share. In light of above, the role of Natural Gas in the coming future cannot be overlooked.

1.5.2 PNG (Piped Natural Gas)

Piped Natural Gas is generally methane with minor proportion of other hydrocarbons. It is procured from the oil / gas wells, treated and transported through a network of pipelines across the country.

1.5.2.1 Benefits

- **Uninterrupted Supply:** PNG ensures adequate and continuous supply of gas to consumers at all times.
- **Safety:** Natural Gas has narrow inflammability range i.e. the combustible mixture of natural gas and air will not ignite if it is less than 5 percent and richer than 15 percent of the air fuel ratio required for ignition. Thus PNG is much safer to use than LPG.
- **Convenience:** Use of LPG cylinder involves lot of inconvenience like booking of LPG cylinder refill time and again, wait for the local distributor to deliver the cylinder and above all non-continuous gas supply. PNG on the other hand, eliminates all the above hassles and the user can enjoy the uninterrupted gas supply with an ease.
- **Billing:** PNG billing is done according to the gas consumption recorded in the gas meter and the customer only pays for the amount of PNG used.
- **Low Maintenance:** No accumulation of soot, ash and greasy spillages which in turn reduces the maintenance cost makes PNG a low maintenance fuel.
- **Environment Friendly:** Natural gas combustion results in almost no emission of sulphur dioxide, carbon monoxide, carbon dioxide etc. This makes PNG a clean and green fuel.

1.5.3 City Gas Distribution - World Scenario (Region wise)

1.5.3.1 United States

- **CNG scenario:**

Currently there are around 200,000 vehicles in United States which are running on CNG. These vehicles are refueled with CNG from 841 CNG stations operated by public sector companies and 699 private CNG stations. Apart from cost saving benefit, the major reason behind the shift to CNG driven vehicles in U.S is the need to reduce greenhouse gas emissions. As per BCG forecast the number of CNG vehicles in U.S will grow from 170,000 in 2013 to more than 500,000 by 2020 at an annual growth rate of 17 percent.

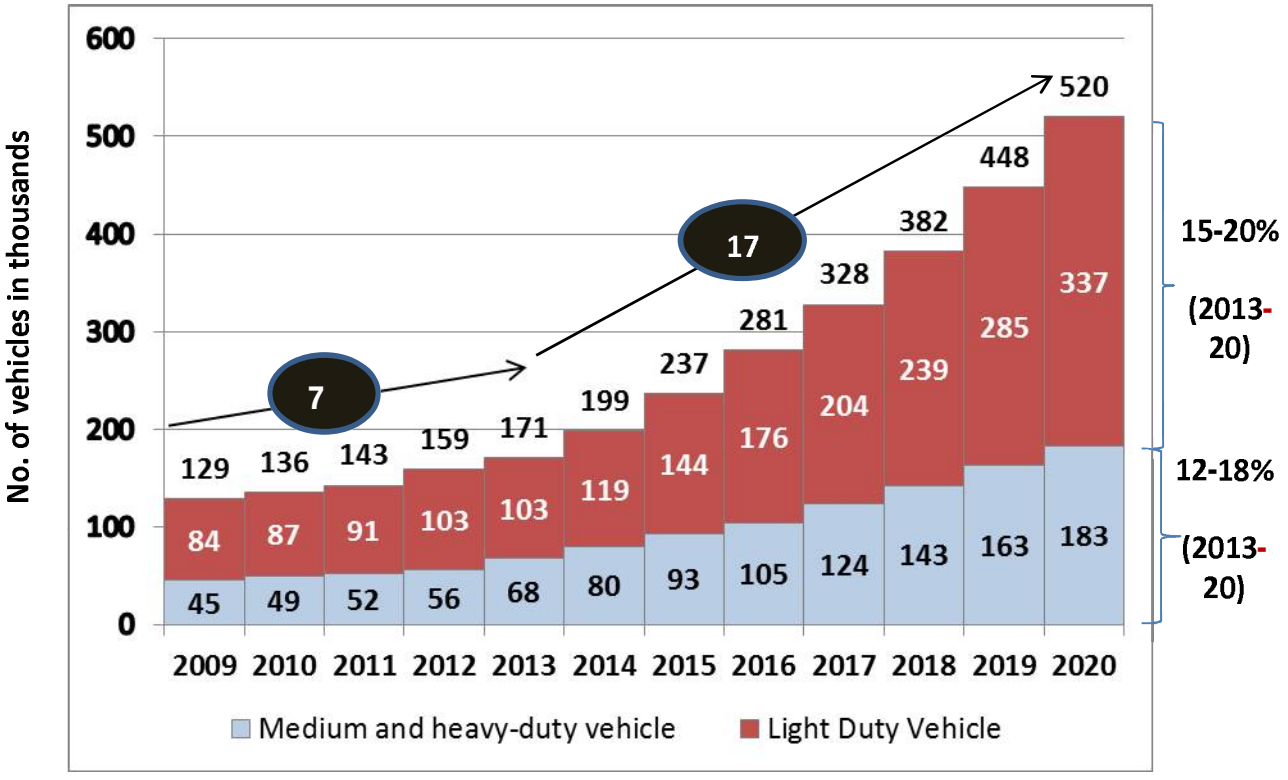

Fig-1.11 CNG vehicles growth forecast, (Source: EIA website)

There are three different types of CNG refueling station models in US. These are:-

- CNG refueling station for Fleet Operators:
- Dedicated CNG stations for the public, and
- CNG refueling at Petrol Stations

- **Piped Natural Gas Scenario In U.S.**

In United States there is a huge demand for natural gas in households. More than 60 million household have natural gas connections primarily used for water heating, space heating, and cooking. Natural gas accounts for more than 50% of the fuel used for heating purpose. The demand of natural gas for heating purpose is very sensitive in U.S due to cold weather conditions, thus making weather as one of the most important factors impacting natural gas demand. There are more than 1200 natural gas distribution companies in U.S. to cater to natural gas demand. Some of these companies are listed below:-

- Southern California Gas Company
- Atmos Energy Corporation
- Nicor Gas
- Pacific Gas
- Consumers Energy Company

1.5.3.2 South America:

The CNG vehicles in South America are generally used for public transport, especially as taxicabs. The total numbers of CNG vehicles in Argentina are around 23,59,673 and the numbers of vehicle fuelling stations are around 1,932 *(Source: The GVR April 2014).*Statistics shows that vehicles per fuelling station in US stands at around 1,221.

The total numbers of CNG vehicles in Colombia are around 4,76,506 which are provided CNG through 703 CNG stations *(Source: The GVR April 2014).* As per the given statistics, a vehicle per fuelling station in Columbia is around 678.

1.5.3.3 Russia:

The first few CNG stations at Melitopol, Gorlovka and Moscow were constructed in Russia in 1939. Currently there are 267 CNG filling stations in Russia operating in 59 Russian regions and are expected to go beyond 400 by the year ending 2016. The most developed regional markets of CNG in Russia are as follows:

- Stavropol and Krasnodar Territories
- The Sverdlovsk region
- Rostov region
- Chelyabinsk region
- Tula region
- The Republic of Bashkortostan and
- The Kabardino Balkar Republic

These regions account for more than half of the CNG sales in Russia. The Government of Russia is also promoting CNG for transportation sector and as per the government new policy, the natural gas vehicles will amount to 50 percent for public transport, 30 percent for commercial transport and 20 percent for agricultural vehicles by the year ending 2030.

The number of vehicles currently running on CNG in Russia are around 90,000. Gazprom is one of the major players in the CNG business in Russia and has also entered into cooperation agreements with Kaluga, Orel, Nizhny Novgorod and Tambov regions etc. so as to promote natural gas as a motor fuel. Currently CNG has drastically been promoted in Eastern Siberia and the Far East. A CNG filling station has been built at Bratsk and in future new CNG filling stations are

expected to develop at Khabarovsk, Blagoveshchensk, Vladivostok and Yuzhno-Sakhalinsk.

1.5.3.4 Europe

As per Natural & Bio Gas Vehicles Association, the total numbers of vehicles running on CNG in all European countries are around 1,899,602. The most number of CNG vehicles come from countries like Italy, Germany, Bulgaria, Sweden, Ukraine, Armenia etc. As per Natural & Bio Gas Vehicles Association, there are around 4,501 CNG filling stations operating all across Europe. Out these, 3595 filling stations are of public sector companies and 906 belong to private sector companies. Also, another 276 CNG filling stations are under planning stage. There has been a good increase in the natural gas vehicles in recent years as compared to past decade. Countries like Italy and Germany have shown great strength in the CNG Market development. Further countries like Belgium, Netherlands, Austria, Czech Republic, and Finland etc. have drastically increased the number of vehicles running on CNG. Details of CNG vehicles and the number of fueling stations present in the major European countries are shown below:

Table-1.6 CNG infrastructure and vehicles Europe

S.NO.	Country	No. of CNG Vehicles	Number Of CNG Filling Stations
1	Germany	98,172	920
2	Italy	885,300	1,040
3	France	13,550	310
4	Bulgaria	61,320	110
5	United Kingdom	718	9
6	Sweden	46,715	205

7	Ukraine	388,000	324
8	Austria	8,323	180
9	Netherlands	7,537	141
10	Switzerland	11,640	139

Source: NGVA (Natural Gas Vehicle Association) (Source: www.ngva.eu/)

- **Piped Natural Gas Scenario in Europe**

Germany, France, Belgium, U.K., Italy, and Netherlands are the major natural gas consuming countries in Europe. These countries are connected to well established gas grid with more than 67 million consumers, out of which more than 90% are households. In the entire European Union, more than 72 million households' have natural gas pipeline connections. In whole of the Europe approx. 42% of the households are connected with PNG, whereas in the U.K and in the Netherlands market is reaching to a saturation point as almost in every home piped natural gas connection is present. Notably, more than 80% of the energy used by households in the Netherlands is by natural gas.

1.5.3.5 Asia

- **Iran**

Iran has been putting in efforts to reduce the dependency on gasoline vehicles and promote the use of Natural Gas Vehicles (NGV) for domestic market. Currently Iran has the world's largest fleet of CNG vehicles. The total number of vehicles running on CNG in Iran is 3500000 which are catered natural gas through around 1904 CNG stations *(Source: The Gas Vehicle Report (GVR- April 2014).* The local manufacturers in Iran are manufacturing the CNG vehicles themselves and also haves the capacity to build 1.5 million CNG cylinders per year. Due to this the Iranian government has stopped the imports of CNG cylinders and is promoting the growth of local manufacturers.

- **Pakistan**

Pakistan has the third largest number of NGV or CNG vehicles in the world. The total number of CNG vehicles in Pakistan is around 27,90,000 and the number of fuelling stations is around 2,997 (Source: The GVR, April 2014). As per the statistics, vehicles per fuelling station in Pakistan are around 931. Most of the public transport which used to run on diesel has been converted to CNG in recent years.

- **China**

China has the second largest number of NGV or CNG vehicles in the world. The total number of CNG vehicles in China is around 30,00,000 and the number of fuelling stations is around 5,*730 (Source: The GVR, April 2014).* The vehicles per fuelling station are around 524.

- **Thailand**

The taxi cabs in Bangkok have been running on CNG for more than 15 years. The Government of Thailand has promoted the use of alternative fuels drastically. PTT PCL Oil Company took the initiative so as to build a network of natural gas refueling stations. In 2008, more than 40,000 new cars, trucks and buses running on CNG were purchased in Thailand. Half of the taxi fleet in Thailand used LPG as a fuel so the government also put in efforts to switch the consumers from LPG to CNG.

As per the current statistics available there are around 4, 41,182 CNG vehicles in Thailand and the number of fuelling stations are around 899.

1.5.4 City Gas Distribution scenario in India

City Gas Distribution in India, started in 1990s is continuously evolving. Indraprastha Gas Ltd., which operates in Delhi & NCR and Mahanagar Gas Ltd. which operates in and around Mumbai are the major CGD entities in India.

1.5.4.1 Evolution of CGD in India

In the eighties, GAIL started techno economic feasibility studies for gas distribution in Mumbai and Delhi with the help of Sofragaz and British Gas. Due to encouraging recommendation of these studies Government of India approved gas allocation in Mumbai and Delhi. The intervention of Hon'ble Supreme Court of India to reduce level of air pollution in Delhi provided the thrust to develop and expand CGD network in city of Delhi and NCR.

The pioneer of CGD in India was Calcutta Gas Company, which started its CGD business in the year 1880 in Calcutta. Gas Authority Of India Limited (GAIL) entered into the CGD operations in early 1990s through the stake in companies Mahanagar Gas Limited (MGL) and Indraprastha Gas Limited (IGL) in Mumbai and Delhi respectively. These initiatives resulted in improvement of quality of air in these cities. As per PPAC and PNGRB website:-

- PNGRB has authorized 28 companies to operate in 57 Geographical Areas
- The total number of CNG vehicle currently operating in India is 2.43 Millions
- Number of CNG filling stations are 2016

1.5.4.2 Piped Natural Gas scenario in India

Piped natural gas in India is presently developed in 57 Geographical Areas. In India piped natural gas has eased the burden on household user as prior to the piped natural gas connections, customers had to order the LPG cylinder and pay

the cost of gas to be used in advance. There are other associated problems with LPG cylinders, the foremost being question mark on ready availability of LPG cylinders. These issues have been resolved with the emergence of PNG. PNG allows household user to pay the price of gas as per the usage, and continuous gas supply is maintained in PNG. Apart from these benefits, other important benefit includes PNG being much safer than LPG. In India presently total number of household's PNG connections are more than 3 million and the Government of India has set a goal to expand the number of household connections to more than 10 million in next 5 years. Thus it is clear that PNG demand will increase significantly in the coming future and continuous availability of gas will also remain a concern in case of any unforeseen circumstances.

Following states and cities have the CGD coverage in India:-

Table-1.7 CGD coverage in India

State	**Geographical Areas**
Harayana	Sonipat
	Chandigarh
	Panipat
Punjab	Jalandhar
	Amritsar
Andhra Pradesh	Kakinada
	Vijaywada
Telangana	Hyderabad
Assam	Tinsukia, Dibrugarh, Sibsagar, Jorhat, Golaghat
Gujarat	Ghandhinagar Mehsana Sabarkantha
	Hazira
	Valsad
	Rajkot

	Navsari
	Surendranagar
	Nadiad
	Kutch (East)
	Kutch (West)
	Ahemadabad City and Daskori Area
	Surat-Bharuch-Ankleshwar
	Anand
	Jamnagar
	Bhavnagar
Madhya Pradesh	Dewas
	Gwalior
	Indore & Ujjain
Maharashtra	Pune city including PimpriChichwad
	Mumbai & Greater Mumbai
	Thane city and adjoining areas
	Rajgadh
	Thane Excluding Already Authorized Area
	Pune District
Delhi	NCT of Delhi
Rajasthan	Kota
Tripura	Agartala
Uttar Pradesh	Meerut
	Mathura
	Agra
	Kanpur
	Bareilly
	Muradabad
	Firozabad

	Khurja
	Allahabad
	Jhansi
Karnataka	Bengaluru
Union Territories	Daman & Diu
	Dadra & Nagar Haveli

(Source: www.pngrb.gov.in)

Brief snapshots of CNG and PNG penetration in India along with the relevant numbers taken from the PNGRB and PPAC website are given in the next two tables as below:

Table-1.8 PNG connections snapshot in India

State	City Covered	CGD Companies	Domestic Nos.	Comm. Nos.	Industrial Nos.
Delhi / NCR	National Capital Territory of Delhi (Including Noida and Ghaziabad)	Indraprastha Gas Ltd.	601192	1652	776
Maharashtra	Mumbai, Thane, Mira-Bhayender, Navi Mumbai, Pune, Kalyan, Ambernath, Panvel,	Mahanagar Gas Ltd., Maharashtra Natural Gas Ltd.	854950	2761	160

	Bhiwandi				
Gujarat	Gandhinagar, Mehsana, Sabakantha, Nadiad, Halol, Hazira, Rajkot, Khambhat, Palej, Valsad, Navsari, Surendra Nagar, Ahmedabad, Vadodara, Surat, Ankeleswar, Bhavnara, Anand.	Sabarmati Gas Ltd., Gujarat Gas Ltd., Hindustan Petroelum Corporation Ltd., Vadodara Gas Ltd, Adani Gas Ltd., Charotar Gas Sahkari Mandal Ltd.	1430566	15808	3913
Uttar Pradesh	Merrut, Mathura, Agra, Firozabad, Kanpur, Bareilly, Lucknow, Moradabad, Khurja	Green Gas Ltd. (Lucknow), Central UP Gas Limited (Kanpur), GAIL Gas Ltd.,Sanwariya Gas Ltd., Siti Energy Ltd.,Adani Gas Ltd.	28784	198	466

Tripura	Agartala	Tripura Natural Gas Company Ltd.	19747	300	47
Madhya Pradesh	Dewas, Indore, Ujjain, Gwalior	GAIL Gas Ltd., Avantika Gas Ltd.	4685	31	74
Rajasthan	Kota	GAIL Gas Ltd.	189	1	9
Assam	Tinsukia, Dibrugarh, Sibsagar, Jorhat	Assam Gas Co. Ltd.	28979	1028	392
Andhra Pradesh/ Telangna	Kakinada, Hyderabad, Vijayawada	Bhagyanagar Gas Ltd.	3748	46	3
Haryana	Sonepat, Gurgaon, Faridabad	GAIL Gas Ltd, Adani Gas Ltd., Haryan City Gas Distribution Ltd.	25894	100	204
Total			2998734	21925	6044

(Source: www.pngrb.gov.in , www.ppac.org)

Table-1.9 CNG infrastructure and vehicles snapshot in India

State	Company Name	No. of CNG Stations	No. of CNG Vehicles
Gujarat	Adani Energy Ltd., Gujarat Gas Ltd.,(An amalgamated entity of Gujarat State Petroleum Corporation Gas Company Ltd. and Gujarat Gas Company Ltd., Sabarmati Gas Ltd., Hindustan Petroleum Corporation Ltd., Vadodara Gas Limited (JV of GAIL Gas Ltd. and Vadodara Mahanagar Seva Sadan)	361	811880
Delhi / NCR	Indraprastha Gas Ltd. (IGL), New Delhi	324	804289
Maharashtra	Mahanagar Gas Ltd.(MGL),Mumbai, Maharashtra Natural Gas Ltd.,(MNGL), Pune, GAIL Gas Ltd.	212	530961
Andhra Pradesh / Telangana	Bhagyanagar Gas Ltd.(BGL), Hyderabad.	32	32774
Rajasthan	Gail Gas Ltd.	3	4010
Uttar Pradesh	Green Gas Ltd. (Lucknow), Central UP Gas Ltd.(Kanpur), Siti Energy Ltd., Adani Energy Ltd., GAIL Gas Ltd., Sanwaria Gas Ltd.	41	97545
Tripura	Tripura Natural Gas Co. Ltd.,Agartala.	5	7560
Madhya Pradesh	Avantika Gas Ltd. (Indore), GAIL Gas Ltd.	21	20508
Haryana	Haryana City Gas Ltd, GAIL Gas Ltd., Adani Gas Ltd.	20	122209
West Bengal	Great Eastern Energy Corporation Ltd.	7	2275
All India Total		**1026**	**2434011**

(Source: www.pngrb.gov.in , www.ppac.org)

1.5.4.3 Regulatory Scenario in India

In India the CGD business is regulated by the Petroleum and Natural Gas regulatory board (PNGRB). PNGRB was constituted under the PNGRB Act, 2006. Petroleum and Natural Gas Regulatory Board (PNGRB) has recently conducted the 6thround of bidding for city gas distribution covering 34 cities of different states. To facilitate the expansion of city gas distribution in India, the government of India has decided to allocate 100 percent domestic gas supply for natural gas consumption in transportation (CNG) and domestic households (PNG).

1.6 PNGRB authorization of various geographical areas (GA's)

The entities authorized by the PNGRB are shown in the table as below:-

Five rounds of CGD bidding covering around 55 Geographical areas have been completed by PNGRB. Another 34 Geographical areas in Round 6 CGD Bidding have also been proposed.

Round 1	Round 2	Round 3	Round 4	Round 5	Round 6
•6 GAs	•7 GAs	•8 GAs	•14 GAs	•20 GAs	•34 GAs

A list of geographical areas authorized by PNGRB is as below:-

Table-1.10 Geographical Areas Authorized by PNGRB

S. No	Name of the CGD Network	Area Covered	Entity Authorized
1	Agartala CGD Network	Agartala CGD Network	Tripura Natural Gas Ltd
2	Agra CGD Network	Agra	Green Gas Limited
3	Allahabad CGD Network	Allahabad	M/s IOCL-AGL
4	Amritsar CGD Network	Amritsar District (Punjab)	M/s GSPL
5	Anand	Anand area including Kanjari &Vadtal Villages (in Kheda District)	Charotar Gas Sahakari Mandali Limited
6	Bareilly CGD Network	Bareilly GA	Central U.P. Gas Limited
7	Belgaum CGD Network	Belgaum	MEIL
8	Bengaluru Rural and Urban CGD Network	Bengaluru Rural and Urban Districts	M/s GAIL Gas Limited
9	Bhavnagar CGD Network	Bhavnagar	M/s Gujarat Gas Company Ltd.
10	Chandigarh CGD Network	Chandigarh	M/s IOCL-AGL
11	Dadra Nagar Haveli CGD Network	UT of Dadra & Nagar Haveli	M/s GSPC Gas Company Limited
12	Daman CGD Network	UT of Daman	M/s Indian Oil-Adani Gas Pvt. Limited

13	Delhi CGD Network	National Capital Territory of Delhi	Indraprastha Gas Limited
14	Dewas CGD Network	Dewas	Gail Gas Limited
15	Dharwad CGD Network	Dharwad	IndianOil-Adani Gas Pvt.Ltd.
16	East Godavari District (excluding area already authorized) CGD Network	East Godavari District	Proposed Consortium of APGDCL and HPCL (CAH)
17	Ernakulam District (Kerala)	Ernakulam District (Kerala) GA	Indian Oil - Adani Gas Private Limited
18	Firozabad Geographical Area (Taj Trapezium Zone)	Firozabad Geographical Area (Taj Trapezium Zone) in the state of UP	GAIL Gas Ltd
19	GhandhinagarMehsana Sabarkantha CGD Network	Ghandhinagar Mehsana Sabarkantha	Sabarmati Gas Limited
20	Gwalior CGD Network	Gwalior	Aavantika Gas Limited
21	Haridwar CGD Network	Haridwar	M/s GAIL Gas Ltd.
22	Hazira	Hazira Geographical Area	GSPC Gas Company Limited
23	Hyderabad CGD Network	Hyderabad	Bhagyanagar Gas Limited
24	Indore CGD Network	Indore including Ujjain	Aavantika Gas Limited
25	Jalandhar CGD Network	Jalandhar	M/s Jay Madhok Energy Pvt. Ltd.

26	Jamnagar CGD Network	Jamnagar	M/s GSPC Gas Company Limited
27	Jhansi CGD Network	Jhansi	M/s Central UP Gas Ltd.
28	Kakinada CGD Network	Kakinada	Bhagyanagar Gas Limited
29	Kanpur CGD Network	Kanpur GA	Central U.P. Gas Limited
30	Khurja	Khurja Geographical Area	Adani Gas Limited
31	Kota CGD Network	Kota	Rajasthan State Gas Ltd. & Gail Gas Limited
32	Krishna District CGD Network	Krishna District (excluding area already authorized)	MEIL
33	Kutch CGD Network	Kutch (West)	M/s GSPC Gas Company Limited
34	Kutch CGD Network	Kutch (East)	M/s Jay Madhok Energy Pvt. Limited
35	Ludhiana CGD Network	Ludhiana	M/s Jay Madhok Energy Pvt. Limited
36	Mathura CGD Network	Mathura	JV of M/s DSM Infratech Pvt. Ltd. & M/s Saumya Mining Pvt. Ltd.
37	Meerut CGD Network	Meerut	Gail Gas Limited
38	Moradabad	Moradabad Geographical Area	Siti Energy Limited
39	Mumbai CGD Network	Mumbai & Greater	Mahanagar Gas

		Mumbai	Limited
40	Mumbai CGD Network (GA-2)	Thane City & adjoining contiguous	Mahanagar Gas Limited
41	Nadiad	Nadiad Geographical Area	GSPC Gas Company Limited
42	Navsari	Navsari Geographical Area	GSPC Gas Company Limited
43	Panipat CGD Network	Panipat	M/s Indian Oil-Adani Gas Pvt. Limited
44	Pune CGD Network	Pune District(Maharashtra) excluding area already authorized	M/s Mahesh Resources Pvt. Ltd. & Others
45	Pune City including Pimpri Chichwad CGD Network	Pune City and adjoining areas	Maharashtra Natural Gas Limited
46	Raigarh CGD Network	Raigarh District(Maharashtra) excluding area already authorized	M/s Mahanagar Gas Limited
47	Rajkot	Rajkot Geographical Area	GSPC Gas Company Limited
48	Sonipat CGD Network	Sonipat	Gail Gas Limited
49	Surat-Bharuch-Ankleshwar	Surat-Bharuch-Ankleshwar Geographical Area	Gujarat Gas Company Limited
50	Surendranagar	Surendranagar Geographical Area	GSPC Gas Company Limited

51	Thane CGD Network	Thane District(Maharashtra) excluding area already authorized	M/s GGCL
52	Tumkur CGD Network	Tumkur	MEIL
53	Udham Singh Nagar CGD Network	Udham Singh Nagar	Indian Oil-Adani Gas Pvt.Ltd.
54	Upper Assam CGD Network	Upper Assam CGD Network	Assam Gas Company Ltd
55	Valsad	Valsad Geographical Area	GSPC Gas Company Limited
56	Vijaywada CGD Network	Vijaywada GA	Bhagyanagar Gas Limited
57	West Godavari District CGD Network	West Godavari District	Proposed Consortium of APGDCL and HPCL (CAH)

(Source: www.pngrb.gov.in)

A map of India covering the cities connected to CGD is as below:-

Fig 1.12 CGD in India snapshot, (Source: www.pngrb.gov.in)

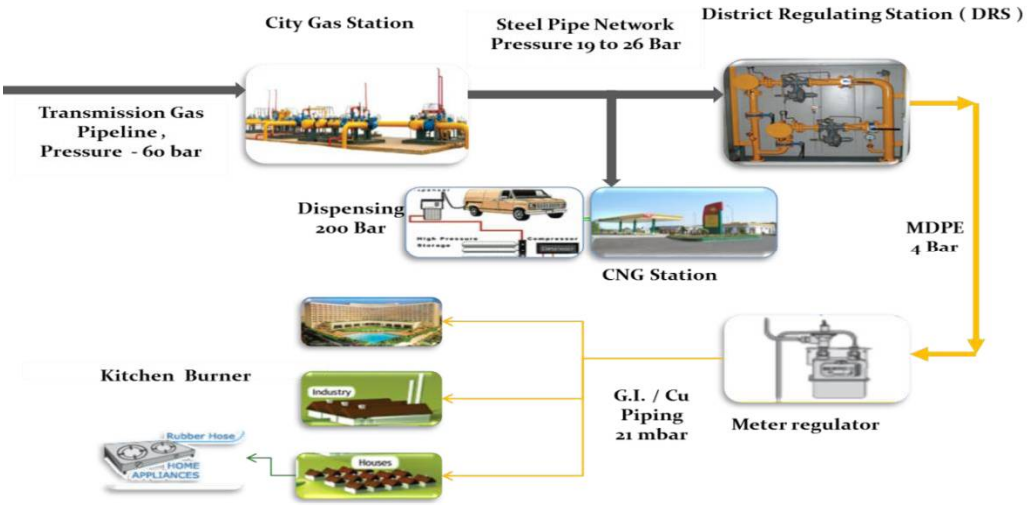

Fig-1.13 CGD network schematic, Source www.iglonline.net

The general pressure regime in a city gas distribution network is as follows:

Steel Mains Transmission Pipeline
- **City Gate Stations (60 bars)**

Steel Mains Distribution Pipeline
- **Industrial, CNG Distribution (19 bars)**

MDPE Pipe Distribution Mains
- **Small Industrial, Commercial (4 bars)**

Meter Regulator (100 millibars)

Residential Burner (21 millibars)

Fig-1.14 Pressure reduction in CGD, Source: www.iglonline.net

1.7 City Gas Distribution Companies around the world and their operations

1.7.1 United States

Since the mid-1980s there has been a drastic change in the structure of natural gas industry in the U.S. Earlier the E&P companies put in efforts to explore and produce natural gas and sell it to the large transportation pipeline companies. The price at which they sold gas was federal regulated. The large transportation pipeline companies transported and sold natural gas to the local distribution companies (LDCs) which in turn sold the gas to the customers. The prices at which the local gas distribution companies can sell gas were state regulated and state regulations governed the prices. The present scenario of natural gas industry in U.S. is completely changed and the industry is much more open to choices and competition. The E&P companies can now sell gas according to supply and demand scenario; there is no regulation on prices at wellhead now. The local distribution companies are offering bundled products to their customers. In many states in U.S. retail unbundling is also taking place. The choices to the end consumers are more as now they can purchase gas directly from the producer or from the local distribution companies.

Presently there are around 1200 Natural gas distribution companies in U.S. and most of them enjoy a monopoly status over their distribution region. Simplified layout of natural gas market in U.S is shown below:-

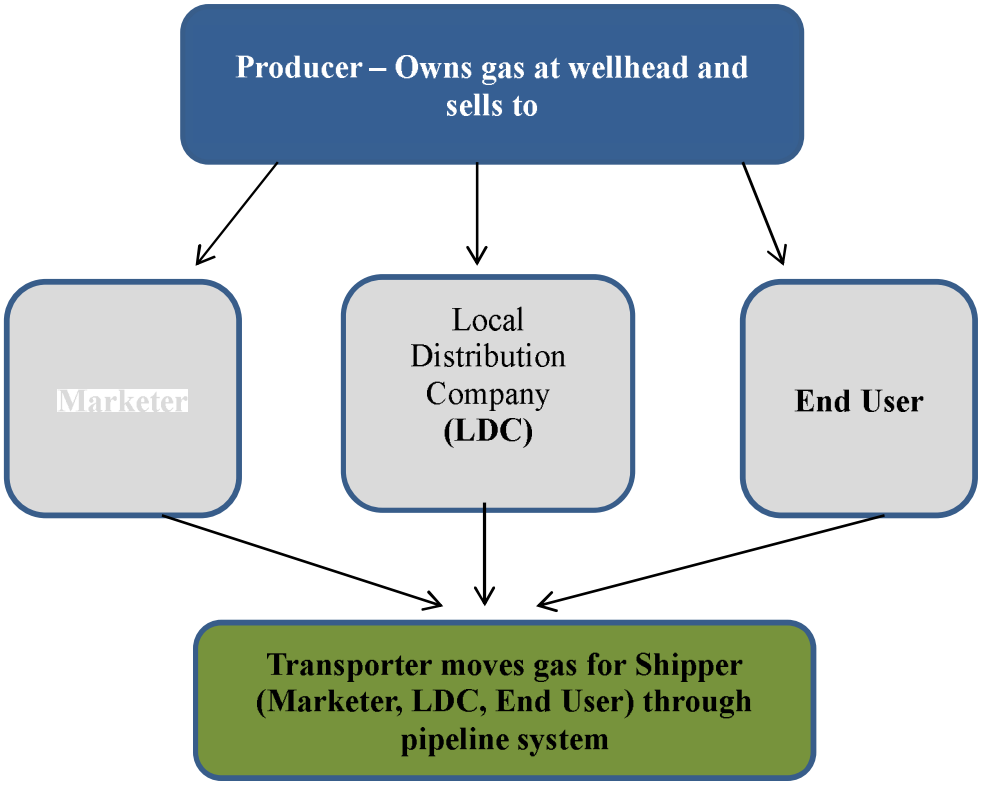

Fig-1.15 Layout of natural gas market in U.S*, Source: www.afdc.energy.gov*

Various natural gas distributors in U.S. can be classified as follows:

- Investor owned
- Privately owned
- Municipal
- Cooperative
- Interstate Natural Gas Pipelines
- Intrastate Natural Gas Pipelines

1.7.2 Europe

Gas distribution initially refers only to the activity of transporting the gas through a low/medium pressure grid, where transportation of gas refers through a transfer through low/medium pressure grid whereas supply of gas refers only to the commercial angle i.e. selling the gas to the end customer or user. Accordingly, EU Directive 2003/55/EC defines: 'distribution'; means the transport of natural gas through local or regional pipeline networks with a view to its delivery to customers, but not including supply. Distribution networks, like transmission, are considered natural monopolies because of huge economics investments involved. Therefore, in a liberalized market distribution and supply of gas are considered separate activities. The regulatory framework of Europe includes the following points:

The directive provides for a separate 'Distribution System Operator' (DSO) responsible for:

- The development of an efficient and secure system
- The operation and maintenance of the system
- Open access to system users on a nondiscriminatory basis

Effective unbundling must be implemented where DSOs are part of a vertical integrated undertaking at least in terms of their:

- Accounts
- Organization
- Decision making from other activities
- Legal form

Originally, local gas distribution companies were provided exclusivity to distribute gas in particular areas and offer a bundled service (distribution, supply and other services such as billing, connections and safety audits/inspections).

There is limited scope for competition in certain distribution systems due to certain constraints like limitations on the size of the market (economically not viable, small and geographically restricted areas, usually in cities). Therefore, a common practice worldwide is that both supply and distribution activities are performed by the same entity under exclusive rights for a certain period of time (monopolistic concession to recover the investments). A special provision of the EU Gas Directive (article 28) allows for the possibility of concession arrangements in gas distribution even today.

Natural gas consumption in EU member states is expected to increase to about 625 mtoe in 2030, which is a considerable increase of 43%. The share of natural gas in the European primary energy demand is expected to rise from 23.9% in 2005 to 29.9% in 2030. At 60% of the total demand increase, most of the growth will come from power generation. In the residential and commercial sector, gas consumption has steadily increased in line with the expansion of the infrastructure and the associated rise in the number of gas users. Over the last 15 years, gas consumption has seen 2.8% growth p.a. to 175 mtoe. Gas currently holds a market share of approx. 35 %, which makes it the market leader in this sector.

Country differences in the household penetration of natural gas are due to a combination of factors. The most fundamental of these relate to the abundance of indigenous supplies of natural gas and the length of time for which natural gas has had a share in the national energy market. For example, Local distribution networks have been slow to develop in Spain where gas was a scarce resource before the opening of the Gazudoc Maghreb European (GME) pipeline in 1996. On the other hand, both the Netherlands and the UK, with very extensive networks have been able to exploit large domestic reserves of natural gas for several decades.

Another important factor that determines the level of PNG penetration for domestic households is the very high distribution costs involved in distribution of gas, particularly for households in regions with scattered population or very

irregular terrain. The potential for switching to natural gas is influenced not only by the proportion of households already using gas but also by the proportion of households which, although not connected to the mains, are within the areas already served and can be converted by extension of the existing network.

Spanish gas network serves an area housing over half of the Spanish population. Similarly, Germany has the largest potential for fuel-switching without further network extension as more than 90% of the population inhabits a locality served by the existing gas pipeline network.-*presently only 42% are connected NG users.* France, Belgium and Denmark also have large potentials for Natural gas usage by domestic households.

UK, Germany, Italy, France and the Netherlands have the largest markets for residential natural gas. Households in the Netherlands, UK, France and Italy are fully dependent on natural gas for total energy consumption. More than 80% of energy used by Dutch households is natural gas, while the number goes to around 66% for UK households. In Belgium and Germany, natural gas accounts for at 33% of household energy consumption.

1.7.3 Russia

Presently the Russian natural gas market consists of two sectors i.e. regulated and deregulated sector. The regulated sector is the main sector and Gazprom is the major supplier of gas. The prices of gas are in line with the Russian Federation Law and the consumers get the gas at state regulated prices. There is a body formed known as the Federal Tariff Service (FTS) of Russia which regulate whole sale price for various price zones.

The leading company in natural gas distribution in Russia is Gazprom. Gazprom and its subsidiaries have around 479 thousand kilometers of gas pipeline network however; new independent gas producers are also emerging in Russia. Among them the two new key players are Novatek and Rosneft.

The main companies involved in local distribution of gas in Russia are as follows:

- **Gazprom**

Gazprom is one of the biggest companies in Russia for exploration, production, transmission, distribution and storage of natural gas. For storage Gazprom is mainly making the use of underground storage facilities and LNG storage facilities.

- **Yamal Lng**

This company is a joint venture of Novatek, Total and CNPC. The total capacity is around 16.5 million tons per year. This project is one of the projects operational in the arctic region. Three LNG trains are constructed with a capacity of 5.5 million tons per year.

- **CB&I**

This is company built Russia's first LNG storage facility at Sakhalin. The company provided the engineering, procurement and construction of two LNG storage tanks along with two 1mmscm full containment LNG storage tanks. They also constructed two 1630 cubic meter LNG Horton sphere pressure vessels.

- **VINCI**

This company has developed four cryogenic LNG storage tanks in contract with JSC Yamal LNG. The inner container of the tank is made up of 9% nickel stainless steel and the external container is pre stressed concrete. The capacity of each of the tank is 160000cubic meters. VINCI and Entrepose Contracting has till now built 30 LNG storage tanks in 11 different countries.

1.7.4 Australia

The major gas distribution networks in Australia are privately owned. South Australia, Victoria, Western Australia and Queensland have privatized state owned networks operated by them in 1993, 1997, 2000 and 2006 respectively. The principal New South Wales network and the new Tasmanian network have always been in private hands. AGL developed the Australian Capital Territory (ACT) network, but in 2000 formed a joint venture with the government owned Actew Corporation. The four main principal players are as follows:

1. Singapore Power International
2. Envestra
3. Babcock & Brown Infrastructure
4. APA Group.

The major gas distribution companies in Australia include:

- AGL
- Alinta Gas
- Allgas Energy Ltd
- Envestra
- Country energy
- TXU networks
- United energy
- Multinet Gas
- Spi Networks
- Powerco

1.7.5 China

China is the fastest growing consumer of natural gas in the world. There are many companies involved in city gas business like Towngas, Xinao Gas, Panva Gas, Wah Sang Gas, Zhengzhou Gas, Beijing Gas etc. Apart from this some local government companies are taking steps to get the pipeline gas by upgrading their existing grid or by developing a new pipeline network. China had nearly 35,498 miles of main natural gas pipelines at the end of 2013.China is focusing on distributors to enhance their storage capacity, as right now storage is just 2% of their annual usage. The distribution companies and their details are listed below:

- **Beijing Gas group Company Limited**

It is the largest pipeline natural gas supplier and service provider in China. It currently has 4.7 million gas subscribers and 14000 km of pipeline network and annual gas sales volume of more than 8 bcm.

- **China gas**

It is one of the largest city gas suppliers in China. It has pipeline network of around 47,668 km and it serves 10.3 million residential users and 62,193 industrial and commercial customers. It has 295 CNG filling stations.

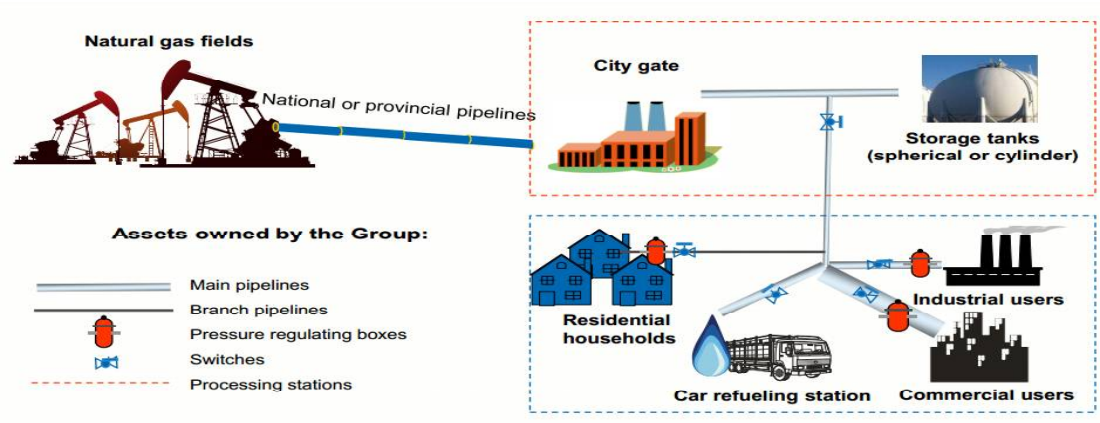

Fig-1.16 Business model of China gas

It is the typical business model of China gas. China gas uses spherical or cylindrical storage tanks instead of underground storage. Its total sales volume of natural gas in FY 2014 was 8044.8 million m3.

- **Town gas**

With a pipeline network of greater than 3500km, and over 1.8 million customers, it is one of the leading gas suppliers in Hong Kong. Town gas operates in 119 city gas projects and it has become the first city gas supplier to invest in an underground storage facility being constructed in phases that will have a capacity to store up to 290 million cubic meters. It has around 1.8 million customers.

1.8 Topic and purpose of study

To further explore on the business problem, a detailed literature review was carried out. CGD industry in India is on exponential growth. Domestic PNG connections as well as NGVs running on CNG are increasing day by day. There is no mechanism to supply un-interrupted gas to its customers. Gas grid in India is not fully developed yet to provide reliable gas supply in case of interruption in feeding pipelines. Not a single CGD company has constructed any gas storage facilities.

Literature survey carried out to find out the variable /factor which will influence the establishment of gas storages in India. Based on the outcome of the study, a framework is to be developed for establishing gas storage in India for city gas distribution. No study ever has been carried out on this topic.

1.9 Problem Statement

After the literature review, the business problem is summarized as follows:

There are an ample number of gas storage facilities in the world which are responsible for meeting base load and peak load demand of natural gas consumers and also provides the security in case of any future disruption in supply, now as India doesn't have any storage facility thus, the future is not properly secured and thus "In the event of any disruption in consistent gas supply due to non–existence of Gas Storages will lead to actual and opportunity loss in CGD industry in India"

1.10 Scope of the study

The study is limited to the analysis of factors that emerged from the extensive literature review undertaken and the expert opinion sought from the Natural Gas Sector in India only.

The scope of the study is limited to Indian conditions covering various probable scenarios that may occur in the natural gas industry which might lead to interruption in the continuous supply of gas. The study also details required changes that may be instrumental in development of conceptual framework for establishment of Natural Gas Storage for CGD in India.

1.11 Thesis Disposition

The study consists of **six chapters**. The first chapter is the **"Introduction"** to the topic and starts with brief details about the Natural Gas and the market scenario worldwide including the global and Indian energy scenario. It further discuss City Gas Distribution scenario in India with a focus on regulatory framework and working of Petroleum and Natural Gas Regulatory board (PNGRB - the downstream regulator of the oil and gas industry in India).

The second chapter gives an insight into the "**Gas Storage"** concept and the different types of gas storages available with brief details of their advantages, disadvantages and the costing analysis.

The third chapter starts with the discussion of storage facilities used in Gas Distribution business all across the globe. It further elaborates the extensive "**Review of Literature"** undertaken on the subject, which clearly highlights the gap in availability of literature that talks of the factors that are influencing the establishment of natural gas storage for CGD industry in India. Literature review thus helped to identify all those variables or building blocks that can help to develop the conceptual framework for establishment of Natural Gas Storage for City Gas Distribution in India. The motivation of research is listed at the end of this chapter.

The fourth chapter explains the "**Research Methodology"** adopted for achievement of the objective(s) of the study undertaken. This explains the rationale of the study followed by the statement of the research problem, objectives of the study, research questions, the research design and sampling process, data collection, sampling size determination, etc. The identified variables are listed in third chapter as well.

The fifth chapter deals with the "**Analysis and Interpretation"** of data for development of conceptual framework for establishment of Natural Gas Storage for City Gas Distribution in India. The factor analysis is done using the Principle Component Analysis (PCA) method. Before using the PCA method, sampling adequacy needs to be checked and this is done by the Kaiser-Meyer-Olkin (KMO) and Bartlett's test. The sampling adequacy result falls in the desired range and thus PCA method can be used. The factor analysis logically reduced the 29 variables into 6 factors which were further discussed and deliberated in detail. From the six factors that have been emerged, all the factors holds a significant influence in development of gas storage facilities by CGD companies but from

these factors some of the factors and variables need special emphasis as they will act as a barrier if not addressed properly. The same is also discussed in detail.

The sixth chapter gives the "**Conclusions and Recommendations**". Conceptual Framework for the establishment of gas storage in India is developed in this chapter.

Bibliography is given at the end as reference.

1.12 Concluding Remarks

India is one of the fastest growing economies in the world and an emerging superpower. Increase in energy requirement to support this growth in economy is essential. Natural Gas is the fuel of the future and technologies need to be developed to ensure its optimum utilization in most economic ways.

The challenges faced by CGD companies have been discussed with respect to the success story pursuant to the development of Gas Storage in US, Australia and Europe. However, what's missing is formulation of comprehensive policy and framework for establishment of strategic Gas Storage in India. Extensive literature survey was conducted to identify the basic elements or fundamental building blocks that need to be addressed to accelerate the development of strategic Gas Storage in India.

Currently there is a dearth of literature on Gas Storage and especially for CGD in India. This thesis also is an attempt to fill the gap owing to nascence of literature on factors that may drive the development of conceptual framework for establishment of Gas Storage for CGD in India by identifying a set of variables that form the literature review and expert opinion to develop and empirically test a model for it. It is hoped that this thesis may add to the existing body of knowledge as literature on the Gas Storage in India is in nascent stage.