

Natural Gas to Drive Green and Sustainable Developments in India

Sanjay Kumar Kar

Abstract The per capita primary energy consumption in India has been increasing and there is a great scope for growth to reach somewhere closer to the leading economies such as the United States, Russia, and China. India's primary energy consumption is still dominated by coal with 54.5 % followed by oil (29.5 %), natural gas (7.8 %), hydro (5 %), renewables (2 %), and nuclear (1.2 %). India being one of the leading emerging economies requires plenty of energy to keep the pace of its economic growth. India's economic development should be driven by green energy, with desirable level of environment protection and ecological preservation. Along with the renewable sources of energy, natural gas is considered to be the fuel for green and sustainable developments in India. The outcomes of green economy are green production, green marketing, green transport, green housing, green electricity, and green consumption. Current scenario suggests that natural gas could be one of the most preferred greener fuel by 2030 in India. Some of the enabling factors likely to drive gas based sustainable economy in India are: higher domestic production, import of equity gas, import of relatively cheaper shale gas (in the form of LNG) from the USA, import of dry gas through pipeline from central Asia, development of regasification infrastructure in India, and development of fully functional national gas grid.

Keywords Green energy · Green economy · Natural gas

1 Primary Energy Demand in India

World Bank indicators suggest that per capita primary energy consumption in India stood at 614 kg of oil equivalent in 2011, a significant improvement from 294 kg in 1980. However, India's per capita energy consumption has been the lowest

S.K. Kar (✉)

Department of Management Studies, NOIDA, Rajiv Gandhi Institute of Petroleum Technology, Raebareli, India

e-mail: skar@rgipt.ac.in; karsanjay1@gmail.com

Table 1 Per capita primary energy consumption in leading economies of the world (kg oil equivalent)

	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
USA	7794	7882	7847	7697	7758	7488	7056	7162	7032	6793
China	1108	1265	1362	1479	1551	1601	1717	1881	2029	NA
Japan	3964	4090	4074	4069	4032	3879	3702	3916	3610	3539
Germany	4096	4129	4064	4133	4020	4075	3825	4033	3811	3754
France	4272	4303	4284	4194	4117	4114	3917	4016	3868	3831
UK	3728	3701	3697	3613	3460	3391	3179	3241	2997	3043
Brazil	1095	1141	1157	1184	1239	1296	1243	1362	1371	NA
Russia Fed.	4463	4500	4553	4706	4733	4850	4559	4932	5113	NA
Italy	3115	3128	3137	3085	3025	2942	2739	2815	2757	2604
India	448	467	479	496	522	539	587	600	614	NA

Source <http://data.worldbank.org/indicator/EG.USE.PCAP.KG.OE/countries?page=2>

amongst the top ten economies in the world (Table 1). Per capita energy consumption in the USA, Russia, and China is 11, 8, and 5 times higher, respectively, than India. Russia and the USA are energy-rich countries as far as their domestic reserves are compared with India. It is observed that the per capita energy consumption in the USA, Japan, Germany, France, and Italy has been on the decline. However, India's per capita consumption has been increasing, albeit from a lower base. India registered 72 % per capita energy consumption growth since 2003 and will continue to grow for next couple of decades. According to the World Energy Council (2013, p. 7), "highly-industrialized" countries, such as India and Mexico, wrestle with providing accessible and environmentally sensitive energy to achieve double-digit economic growth. It is to be noted that India scores low on energy security (76), energy equity (110), and environmental sustainability (121), awarded an overall rank and score of 115 and "CDD", respectively (WEC 2013).

1.1 Coal

According to BP Statistics (2014) at the end of 2013 total coal reserves in India stood at 60,600 million metric tonne (MMT) with 6.8 % share of global reserves. The USA was the leader in terms of reserves (237,295 MMT, 26.6 %) followed by Russian Federation (15,7010 MMT, 17.6 %), China (114,500 MMT, 12.8 %), and Australia (76,400 MMT, 8.6 %). At the end of 2013, reserve-to-production (R/P) ratio of coal in India stood at 100 years compared to USA (266 years), Russian Federation (442 years), and Australia (177 years). Only China had a lower R/P ratio of 31 years amongst the leading developed and developing countries because China had the largest production share of 46.6 % (3680 MMT). In terms of coal production share, USA was placed in second position with 11.3 % (892.63 MMT) followed by India with 7.7 % (605 MMT), Australia with 6 % (478 MMT), Indonesia with 5.3 % (421 MMT), and Russia with 4.4 % (347.1 MMT). In most

parts of the world, coal is used to run coal-fired power plants, especially in the USA, China, and India. For instance, in India 66 % of the installed capacity of power plants are coal-fired. One of the reasons for higher percentage of coal-fired power plant could be lower domestic coal price compared to international standard. According to the Planning Commission (2012, p. 167), the price of domestic coal is about Rs. 342/MkCal compared Rs. 363/MkCal in the USA and Rs. 636/MkCal in China. The price differential between domestic and imported coal creates distortions in the power sector.

1.2 Oil

At the end of 2013, India was placed at 4th position with a consumption figure of 175.2 MMT of oil with a consumption share of 4.2 % just behind Japan with 5 % (208.9 MMT). The USA and China with consumption share of 19.9 % (831 MMT) and 12.1 % (507.4 MMT), respectively, were far ahead of India. However, from consumption point of view India is a larger market compared to developed countries such as Russian Federation, Canada, Germany, and the United Kingdom. Even oil consumption in India was marginally higher than entire Africa (170.9 MMT). Considering the very thin spread of proven oil reserves, high demand, and moderate production at the current production rate of 5.7 thousand million barrels, India's oil resources could be exhausted by 2030–2031. At the end of 2013, reserve-to-production (R/P) ratio (in years) of crude oil for countries such as the United Kingdom, Indonesia, China, and the USA stood at 9.6, 11.6, 11.9, and 12.1 years, respectively. If the R/P ratio to be believed, then at the current rate of production the leading consumer of oil will have to import 100 % oil just after a decade. Therefore, most of the countries are constantly looking for economically viable and environmentally sustainable alternatives to oil. Many believe probably natural gas could be one of the viable alternatives for the future.

1.3 Renewables

At the end of 11th Five Year Plan (FYP), installed capacity of renewable power was around 25 GW and the 12th FYP envisages for capacity addition of about 30-GW grid-connected power. The 12th FYP (2012–2017) is giving a significant thrust on wind energy with an estimated capacity addition of 15GW, followed by solar (10,000 MW) and other renewable sources (5 GW). The costs of power produced from various renewable sources are coming down and getting increasingly affordable. The costs of producing one unit of power (kWh) from various renewable sources are estimated to be small hydro (Rs. 3.54–4.88), wind (Rs. 3.76–5.96), biomass (Rs. 5.12–5.83), bagasse cogeneration (Rs. 4.61–5.73), and solar (Rs. 10.39–12.46).

1.4 Coal-bed Methane (CBM)

Coal-bed methane (CBM) is an eco-friendly natural gas, extracted from underground coal reserves. India, having the fourth largest proven coal reserves in the world, holds significant prospects for exploration and exploitation of CBM. According to DGH, the prognosticated CBM resources in the country are about 92 TCF (2608 BCM). Coal-bed methane extraction seems to be another alternative solution to meet the demand supply gap. However, efficient production of CBM is becoming a real challenge for the exploration and production companies due to lack in detailed reservoir characterization (Ojha et al. 2011), low quality of coal, low porosity, and permeability (PNGRB 2013). Also, regulatory challenges related to the delineation of blocks for mining and CBM exploitation need immediate attention. Environmental challenges linked to higher requirement of the land and disposal of water need review and reconsideration. Logistic challenges associated with the requirement to drill a large number of wells at low cost need to be addressed at the earliest. Another area which demands greater attention is linked to safety of workers in the CBM mines. As most of the prospective coal mines lie in areas affected by insurgency, and workers face a serious threat to safe operations.

Efforts have been made to mobilize resources, facilitate processes, and remove existing bottlenecks to make India one of the largest producers of CBM. It is well known that CBM gas is clean and having similar calorific value as compared to natural gas and can be directly fed into the pipeline for end use. Since 1997 total prognosticated CBM resources, contracts awarded, for 33 CBM blocks with a potential of about 63.85 TCF (1808 BCM), of which, so far, 8.92 TCF (252.69 BCM) has been established as gas in place (GIP). According to the DGH estimation, the total CBM production is expected to be around 4 MMSCMD by the end of 12th plan. Experiences of CBM production in some of the states like West Bengal suggest that few critical areas such as easier land acquisition, affordable technology, well-developed pipeline infrastructure, and suitable pricing could prove instrumental for faster progress in the field of CBM gas production and consumption in India. The CBM production can improve the supply of gas in states such as West Bengal, Jharkhand, and Odisha. Currently, these states lack cross-country gas pipeline infrastructure. But the availability of CBM gas locally will encourage investors and companies to build desirable infrastructure for distribution and consumption of CBM.

1.5 Natural Gas

Natural gas is considered to be a cleaner fossil fuel, and for several decades, it had been driving economic growth and prosperity in countries such as the USA, Canada, Mexico, Argentina, Belarus, Italy, the UK, Japan, and Malaysia. Natural gas found to have a better geographical spread compared to crude oil.

2 Natural Gas in India

2.1 Domestic Production

Compound annual growth rate (CAGR) of net domestic natural gas production (Table 2) for the period 2003–2004 to 2012–2013 had been only 3 %. During the period, Tamil Nadu had shown the highest CAGR of 9 % and Gujarat had shown the lowest with –6 %. Net production from the private/JVs had achieved 12 % CAGR during the stated period. Mumbai High had a marginally negative CAGR (–0.02 %).

2.2 Domestic Natural Gas Availability

Net availability of domestic natural gas increased from 30.91 billion cubic meter (BCM) in 2003–2004 to 39.71 BCM in 2012–2013. Net availability data presented in Table 3 suggest that there was a marginal increase during 2003–2004 and 2007–2008 and a substantial surge for the next two years followed by a visible fall in the years 2011–2012 and 2012–2013. This has been due to fall in production in D-KG blocks.

2.3 Demand–Supply Gap Analysis

Current demand scenario suggests that India's natural gas demand is higher than domestic gas availability. India is a gas deficit country and projections suggest that domestic requirements will be met primarily by importing gas.

According to a recent report by the Petroleum and Natural Gas Regulatory Board (PNGRB), the gas import dependence is projected to reach 70 % by 2030 from the current level of 58 % in 2012–2013. The total realistic demand is projected to reach 746 MMSCMD by 2030 from current 242.7 MMSCMD in 2012–2013. The gas deficit figure is going to exceed 500 MMSCMD by 2030 (Table 4) which is higher than the total expected demand in 2022–2023. The situation looks very scary considering the limited domestic gas availability and increasing dependence on imported gas.

Historical consumption statistics clearly indicate that power sector has been the largest offtaker of natural gas (Table 5) followed by fertilizer and captive use/LPG shrinkage. This has been due to favourable government policy towards these sectors. Urea plants, LPG plants, gas-based power plants, and city gas distribution (CGD) have been given priority for domestic gas supply from the fields under New Exploration Licensing Policy (NELP).

Table 2 Trend of natural gas production in India (2003–2004 to 2012–2013), (in MMSCM)

State	2003–2004	2004–2005	2005–2006	2006–2007	2007–2008	2008–2009	2009–2010	2010–2011	2011–2012	2012–2013 ^a
A. onshore										
Assam and Arunachal Pradesh										
Net production	2213	2272	2493	2570.11	2666.00	2623.00	2529.53	2516.73	2741.34	2721.70
Gujarat										
Net production	3389	3662	3810	3277.39	2913.00	2574.00	2404.23	2230.24	1999.68	1995.45
Tamil Nadu										
Net production	537	628	867	1112.95	1152.00	1233.00	1163.62	1105.95	1277.13	1199.15
Andhra Pradesh										
Net production	1914	1697	1655	1515.78	1557.00	1517.00	1478.13	1382.62	1360.54	1248.11
Tripura										
Net production	508	497	480	519.78	534.00	553.00	562.35	609.87	643.90	646.69
West Bengal (CBM)										
Net production	0.00	0	0	0.00	0.57	3.02	5.22	36.38	69.26	100.07
Rajasthan										
Net production	0.00	0	0	0.00	0.00	0.00	238.59	430.79	223.37	685.43
Net production	0.00	0	0	0.00	0.00	0.00	221.58	382.11	222.91	635.34
A. onshore total										
Net production	8561	8756	9305	8996.01	8822.57	8503.02	8364.66	8263.90	8314.76	8546.51
B. offshore										
Mumbai High										
Net production	17,235	16,769	16,351	16,010.6	15,879	16,027	13,452.23	17,035.2	16,850.4	17,521.6
Private/JVCs										
Net production	5110	5250	5669	5784.83	6777.00	7221.00	18,371.89	25,930.2	20,827.4	13,637.6
Total (A&B)										
Net production	30,906	30,775	31,325	30,791.4	31,478.6	31,751.0	46,485.9	51,229.3	41,025.9	39,705.7
Net production (BCM)	30.9	30.8	31.3	30.8	31.5	31.8	46.5	51.2	41.0	39.7

^aProvisional figure for 2012–13

Source: Petroleum planning analysis cell, Government of India

Table 3 Trend of domestic gas availability and sales in India

	2003–2004	2004–2005	2005–2006	2006–2007	2007–2008	2008–2009	2009–2010	2010–2011	2011–2012	2012–2013
Net availability (BCM) ^a	30.91	30.78	31.33	30.79	31.48	31.75	46.49	51.23	41.03	39.71
Sales by producing companies (BCM) ^b	26.71	26.51	26.86	26.77	26.97	27.06	40.83	46.04	41.03	34.30

^aDenotes natural gas available for consumption, which is derived by deducting gas flared from gross production by producing companies

^bDenotes gas available for sale, which is derived by deducting internal use of gas by producing companies from net availability

Source Petroleum planning and analysis cell

Table 4 Natural gas demand–supply projections in India unit: MMSCMD

Year	Power	Fertilizer	City gas	Industrial	Petchem/refineries/internal consumption	Sponge iron/steel	Total realistic demand	Domestic supply	Gas deficit
2012–2013	86.5	59.9	15.3	20.0	54.0	7.0	242.7	101.0	–141.7
2013–2014	104.6	60.0	16.2	20.0	56.6	8.0	265.3	102.5	–162.8
2014–2015	122.7	60.4	17.2	22.0	59.3	8.0	289.5	110.9	–178.6
2015–2016	140.8	17.2	18.2	25.0	62.1	8.0	271.3	120.4	–150.9
2016–2017	158.9	18.2	22.3	27.0	65.0	8.0	299.4	156.7	–142.7
2017–2018	173.9	22.3	26.6	28.0	68.1	9.0	327.9	161.0	–166.9
2018–2019	188.9	26.6	31.2	32.0	71.3	9.0	359.0	166.0	–193.0
2019–2020	203.9	31.2	35.9	35.0	74.7	10.0	390.7	171.0	–219.7
2020–2021	218.9	35.9	41.0	37.0	78.3	10.0	421.1	176.0	–245.1
2021–2022	233.9	41.0	46.3	37.0	82.0	10.0	450.1	182.0	–268.1
2022–2023	248.9	46.3	50.0	39.6	85.9	10.4	481.0	187.0	–294.0
2023–2024	263.9	110.1	54.0	42.4	90.0	10.8	571.1	193.0	–378.1
2024–2025	278.9	110.1	58.3	45.4	94.2	11.3	598.1	198.0	–400.1
2025–2026	293.9	110.1	62.9	48.6	98.7	11.7	625.9	204.0	–421.9

(continued)

Table 4 (continued)

Year	Power	Fertilizer	City gas	Industrial	Petchem/ refineries/ internal consumption	Sponge iron/ steel	Total realistic demand	Domestic supply	Gas deficit
2026– 2027	308.9	110.1	68.0	52.1	103.4	12.2	654.6	211.0	–443.6
2027– 2028	323.9	110.1	73.4	55.8	108.3	12.7	684.1	217.0	–467.1
2028– 2029	338.9	110.1	79.3	59.7	113.5	13.2	714.5	223.0	–491.5
2029– 2030	353.9	110.1	85.6	63.9	118.9	13.7	746.0	230.0	–516.0

Source Compiled from PNGRB (2013)

Table 5 Sectorwise natural gas offtakes (MMSCM) in India

Industry	2004– 2005	2005– 2006	2006– 2007	2007– 2008	2008– 2009	2009– 2010	2010– 2011	2011– 2012	2012– 2013 ^a	CAGR ^c (%)
<i>Energy purposes</i>										
Power generation	12,099	11,878	11,963	12,037	12,603	21,365	23,583	18,912	12,849.0	7
Industrial fuel	3569	3780	3205	3323	5912	2322	999	1127	1139.0	–15
Tea plantation	142	151	170	160	154	167	193	175	182.0	3
Domestic fuel	343	75	443	38	102	246	1584	1913	1996.0	28
Captive use/ LPG shrinkages	4944	5048	5034	1804	1885	5433	5770	6343	5921.0	4
Others	231	1120	40	1324	1535	1838	6551	5759	3224.0	58
Total	21,328	22,052	20,855	18,686	22,191	31,371	38,680	34,229	25,311	7
<i>Non-energy purposes</i>										
Fertilizers	8173	7762	8497	9823	9082	13,168	13,429	10,406	10,702.0	4
Petrochemicals	1236	1175	1377	1432	1105	1264	1183	576	437.0	–10
Others ^b	38	36	639	638	611	703	1098	1508	1950.0	69
	9447	8973	10,513	11,893	10,798	15,135	15,710	12,490	13,089	4
Grand total	30,775	31,025	31,368	30,579	32,989	46,506	54,390	46,719	38,400	6
Grand total (MMSCMD)	84.3	85.0	85.9	83.8	90.4	127.4	149.0	128.0	105.2	6

^aProvisional, ^bSponge Iron use, ^cCAGR has been calculated for 7 years only (2004–2005 to 2011–2012)

Source Adapted from Petroleum Statistics (2012, 2013)

As India is not self-sufficient in terms of meeting increasing natural gas requirements, importing of gas through various modes is holding paramount importance for the country. Therefore, being one of the crucial gas consumption centres, the country is all set to play critical role in the global gas trade. Considering the significant gas import in future India could influence gas trading in a bigger way. Over the last couple of years, this was visible to a certain extent. The following section on gas trade discusses important developments.

2.4 Natural Gas Trade

In recent years, natural gas trade has become very prominent in global energy trade. In 2012, 1033.4 BCM of gas was traded across the globe. About 68 % of total gas trade was contributed by dry gas (pipeline) and 32 % by liquefied natural gas (LNG). Europe imported about 377 BCM of dry natural gas, which is 53 % of global dry gas import. Whereas Asia contributed about 57 % of LNG import. Asia has become a major destination for LNG exporters. It is expected that Asia would continue to remain as a major destination for LNG suppliers. Strong demand from China and India, in addition to traditional importers such as Japan and Korea, will ensure that the Asia Pacific market remains profitable for LNG suppliers (IGU 2013).

In some of the developed and emerging markets, gas is increasingly becoming a fuel of choice for electricity generators, provided heating and cooling, and driving economic growth. Such developments could prove beneficial for natural gas trade in the near future. Natural gas trade statistics suggest that the USA has been historically one of the largest importers of natural gas, especially dry gas from Canada and Mexico. But the recent shale gas revolution in the USA could change the dynamics of future global natural gas trade. Probably, USA would emerge as one of the largest exporter of natural gas, especially LNG in future.

2.4.1 Import in the Form of LNG

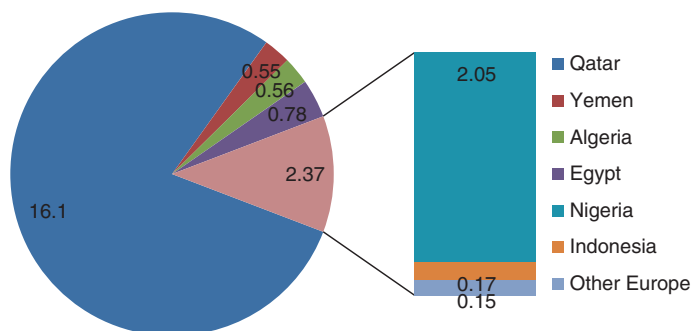
Gas resources are not uniformly distributed across the globe, the consumption centres are away from production centres. The consuming countries do not have adequate gas reserves and production, creating a need for importing natural gas. Due to geographical positioning and distance from production centres, countries such as Japan and India do not have many options but to rely on importing LNG. India, of course, wishes to get gas from Iran, Turkmenistan, Myanmar, and Burma. However, till date no progress has been made to build pipeline from Iran to India.

Due to fall in domestic production and unavailability of gas import through the pipeline from the neighbouring countries, India's LNG import has been rising constantly and will continue to rise in future also. As per the Petroleum Planning and Analysis Cell, India imported less than 1 BCM in 2003–2004 and the figure reached 16 BCM by 2011–2012 and came down to 15 BCM by 2012–2013 (Table 6). However, the BP statistics (2013) indicate that India imported 20.4 BCM of natural gas in 2012. Qatar was the prime source contributing 79 % of supply (Fig. 1) followed by Nigeria (10 %), Egypt (3.84 %), Algeria (2.75 %), and Yemen (2.70 %).

Table 6 Import of LNG in India (2003–2004 to 2012–2013)

Year	Unit	2003–2004	2004–2005	2005–2006	2006–2007	2007–2008	2008–2009	2009–2010	2010–2011	2011–2012	2012–2013
Total LNG imports	MMT	0.25	2.50	5.06	6.81	8.25	7.96	8.922	9.73	11.632	10.901
Total LNG imports	BCM	0.34	3.45	6.98	9.40	11.38	10.98	12.31	13.43	16.05	15.04

Source Petroleum planning and analysis cell, Government of India

**Fig. 1** LNG import (BCM) in India, 2012

LNG Infrastructure

As India does not have cross-border pipelines to import dry natural gas, it has no option but to build infrastructure for importing liquid natural gas. LNG has limited direct use so needs regasification for transportation through pipelines and final consumption. This necessitates LNG regasification plants in the country. Such infrastructures are bound to develop near the coastal belt as the LNG imported through the ships under cryogenic condition.

Considering rising gas demand, Petronet LNG Ltd. was formed to set up LNG terminal in India. The first LNG terminal came up in Dahej, Gujarat, with a name-plate capacity of 5 MMTPA. This terminal has been operational since January 2004 and since then it received more than 1000 cargoes. Currently, four LNG terminals at Dahej, Hazira, Dhabol, and Kochi (Map 1) are operational with total capacity of 25 MMTPA (Table 7). It is learnt that in the near future, the Dahej terminal to be expanded to 12.5–15 MMTPA and Kakinada (Andhra Pradesh) terminal to be operational by 2014–2015. Additional terminals are planned in Ennore (Tamil Nadu), Mundra (Gujarat), Pipavav (Gujarat), Paradip (Odisha), and Dhamara (Odisha). It is projected that by 2030, India will have regasification capacity of about 105 MMTPA¹ (391 MMSCMD). Due to this, the projected

¹1MMTPA of LNG = 3.726 MMSCMD.



Map 1 Location of LNG regasification facilities in India

deficit would come down 125 MMSCMD. The deficit could be brought down further by setting up additional terminal or expanding the existing terminal. Else, dry natural gas could be imported to bridge the demand–supply gap.

Current Sources

Current statistics suggest that Middle East and African region have been the preferred destination for LNG import to India. The primary reason for this could be (i) availability of gas at a cheaper price, (ii) availability of long-term contracts, especially in the case of Qatar, and (iii) transportation cost.

Sourcing natural gas from the Middle East is cheaper compared to sourcing from Trinidad. LNG freight cost from Peru to West of India is the costliest option (Table 8). Therefore, while exploring sources of gas, buyers are very careful about freight cost along with the cost of gas.

Table 7 LNG regasification capacity in India

	Dahej	Hazira	Dhabol	Kochi	Ennore	Mundra	Pipavav	Kakimada	Gangavaram	Paradip	Dhamra	Total capacity (MMTPA)	Total capacity (MMSCMD)
2012–2013	10	3.6	1.2	2.5	0	0	0	0	0	0	0	17.3	64.5
2013–2014	10	5	5	5	0	0	0	0	0	0	0	25	93.2
2014–2015	12.5	5	5	5	0	0	0	2.5	0	0	0	30	111.8
2015–2016	15	5	5	5	5	5	0	5	0	0	0	45	167.7
2016–2017	15	10	5	5	5	5	0	5	5	0	0	55	204.9
2017–2018	15	10	5	5	5	10	3	5	5	4	5	72	268.3
2018–2019	15	10	5	5	5	10	3	5	5	4	5	72	268.3
2019–2020	15	10	5	5	5	10	3	5	5	4	5	72	268.3
2020–2021	15	10	5	5	5	10	3	5	5	4	5	72	268.3
2021–2022	15	10	5	5	5	10	3	5	5	4	5	72	268.3
2022–2023	15	10	10	10	5	10	5	5	10	10	5	95	354.0
2023–2024	15	10	10	10	5	10	5	5	10	10	5	95	354.0
2024–2025	15	10	10	10	5	10	5	5	10	10	10	100	372.6
2025–2026	15	10	10	10	5	10	10	5	10	10	10	105	391.2
2026–2027	15	10	10	10	5	10	10	5	10	10	10	105	391.2
2027–2028	15	10	10	10	5	10	10	5	10	10	10	105	391.2
2028–2029	15	10	10	10	5	10	10	5	10	10	10	105	391.2
2029–2030	15	10	10	10	5	10	10	5	10	10	10	105	391.2

Source Compiled from published sources

Table 8 LNG freight costs (\$/MMBTU)

	Japan/ Korea	South China/ Taiwan	West India	South-west Europe	North-west Europe	North-east USA	Argentina
Middle East	2.05	1.81	0.66	1.93	2.33	2.42	2.55
Australia	1.32	1.19	1.37	2.94	3.26	3.06	2.7
Trinidad	4.44	4.18	3.03	1.28	1.26	0.6	1.49
Nigeria	3.37	3	2.23	1.28	1.37	1.35	1.5
Algeria	3.37	3.13	2.02	0.42	0.73	0.97	1.83
Belgium	3.84	3.47	2.35	0.63		0.88	2.04
Peru	2.83	3.18	3.44	2.88	2.97	2.48	1.3
Russia	0.71	0.93	1.99	3.5	3.7	3.75	3.26

Note Cost data is for in July 2011

Source LNG Daily (2013)

Future Prospects for LNG Sourcing

LNG sourcing from India's standpoint is going to change dramatically by 2020. Over dependence on Qatar is bound to reduce and the LNG sourcing mix is going to spread across the globe. In particular, Australia and USA are going to play all important roles in the changing dynamics of LNG sourcing. Sourcing gas from Australia found to be costlier compared to sourcing from Middle East and Africa. Angola and Algeria could be important destinations in the future. Many liquefaction projects coming up in the USA could prompt not only India but also many Asian buyers to source LNG linked to Henry Hub pricing. Sourcing gas from USA may be a better option compared to Australia because the gas price found to be cheaper in the USA. According to industry sources, landing cost of US LNG in India could be around \$9–10/MMBTU compared Australian LNG costing about \$13–14/MMBTU. Even sourcing of LNG from Israel through Egypt could be a possible option.

LNG Pricing

LNG pricing is very important and critical component of LNG trade. There have been many variations in LNG pricing formula across the globe. Some of the important prevailing prices are based on the following: gas-on-gas competition, oil price escalation, bilateral monopoly, and netback from the final product (IGU 2011). Gas-on-gas competition is the dominant pricing mechanism prevalent in the USA and UK. The price of gas is determined by the demand–supply over a variety of periods ranging from weekly to annually or even longer. Trading takes place at physical hubs, such as Henry Hub (US), and National Balancing Point (NBP) in the UK. Trading has been supported by well-developed future markets such as New York Mercantile Exchange or Inter Continental Exchange and online

commodity exchange such as an Online Capital Markets Limited. Long-term contracts rely on gas price indices rather than competing fuel indices.

Oil price escalation is visibly dominant in the continental Europe and Asia. Essentially, the gas price is determined by having a base price and an escalation clause, linked to the price(s) of one or more competing fuels, for example, competing fuel in Europe being gas oil and/or fuel oil, and that is in Asia typically being crude oil. The escalation clause takes care of price adjustment in the upward direction and also inflation.

Bilateral monopoly negotiations are very commonly observed in interstate gas dealings in the former Soviet Union, and Central and Eastern Europe. Gas prices determined through government-level negotiations for a period of one year. Such negotiations often involve elements of barter, with buyers paying for portion of their imported natural gas as the transit services or investing in field developments or pipeline projects.

Net back price from final product-based price is derived from the final price the buyer gets from the consumer by selling the final product. For example, the price received by a gas supplier such as GAIL India from the power sector should be based on the market determined price of electricity. The net back price is commonly seen when gas is used as a feedstock to produce derived products such as ammonia or methanol, and constitutes a major component of variable cost in producing the finished product.

Because of the theoretical link between oil and natural gas, oil is traded frequently and globally and therefore has an established price, a large number of exporters price natural gas based on oil. LNG pricing is certainly derived from the pricing mechanism prevalent in the country/continent of origin or consumption.

In the recent years, pricing of LNG has seen significant interest, but still the diversity of pricing remains as it is. Pricing is expected to continue to be a major issue with buyers demanding that LNG Selling Purchase Agreements (SPAs) be indexed to North American gas prices. For instance, Gas Authority of India Limited (GAIL) signed a 20-year deal with Sabine Pass Liquefaction to import LNG from the USA from 2017 to secure long-term supplies at prices linked to the US benchmark Henry Hub. LNG import from Sabine Pass could be about \$5–6/MMBTU cheaper compared to Gorgon gas project in Australia. It can be observed that the oil linked Gorgon LNG deal (\$15.8/MMBTU) significantly expensive compared to Henry Hub-linked Sabine Pass deal (\$10–11/MMBTU). Gas buyers are looking for an optimal sourcing mix with supply security, so more hybrid deals using both gas hub and oil-indexed pricing are likely to emerge in future.

2.4.2 Import Via Pipeline

Current Status

Currently India does not import natural gas through pipelines. Due to unnecessary delay or inaction with respect to proposed pipelines such as Turkmenistan–Afghanistan–Pakistan–India (TAPI), Iran–Pakistan–India, and Myanmar–Bangladesh–India, natural

gas import through the pipeline has remained as a dream for India. TAPI pipeline is expected to feed imported natural gas to the national gas grid by 2017–2018. As per the gas sale purchase agreement (GSPA), India is going to receive 38 MMSCMD of gas for 30 years from the year of operations. That means if the TAPI venture materializes, then India's gas deficit could be about 87 MMSCMD by 2029–2030. According to informed sources in the industry, TAPI project is progressing well and the consortium leader to be finalized soon.

Possible Sources of Dry Gas Import

India has been exploring 2700-km on-land gas pipeline from Iran to India via Pakistan; discussions are also on over the possibility of laying an alternate 1400-km sub-sea deep-water pipeline from Iran to India crosses the sea of Oman (Airy 2014). Turkmenistan and other central Asian countries and the Russian Federation could be possible sources of importing dry gas through pipelines. There has been a proposal to build 15,000 km Asian Gas Grid to enhance gas demand–availability scenario in Asia. The proposed grid could be an extension of the \$7.6-billion Turkmenistan–Afghanistan–Pakistan–India (TAPI) 1735-km pipeline (Jayaswal 2013). Gas availability (38 MMSCMD) through TAPI is certainly going to impact the economic prosperity in India, especially north Indian states where infrastructure has not developed owing to unavailability of gas.

India has been eyeing sourcing natural gas from gas-rich eastern neighbours such as Bangladesh and Myanmar. In recent times, there has been a renewed interest to revive a 16-year-old proposal for a 900-km pipeline covering Myanmar, Bangladesh, and India. However, progress on this front seems to be insufficient and may not bring any medium term result.

If all ambitious cross-border pipeline projects materialize, then the gas market in India could see a faster transformation than anticipated. But such projects are not free from multifaceted challenges, including geopolitical tensions in the zone. However, from energy security and economic prosperity point of view, all stakeholder countries are likely to rise above differences to make the project happen at the earliest.

Challenges of Building Transnational Pipelines

Striking transnational pipeline deals are full of challenges from conceptual stage to operational stage and even further. Some of the possible challenges are as follows: aligning with the interest of multiple independent and sovereign countries, understanding the inherent interest of resource-rich countries, understanding the interest of the transit countries, getting investors for diversifying risks, and identifying and understanding geopolitical risks and project risks.

Strategic Steps Needed

It is very important to categorically identify and understand all the possible risks involved with transnational pipelines and working towards avoiding such risks with carefully developed legally binding contracts. Prior to reaching the contract stage, taking path breaking steps needs kind attention at various levels. Some of the steps are as follows: developing trained and dedicated energy diplomats, building continuous and meaningful government to government relationship, developing fruitful Indian industry to foreign government relationship, and choosing companies in the resource-rich countries as strategic partners in Indian projects. The Government of India should identify key energy diplomats, train, and deploy them for dealing with energy diplomacy.

3 Gas Pricing in India

The Indian gas market is predominantly monopolistic in its operation due to a huge demand and supply gap (Rangarajan Committee 2012, p. 78). Price is administratively determined for each source of domestic supply, and the imported gas pricing is more or less determined by the market factors. The following section discusses the issues, challenges, and future of gas pricing in India.

3.1 Existing Pricing Regimes

There are broadly two pricing regimes for gas in the country, namely (a) administered pricing mechanism (APM), and (b) non-APM (market-driven). The price of APM gas is set by the Government principally on a cost-plus basis. On the other hand, the market-driven pricing is broadly divided into two categories: (i) imported LNG and (ii) domestically produced gas from NELP and pre-NELP fields.

The pricing mechanism of domestic gas under the NELP is driven by the production sharing contract. Under the last round of NELP, 100 % cost recovery was allowed. Many economists argue that the full cost recovery incentivizes the contractor to artificially build higher cost and recover. Of late, the regulatory body has been very stringent while allowing cost recovery. On the other hand, some do argue in favour of cost recovery as this allows the contractor to de-risk investments to a greater extent. The matter is so complex that multiple committees have been set up to come up with the right kind of solution to address concerns of the industry and the government. The Rangarajan committee² recommends for profit sharing model and the Kelkar panel argues in favour of cost sharing. The Kelkar panel³

²Committee on the PSC Mechanism in Petroleum Industry.

³Kelkar panel on 'Roadmap for Reduction in Import Dependency in Hydrocarbon Sector by 2030'.

argues that gold plating is not possible in oil and gas exploration and production as the contractor needs to invest upfront without any assured return. Technically speaking, the argument sounds very logical as, for any capital structure higher risk-adjusted capex could reduce returns for the contractor so there is no incentive for over investment. An expert in the regulatory body closely involved in NELP opined that both the committees probably address a part of the problem. Arguably India needs a balanced approach to attract foreign investment in this sector, allow the foreign companies to operate, produce more oil and gas domestically, and create win-win-win situation for the contractor, the government, and the consumer.

3.2 Challenges of Gas Pricing

At this point in time, in India, gas prices cannot be completely market-driven because the government being the owner of the natural resources cannot ignore socioeconomic sentiments of the consumer and society at a large. The bottom line of such thinking process is moving away from market determined pricing. The Planning Commission acknowledges that high LNG pricing in Asia can "kill the goose that lays the golden eggs". It is neither in the producer's interest nor in the national interest to take natural gas to unviable levels by linking to crude prices. Reliance Industry, producer of gas from the KG-D basin, has been arguing in favour of aligning domestic gas prices with international prices, essentially implementing import parity price.

Asian LNG price is linked to the Japan Customs-cleared Crude (JCC) and found to be on the higher side compared to Henry hub price. Very often the government is not quite sure of which benchmark to follow for deciding "arm's length" price. In the presence of multiple natural gas pricing mechanisms across the globe, any one of them may not fit into India's requirements.

In a free market the entire stakeholder's interest needs to be protected, the government seems to be at least concerned about some of them. The Government is very careful while increasing gas price, as would have immediate impact on fertilizer, power, and other priority sectors. Every dollar increase in gas price likely to have Rs. 3000–4000 crore/year burden on fertilizer producers and Rs. 10,000 crore/year on gas-based electricity generation units (Chandrasekhar 2013). The pricing formula suggested by Rangarajan Committee would have more than doubled gas price to around \$8.8 per million British thermal unit (Ranjan 2014) and every dollar increase in gas price could have lead to a Rs. 1370 per tonne rise in urea production cost and a 45 paise per unit increase in electricity tariff (for just the 7 % of the nation's power generation capacity based on gas).

The stiff price rise would have impacted the CNG and PNG users. It is estimated that \$1/MMBTU price increase likely to push CNG and PNG (domestic cooking) price by a minimum of Rs. 2.81 per kg increase in CNG price and a Rs. 1.89 per standard cubic metre (TOI 2014). Considering the socio-economic implications, the new (NDA) government decided to review the earlier price hike

decision of the earlier (UPA-II) government. In the August-end, the government constituted a four-member panel comprising of secretaries of power, fertilizer, and expenditure with additional secretary in the Oil Ministry as its member secretary to relook at the proposed gas price revision.

On the other hand, the increase in gas price would have brought windfall for the government—about USD 2.08 billion (Rs. 12,900 crore) from additional profit petroleum, royalty, and taxes accruing from doubling of domestic gas price.

The government sounds interested to safeguard the interest of the investors, preserve end user sentiments, address popular constituencies, and sanitize political outburst. For obvious reasons, Government tries to balance between social equity and economic rationality while deciding on critical matters such as gas allocation and pricing.

3.3 Role of Government

The central government plays important role in setting the price of natural gas in India. Often the right pricing, price for producers justifiably is not the right price from a consumer standpoint. Energy economists argue in favour of reducing subsidy and increasing domestic gas price closer to price prevalent in international market. On the other hand, some of the socio-economists clearly favour lower domestic gas price for enhancing affordability and accessibility. Historically, the government prefers the socio-economist's approach of improving energy equity and enhancing desirable infrastructure. However, the government should not treat affordability and accessibility in isolation; rather, it should be linked to the availability of natural gas. Setting an import parity gas price for domestic producers could lead to higher investment in exploration and production (E&P) activities leading to more exploration and commercial production. This could possibly improve domestic gas supply and reduce costly import leading to better balance of payment conditions.

3.4 Future of Gas Pricing in India

On 27 June 2013, the Cabinet Committee of Economic Affairs (CCEA), based on the recommendations made by the Rangarajan Committee, cleared the new gas pricing mechanism, the domestic gas price would be computed based on the trailing 12-month average of the following:

- (a) volume-weighted net back pricing of Indian LNG imports and
- (b) volume-weighted price of USA's Henry Hub, UK's NBP, and Japan's JCC-linked price

The new pricing mechanism was due on 1 April 2014 for the period of April 2014–2019. However, the new pricing was delayed for more than 6 months and revised price is determined on the basis of Gross Calorific Value (GCV) instead of Net Calorific Value (NCV).

The gas price is proposed to be determined as per the formula given below

$$P = VHH \text{ PHH} + VAC \text{ PAC} + VNBP \text{ PNBP} + VR \text{ PR} \text{ VHH} + VAC + VNBP + VR$$

where

- (a) VHH = Total annual volume of natural gas consumed in USA and Mexico.
- (b) VAC = Total annual volume of natural gas consumed in Canada.
- (c) VNBP = Total annual volume of natural gas consumed in EU and Former Soviet Union (FSU), excluding Russia.
- (d) VR = Total annual volume of natural gas consumed in Russia.
- (e) PHH and PNBP are the annual average of daily prices at Henry Hub (HH) and National Balancing Point (NBP) less the transportation and treatment charges.
- (f) PAC and PR are the annual average of monthly prices at Alberta Hub and Russia, respectively, less the transportation and treatment charges.

The new gas price is effective from 1 November 2014 and needs revision every 6 month. The revised price will be announced 15 days before the date of implementation (CCEA 2014). The pricing is for all natural gas domestically produced—conventional, shale, or coal-bed methane (CBM)—with a few exceptions to be reviewed every quarter. The new pricing guidelines exclude contracts fixed for certain period, till the end of such period and contracts where a specific formula for natural gas price indexation/fixation, e.g., Panna–Mukta–Tapti (PMT), Ravva, PY-1, and RJ-ON/6 has been operations.

4 Independent Downstream Regulator

Indian petroleum industry was controlled by the government for a long time. Downstream market, especially marketing of petroleum products, was deregulated in the 2002. Decontrol meaning there is going to be free and fair competition in the market, therefore, need of an independent regulator. So, the government mooted the idea of establishing an independent regulator for the downstream petroleum industry. The Petroleum Regulatory Board Bill was first introduced in the Lok Sabha on 06 May 2002 and was then referred to a Group of Ministers, which, in turn, referred it to the Parliamentary Standing Committee on Petroleum and Chemicals for examination on 17 May 2002. The report of the Committee was presented to the Lok Sabha on 08 May 2003 that suggested nearly 26 amendments. After incorporating those amendments, the Bill was then renamed as the PNGRB Bill, 2003. However, the Bill lapsed on account of the dissolution of the 13th Lok Sabha, in terms of Article 107(5) of the Constitution. The Ministry of Petroleum and Natural Gas (MoPNG), therefore, introduced the Petroleum and

Natural Gas Regulatory Board (PNGRB) Bill, 2005, in the Rajya Sabha, on 21 December 2005. The Bill provided for the setting up of the PNGRB, to regulate the downstream petroleum and natural gas sectors. The PNGRB Act (2006) received assent of the President, Government of India, on 31 March 2006.

4.1 Objectives of Petroleum and Natural Gas Regulatory Board (PNGRB)

The primary objective of setting up to “protect the interests of consumers and entities engaged in specified activities relating to petroleum, petroleum products and natural gas and to ensure uninterrupted and adequate supply of petroleum, petroleum products and natural gas in all parts of the country and to promote competitive markets and for matters connected therewith or incidental thereto” (PNGRB Act 2006). The mandate of the board is to regulate the downstream business of petroleum and natural gas is to (i) protect the interest of the consumers and entities, (ii) phase out monopoly and establish competition, and (iii) ensure much needed transparency.

4.2 Role of the PNGRB

The PNGRB Act (2006) received assent of the President, Government of India, on 31 March 2006. As per the PNGRB Act (2006), the board is authorized to regulate refining, processing, storage, transportation, distribution, marketing, and sale of petroleum, petroleum products, and natural gas-related activities excluding the production of crude oil and natural gas. The Board has been empowered to authorize entities to (i) market any notified petroleum, petroleum products or natural gas; (ii) establish and operate LNG terminals; (iii) lay, build, operate, or expand a common carrier or contract carrier; and (iv) lay, build, operate, or expand a city or local natural gas distribution network. In addition to the above-mentioned role, PNGRB has been given a mandate to protect consumer interest by fostering fair trade and build competition environment in the downstream oil and gas sector (Table 19).

5 Gas Pipeline Infrastructure

5.1 Cross-Country Gas Pipeline Network

Cross-country pipeline truly works as the circulatory system of economic activity in India. Most importantly for green manufacturing, growth, development, and economic progress, the cross-country pipeline network having pan-India presence

is most desirable. As of 31 December 2013, India had 15,340 km of functional cross-country pipeline with designed capacity of 395 MMSCMD. However, the average capacity utilization rate was just about 48 % in 2013. The pipeline network having highest designed capacity with maximum capacity utilization is Hazira–Vijaipur–Jagdishpur (HVJ) pipeline (Table 9). This pipeline proves to be the most important connecting link between sources of gas and consumption points in central and north India. Because of gas supply through this pipeline, many power plants, fertilizer plants, and industrial consumers are getting green fuel/feedstock. Also, green transport drive through CNG in Delhi and NCR completely relies on the HVJ pipeline. We can infer that the HVJ pipeline is source of green prosperity.

In addition to the already operational pipeline network, an additional pipeline network of 10,470 km is under execution or construction stage (Table 10). Also, pipeline network between Kakinada–Srikakulam (350 km) and Duragpur–Kolkata (160 km) is under proposal stage. The cross-country pipelines under discussion would cover almost entire country with coverage of 26,320 km. But the intention of the government of India is to take the network beyond 30,000 km at the earliest.

5.2 *Entities*

Natural gas infrastructure is developed by companies authorized to sell natural gas in designated geographical areas or cities (Table 11). Similarly, the cross-country pipeline network is developed by companies authorized by the government or PNGRB.

5.3 *National Gas Grid*

CGD network development is not uniform across India. States such as Gujarat, Maharashtra, and Delhi have better developed CGD network. States such as Haryana, Rajasthan, Madhya Pradesh, Uttar Pradesh, Tamil Nadu, and Andhra Pradesh have moderately developed CGD network. But most of the other states such as Karnataka, Kerala, Chattishgarh, Punjab, Jammu and Kashmir, Himachal Pradesh, Uttarakhand, Goa, Bihar, West Bengal, Jharkhand, and Odisha lack CGD network. Except Assam and Tripura, other north-eastern states like Manipur, Meghalaya, Mizoram, and Nagaland severely lack the pipeline infrastructure necessary for effective natural gas distribution. For sustainable green economic growth, India needs to have a well-developed national gas grid and CGD network. The government of India has been actively pursuing the objective of building a national gas grid to reach maximum number of cities, villages, households, and industries to provide natural gas-a greener energy option. By 2029–2030, the design capacity of pipeline network in India is expected to reach 815 MMSCMD

Table 9 Gas pipeline network, capacity, and capacity utilization in India (as on 31 December 2013)

Network/region	Entity	Length (km)	Design capacity (MMSCMD)	Average flow in 2013–2014 (April–Dec) (MMSCMD)	% capacity utilization as on 31 December 2013	Pipeline size
HVJ GREP–DVPL & Spur (Hazira–Vijaipur–Jagdishpur)	GAIL	4435	57.3	44.0	77	36"
DVPL-1 (42") (Dahej–Vijaipur)–GREP Upgradation	GAIL	1112	54	14.85	28	42"/48"
VDPL-1(36"), DVPL-2 (48") (Vijaipur–Dadri)	GAIL	262	5	0.68	14	48"
Chhatnasa–Jhajjar–Hissar P/L (Including Spur lines) commissioned up to Sultanpur, Jhajjar–Hissar under hold (111 km). Flow of 5 Million up to 2011–2012	GAIL	873	20	9.51	48	36"/16"
Dahej–Uran–Panvel (DUPL/DPPL) including spur lines	GAIL	803	11	2.60	24	30"/18"
Dadri Bawana Nangal P/L, Dadri–Bawana: 106 km	GAIL	1004	16	0.89	6	36"/30"/24"/18"
Bawana–Nangal: 501 km, spur line of BNPL: 213 km. Flow of 11 Million up to 2011–2012	GAIL	41	6	0.33	5	36"–4"
Dhabol–Bangalore pipeline (including spur)	GAIL	8	2.5	0.55	22	24"
Assam (Lakwa)	GAIL	61	2.3	1.46	65	12"
Tripura (Agartala)	GAIL	144	3.0	0.38	13	12"
Ahmedabad	GAIL	154	2.35	1.02	43	12"
Rajasthan (Focus Energy)	GAIL	670	15.4	2.25	15	24",16"
Bharuch, Badodara (Undera) included RLNG + RIL	GAIL	129	24.0	22.9	95	26"
Mumbai	GAIL	877	16.0	6.0	37	18"
KG Basin (included RLNG + RIL)	GAIL	268	9.0	3.51	39	18"
Cauvery Basin	Reliance	1469	80.0	48.0	60	48"
East–West Pipe Line (RGTL)	GSPCL	1874	50.0	22.0	44	Assorted
GSPCL Network including spur lines	AGC	1000	6.0	4.50	75	16"
Assam Gas Company (Duliajan to Numaligarh)	IOCL	132	9.5	2.97	31	30"/10"
Dadri–Panipat	ONGC	24	6.0			
Uran Trombay						
Sub total		15,340	395	188	48	

Source Petroleum planning analysis cell

Table 10 Gas pipeline execution/construction

Network/region	Entity	Length (km)	Design capacity (MMSCMD)	Pipeline size
Kochi–Kottanad–Bangalore–Mangalore	GAIL	1156	16	24"/18"/12"
Dhabhol–Bangalore (DBPL)	GAIL	1414	16	36"/30"/24"/18"
Surat–Paradip	GAIL	1550	75	36"/24"/18"
Jagdishpur–Haldia ^a	GAIL	2050	32	
Mallapuram–Bhilwada ^a	GSPL	1600	30	
Mehsana–Bhatinda ^a	GSPL	1670	30	
Bhatinda–Srinagar ^a	GSPL	740	15	
Vijaipur–Kota (Kota) extended up to Chittorgarh	GAIL	290	2	18"/16"/12"
Sub total		10,470	216	

^aCompetitive bidding

Source Petroleum planning analysis cell, Government of India

Table 11 City gas distribution network coverage in India

Name of the CGD network	Area covered	Entity authorized by PNGRB/Govt.
Sonipat CGD, Meerut CGD, Dewas CGD, Kota CGD	Network Sonipat, Network Meerut, Network Dewas, Network Kota	Gail Gas Limited
Kakinada	CGD Network Kakinada	Bhagyanagar Gas
Mathura CGD	Network Mathura	JV of M/s DSM Infratech Ltd. and M/s Saumya Mining
Agra CGD	Network Agra	Green Gas Limited
CGD Network Hyderabad	Hyderabad	Bhagyanagar Gas
Indore CGD Network	Indore including Ujjain	Aavantika Gas
Ghandhinagar, Mehesana, and Sabarkantha CGD Network	Ghandhinagar, Mehesana, and Sabarkantha	Sabarmati Gas Ltd.
Pune City CGD Network	Pune and Pimpri-Chinchwad city including adjoining areas of Hinjewadi, Chakan and Talegaon	Maharashtra Natural Gas Limited (MNGL)
Kanpur CGD, Bareilly CGD Area	Network Kanpur GA, Bareilly GA	Central UP Gas Limited
Delhi CGD Network	National Capital Territory of Delhi	Indraprastha Gas Limited (IGL)

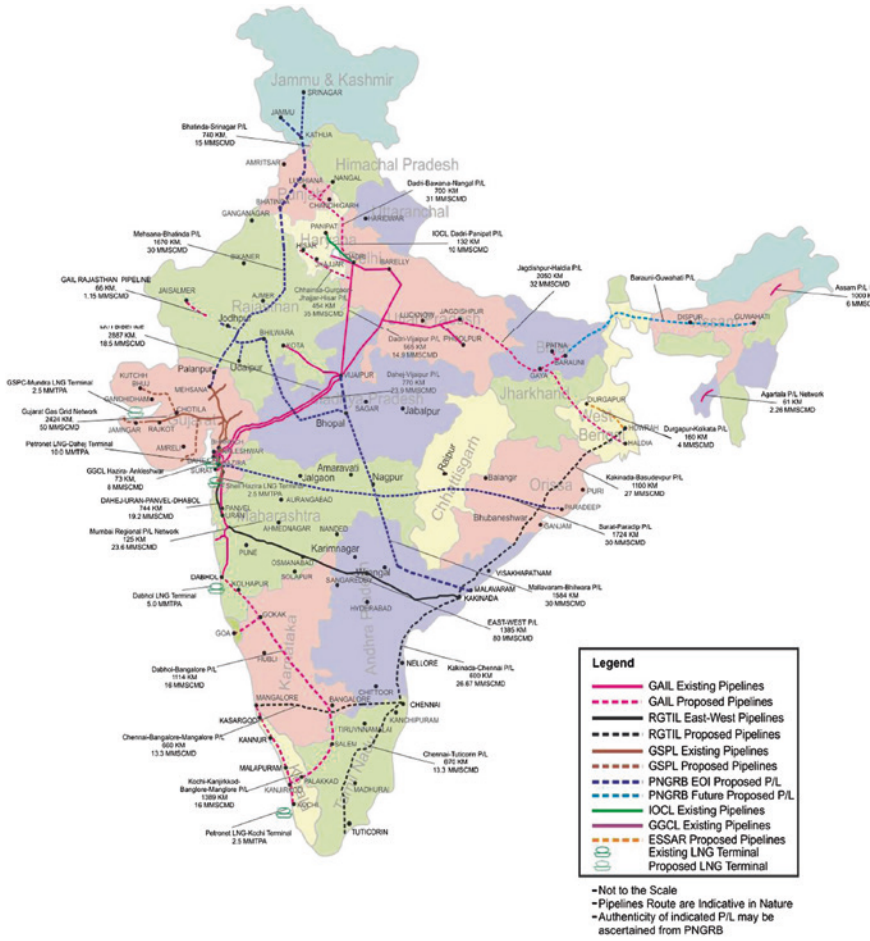
(continued)

Table 11 (continued)

Name of the CGD network	Area covered	Entity authorized by PNGRB/Govt.
Mumbai CGD Network	Mumbai and Greater Mumbai	Mahanagar Gas Limited (MGL)
Vijayawada CGD	Vijayawada GA	Bhagyanagar Gas Limited (BGL)
Mumbai CGD Network (GA2)	Thane City and adjoining contiguous areas including Mira Bhayender, Navi Mumbai, Thane City, Ambernath, Bhiwandi, Kalyan, Dombivily, Badlapur, Ulhasnagar, Panvel, Kharghar and Taloja.	Mahangar Gas Limited (MGL)
Rajkot, Navsari, Nadiad, Surendranagar	Rajkot GA, Surendra Nagar GA, NAVsari GA, Nadiad GA	GSPC Gas Ltd.
Ahmedabad, Faridabad, Khurja	Ahmdebad GA, Faridabad, and Khurja Geographical Area	Adani Gas Limited (AGL)
Chandigarh, Allahabad	Ahmdebad GA, Allahabad	JV of IOCL and AGL
Jalandhar CGD Network	Jalandhar	M/s Jay Madhok Energy Pvt. Ltd.
Gwalior CGD Network	Gwalior	Aavantika Gas Limited
Surat-Bharuch-Ankleshwar	Surat-Bharuch-Ankleshwar Geographical Area	Gujarat Gas Company Limited

Source Compiled from the Website of PNGRB

and length of the pipeline network is estimated to reach 32,727 km in length from 12,144 km in 2012. The gas grid capacity in India (pipeline emanating from the source) is expected to reach 517 MMSCMD in 2021–2022 from the present 243 MMSCMD (PNGRB 2013). Currently the supply or receiving points of natural are predominantly in the south/west India. Consumption centres are developed in the west and gradually shifting towards north and central India. For a longer period of time, the eastern India remained gas starved due to lack of production and distribution network (Map 2). A fully developed and functional national gas grid will ensure fair and equitable access to natural gas across the country. So, by 2030 the eastern India is likely to play an important role in terms of LNG regasification facilities, gas transmission, and consumption.



Map 2 Gas pipeline network in India. Source GAIL

6 Natural Gas Demand and Supply

Currently about 42 % of the natural gas demand comes from the western Indian states such as Gujarat and Maharashtra. The west and north region will remain as major demand drivers of natural gas even in 2029–2030 (Table 12). This is due to better gas infrastructure leading to greater accessibility of natural gas attracting more end users.

In India, natural gas has been a preferred fuel for many end users ranging from power sector to domestic consumers. End users across various segments use natural gas as a fuel or feedstock (Table 13). Domestic, commercial, transport, and

Table 12 Gas demand and supply (MMSCMD) in India

Zone	States	2012–2013	2016–2017	2021–2022	2026–2027	2029–2030
North	Uttar Pradesh, Uttaranchal, J&K, Haryana, Punjab, Delhi, Himachal Pradesh, Rajasthan	62.98	88.4	144.66	188.74	215.11
East	West Bengal, Bihar, Jharkhand, Orissa	10.35	21.66	31.03	53.24	60.68
West	Maharashtra, Gujarat, Goa	102.8	165.13	191.78	207.5	236.5
North East	Assam, Arunachal Pradesh, Manipur, Meghalaya, Nagaland, Tripura, Mizoram, Sikkim	5.13	5.29	10.47	20.67	23.56
South	Tamil Nadu, Kerala, Karnataka, Andhra Pradesh	48.2	81.28	116.71	151.89	173.11
Central	Madhya Pradesh, Chattisgarh	13.21	16.29	22.33	32.52	37.07
	Total demand	242.67	378.05	516.98	654.56	746.03
	Domestic supply	101	156.7	182	211	230
	Deficit	141.67	221.35	334.98	443.56	516.03

Source PNGRB (2013)

Table 13 End users of natural gas

End user	Carbon molecule	Purpose	Substitute
Power	C1	Used as a fuel in thermal power generation	Coal
Cement	C1	Used as a fuel in gas fired boilers	Coal, LPG, Naphtha Furnace Oil and high-speed diesel (HSD)
Ceramic	C1	Industrial fuel for spray dryers and is used for combustion in a kiln.	Diesel, Coal, Furnace Oil, Naphtha, C-nine and LPG, etc.
City gas	C1	Used as a fuel for heating, cooking and cooling (domestic and commercial use)	LPG and electricity
Transport sector	C1	Used in the form of CNG as a transportation fuel	Diesel, Petrol, and Auto LPG

(continued)

Table 13 (continued)

End user	Carbon molecule	Purpose	Substitute
Fertilizers	C1	Natural gas is the principal feedstock for the manufacturing of ammonia, an intermediate product primarily used in the manufacture of nitrogenous fertilizers such as urea, nitric acid, ammonium nitrate, and ammonium sulphate.	Naphtha and Fuel Oil
Petrochemicals	C2/C3	Specific fractions in feedstock are used for manufacture of ethylene and propylene	Naphtha and Propane Gas
LPG	C3/C4	Specific fractions are extracted to produce LPG	Crude Oil
Methanol	C1	Feedstock	Naphtha and biomass

Source Kar and Sahu (2012)

some of the industries such as power, cement, and ceramic use natural gas as a fuel. Other industries such as fertilizer, chemical, and petrochemical use natural gas as feedstock/raw material to produce derived products.

6.1 Gas Allocation Policy

Domestic natural gas is considered green, clean, and premium source of fuel and feedstock, and with limited availability requires judicious and fair allocation to various demanding sectors. Considering the importance of fair allocation of domestic natural gas the government of India through Ministry of Petroleum and Natural Gas formulated “Natural gas use policy” in 1990 [Standing Committee on Petroleum & Natural Gas (SCPNG), 2013–2014]. Keeping in mind the potential demand of natural gas from various sectors, such as fertilizer, power, sponge Iron, LPG, industrial use, petrochemicals, an optimal allocation policy was desirable. In order to rationalize the allocation of natural gas from nominated blocks without any discrimination to any sector or region, the Government of India constituted the Gas Linkage Committee (GLC) of Secretaries in July 1991. The committee was well represented by the important stakeholders such as power, fertilizer, steel, chemical and petrochemicals and Planning Commission, Department of Economic Affairs, Department of Expenditure (Ministry of Finance), and three national oil and gas companies, namely GAIL, ONGC, and Oil India Limited. After giving due consideration to the demand, availability, and imputed economic value of natural gas in various sectors, GLC decided to allocate natural gas to various sectors

on “firm basis” and “fall back basis”. The concept of “fall back allocations” has been made to optimally use the temporary surplus gas in the system. As there was no further APM gas available for allocation to new consumers, GLC dismantled on 9 November 2005.

On 28 October 2010, Government of India formulated a policy on pricing and commercial utilization of non-APM gas produced by NOCs. As per the guidelines of the allocation of non-APM gas, the allocation should be done on the following priority basis:

- (a) Gas-based fertilizer plants
- (b) LPG plants
- (c) Power plants supplying to the grid
- (d) CGD systems for domestic and transport sectors
- (e) Steel, refineries, and petrochemical plants for feedstock purposes,
- (f) CGD systems for industrial and commercial customers, and
- (g) Any other customers for captive and merchant power, feedstock or fuel purposes.

The gas producing companies are directed to follow the sector priority as indicated above and preference in allocation to be given to APM shortfall before meeting new demand. Within a sector, priority is accorded to the region where gas is produced.

Until 2012, the government did not develop any gas allocation policy for domestic gas produced from small/isolated fields. However, on 16 January 2012 the government came out with pricing and allocation policy for small/isolated fields similar to the policy developed on 28 October 2010.

The NOCs were given freedom to allocate gas from small discoveries whose peak production was less than 0.1 MMSCMD. Concerns were raised by various stakeholders about applying pricing and allocation policy of large and main-stream fields to small/isolated fields. Critical pricing and allocation issues related to small/isolated fields were actively deliberated, and the policies were revised. As per the revised policy guidelines notified on 8 July 2013, the sector priority has been lifted and the new customers to be treated on parity with existing customers for allocation of gas (Standing Committee on Petroleum & Natural Gas 2013–2014, p. 7). In case of additional availability of gas after providing for gas supplies to the existing customers, the additional gas has to be allocated through open competitive bidding process and the highest price bidder to be awarded.

Pre-NELP blocks are essentially the blocks which were awarded to national oil companies (NOCs) on nomination basis, but in some blocks the NOCs did not go beyond the discovery stage or did not reach commercial production stage due to financial or technology constraints. Such blocks or fields were auctioned to private companies for efficient and effective utilization of national resources. However, the government kept the provision of appointing a nominee for purchasing the gas from the producers and marketing it. For instance, GAIL has been appointed as the government nominee in PMT fields and Ravva fields for marketing under the directions of the government. The producers, in the rest of pre-NELP blocks, sell

the gas as per the terms of production sharing contracts (PSCs) signed between the government and the operators.

During the pre-NELP period, exploration and production policies were believed to be less transparent and heavily loaded in favour of national oil companies. In order to establish competitive parity, openness, and transparency under NELP, the Government auctioned blocks to private investors/NOCs/consortia. To ensure a level playing field, the government extended the same fiscal and contract terms to the investors under the NELP. Under the NELP contracts, certain amount of freedom has been allowed to the contractor to market gas within the framework of policy on the utilization of natural gas.

The government had constituted an Empowered Group of Ministers (EGoM) to take decisions on utilization of gas produced under NELP blocks (including KG-D6). The EGoM constituted for pricing, and commercial utilization of gas under the NELP has laid down following sector priority for allocation of gas from KG-D6 block (PIB 2014):

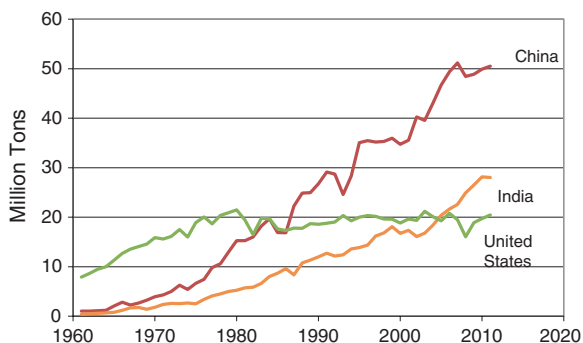
- (i) Gas-based urea plants,
- (ii) Gas-based LPG plants,
- (iii) Gas-based power plants for supply of electricity to state distribution companies at regulated tariff for the period of power purchase agreement (PPA),
- (iv) CGD entities for supplying to domestic and transport sectors, and
- (v) Other sectors such as steel plants (only for feedstock and not for the captive power requirement), petrochemical plants (only for feedstock and not for the captive power requirement), refineries, CGD entities for supply to commercial and industrial sector customers consuming up to 50,000 SCMD (standard cubic meters per day), captive power plants

6.1.1 Fertilizer

India is the second largest consumer of fertilizers in the world, only after China (Graph 1). According to the Department of Fertilizers, India is almost completely dependent on import of supply of phosphatic and potassic fertilizers due

Graph 1 Fertilizer consumption in China, India, and the USA, 1961–2011.

Source http://www.earth-policy.org/data_highlights/2014/highlights43



to non-availability of resources within the country. Nitrogen is the only nutrient where the country can achieve near self-sufficiency. Out of our total requirement of about 30 MMTPA of urea, about 8 MMTPA (27 %) urea is imported. For cost-effective domestic urea production (22–23 MMTPA), natural gas remains to be the best possible source of feedstock. About 14 MMTPA of domestic urea is from domestic natural gas and the rest (8–9 MMTPA) is being produced from imported LNG/naphtha. There is no second thought to explain fertilizer industry plays a vital role in the development of the Indian agricultural sector and overall economy of the country. So the fertilizer sectors obviously and justifiably figure at the of gas allocation policy.

The fertilizer sector is the second largest demand driver of natural gas in India. Natural gas demand in this sector is projected to reach 106 MMSCMD by 2016–2017 from 55 MMSCMD in 2012–2013.

This sector is not only the second largest demand driver from a volume point of view, but also one of the most important sectors from socioeconomic progress view point. Also, fertilizer subsidy is another concern for the government. For example, the central government spent 74,569.85 crores (\$12.428 billion⁴) as fertilizer subsidy in 2011–2012 and 70,592 crores (\$11.765 billion) in 2012–2013 (DoF 2014). Considering the above fact the use of natural gas seems to be one of the key solutions to increase nitrogen self-sufficiency and reduce subsidy burden on the exchequer. Therefore, the government of India has been historically careful while allocating domestic gas to this sector. India is an agrarian economy, and Indian farmers are hugely dependant on fertilizers for higher agricultural productivity.

6.1.2 Domestic LPG (Used for Cooking)

In India, domestic LPG is considered to be a sensitive product and subsidized for the larger benefit of social strata under financial stress and hardship. The country is highly import dependant for meeting domestic LPG demand. Any disruption in supplies of LPG could lead to social disturbance and public outcry. In order to enhance public life and reduce import dependency the government promotes use of domestic natural gas for manufacturing LPG to meet domestic LPG demand. Further, the EGoM has also decided that higher fractions such as propane, butane and pentane should be extracted first and only the lean gas should thereafter be supplied to other sectors. Hence, high priority for the LPG sector sounds to be rational.

6.1.3 Power Sector

Currently gas-based power plants with a capacity of 21.3 GW (Table 14) constitute 9 % of total installed capacity of 237.7 GW. To achieve high economic growth, providing 24 × 7 electricity to all and seamless rural life could be viable

⁴Exchange rate of USD = INR 60 has been used.

Table 14 All India installed electricity generation capacity (MW) as of 28 February 2014

	Thermal							RES	Hydro	Nuclear	Grand total	Share (%) of gas
	Coal	Gas	Diesel	Thermal total	Nuclear	Hydro	RES					
Northern	35,283.5	5281.26	12.99	40,577.75	1620	15,994.75	5729.62	63,922.12	8.3			
Western	54,069.51	9739.31	17.48	63,826.3	1840	7447.5	9925.19	83,038.99	11.7			
Southern	26,582.5	4962.78	939.32	32,484.6	1320	11,398.03	13,127.33	58,329.96	8.5			
Eastern	24,727.88	190	17.2	24,935.08	0	4113.12	417.41	29,465.61	0.6			
North-east	60	1208	142.74	1410.74	0	1242	252.65	2905.39	41.6			
Islands	0	0	70.02	70.02	0	0	10.35	80.37	0.0			
All India	140,723.4	21,381.35	1199.75	163,304.5	4780	40,195.4	29,462.55	237,742.44	9.0			
Share (%)	59.2	9.0	0.5	68.7	2.0	16.9	12.4	100.0				

Source: Gol, CEA 2014

by additional production of power (electricity). Gas-based combined cycle power plants considered to be an efficient and greener option. Keeping in mind socio-economic prosperity, the gas allocation to power sector has been given the third top most priority. Apart from that, the power sector, especially coal-based power plants, found to be one of the biggest contributors to environmental pollution in India. Chen et al. (2011) suggest that “local” pollutant concentrations are exceedingly high in many developing countries and they impose substantial health costs, including shortened lives. A study conducted by Cesur et al. (2013) found evidence that air pollution severely impacts infant mortality and several illness and premature death (Greenpeace India 2014). The study estimates the monetary cost associated with these health impacts exceeds Rs. 16,000 to Rs. 23,000 crores (USD \$3.3–4.6 billion) per year.

6.1.4 City Gas Distribution

CGD sector in India has been growing, and major important cities have been covered under CGD network. It is observed that the growth has been slower than the expected lines. The primary reason could be due to lack of domestic gas supply (Table 15), expensive imported gas, cancellation/delay in the bidding process, and policy bottlenecks. The most important objective of building CGD network is to

Table 15 Domestic gas allocation for CGD network in India

Entities and areas of operation	APM allocation			PMT allocation	RIL KG D6 allocation			Grand total allocation
	Firm	Fallback	Total		Firm	Fallback	Total	
IGL, Delhi + Gautam Buddha Nagar + Faridabad and Gurgaon	2.7	0	2.7		0.31	0.3	0.61	3.31
MGL, Thane-Navi Mumbai City Gas	2		2		0.37		0.37	2.37
Bhagyanagar Gas Limited	0.1		0.1		0.15	0.37	0.52	0.62
TNGCL, Tripura	0.13		0.13				0	0.13
Green Gas Limited, Lucknow	0.1	0	0.1		0		0	0.1
Green Gas Limited, Agra	0.04	0	0.04		0.02	0.01	0.03	0.07
Central UP Gas Limited, Kanpur	0.1		0.1			0.1	0.1	0.2
CUGL, Bareilly	0.05		0.05			0.01	0.01	0.06
MNGL, Pune City Gas	0.4		0.4			0.2	0.2	0.6
AGCL	0.01		0.01				0	0.01
Gujarat Gas Company	0.29	0.17	0.46	2.13		0.6	0.6	3.19

(continued)

Table 15 (continued)

Entities and areas of operation	APM allocation			PMT allocation	RIL KG D6 allocation			Grand total allocation
	Firm	Fallback	Total		Firm	Fallback	Total	
Vadodara Municipal Corporation		0.1	0.1				0	0.1
GAIL GAS			0		0.02		0.02	0.02
GAIL Agra Firozabad						0.3	0.3	0.3
GAIL Vadodara						0.13	0.13	0.13
Sabarmati Gas					0.08	0.15	0.23	0.23
HPCL					0.05		0.05	0.05
Aavantika Gas					0.01		0.01	0.01
Soumya DSM					0.02		0.02	0.02
Adani Energy Ltd.					0.2		0.2	0.2
Total	5.92	0.27	6.19	2.13	1.22	2.17	3.39	11.71

Source Infraline energy

increase natural gas penetration and enhance accessibility of natural gas for the end users. Greater use of natural gas could reduce environmental pollution and improve quality of life. A recent study conducted by Cesur et al. (2013) indicates that the expansion of natural gas infrastructure has caused a significant decrease in the rate of infant mortality in Turkey. In particular, a one-percentage point increase in the rate of subscriptions to natural gas services would cause the infant mortality rate to decline by 4 %.

Important consuming segments under CGD are industrial, transport, commercial, domestic, and others. Use of natural gas in these segments could replace existing polluting fuels and help green growth in India.

Industrial Customers

Natural gas has different industrial uses, including providing the base ingredients for wide varieties of products such as plastic, fertilizer, anti-freeze, chemicals, and fabrics. Also, industrial customers in ceramic, steel, and food processing, etc., use natural gas as a fuel for heating and cooling. Industrial segment is the largest consumer of natural gas under the CGD category. In states such as Gujarat, Maharashtra, and Andhra Pradesh, natural gas available for the industrial sector is helping industrial growth. For example, easy access to natural gas has been helpful in setting new industrial units in Morbi, Himmatnagar, Mehesana, Rajkot, and Vapi (Kar and Sahu 2012; Kar et al. Forthcoming). Their research findings suggest that industrial units in Gujarat are very happy to receive continuous and constant supplies of natural gas at the desired pressure. Natural gas found to be economical, safe, reliable, and eco-friendly, so many of the existing and new industrial units prefer natural gas as a fuel. On the other hand, the industrial segment is found to be the cash cows for the gas marketing entities. So natural gas offers win-win-win

situation for customers–entities–environment. Gujarat is the leading state having well-developed natural gas infrastructure support leading to higher penetration and share of industrial connections (Table 16). The state has the highest share of about 69 % of industrial customers.

Domestic Customers

While supplying natural gas, the domestic customers using natural gas for cooking should be treated with top most priority. The regulatory body very much acknowledges the emergency need and builds necessary measures to ensure a fair deal for the domestic customers. Any entity bidding for natural gas supply in a city needs to ensure supply of natural gas to a minimum number of domestic consumers. Regulatory body considers the domestic supply as mandatory, and the entities consider this as obligatory. Some entities operating in semi-urban and rural, or less developed markets consider serving domestic consumers as social service as the cost of serving the domestic customers is much higher than any other segment and margin from domestic customers is comparatively low. An average household consumes about 0.5 SCM/day of natural gas. Currently, in terms of volume this segment is not the most attractive segment for the gas marketing companies.

Road Transport

The country transports nearly 57 % of the total goods by road, as compared to 22 % in China and 37 % in the USA (Planning Commission 2012, p. 196). The transport sector is one of the largest consumers of liquid hydrocarbon in India, a major contributor to greenhouse gases (GHGs), especially in the bigger cities due to the greater density of the vehicle population. To reduce GHGs emissions, the conversion of diesel and petrol-driven vehicles to compressed natural gas (CNG) fuel powered has been initiated. CNG drive was enforced through Supreme Court intervention in Delhi. As of 31 March 2013, close to 1.9 million vehicles were running on CNG and Delhi/NCR contributed the maximum number followed by Gujarat (Table 17). In terms of number of CNG stations Gujarat leads the way with above 300 CNG stations followed by Delhi/NCR, and Maharashtra. Bigger states such as Uttar Pradesh, Madhya Pradesh, Tamil Nadu, and Rajasthan are lagging behind and need to build better CNG infrastructure.

Commercial

The commercial segment is one of the most important segments for the gas marketing companies. The commercial segment is not well developed in India as the use of natural gas has been limited to cooking and to some extent for cooling. Extensive use of natural gas for cooling and heating will have greater impact

Table 16 PNG connection status in India (as of 31 March 2013)

State	City covered	Company	Number of domestic PNG connections	Domestic PNG share (%)	Number of Comm. PNG connections	Comm. PNG share (%)	Number of Ind. PNG connections	Ind. PNG share (%)
Delhi	Delhi, NOIDA, Greater NOIDA, Ghaziabad	IGL	410,000	18.14	1370	8.0	570	10.6
Maharashtra	Mumbai, Thane, Mira-Bhayandar, Navi Mumbai, Pune, Kalyan, Ambermath, Panvel, Bhiwandi	MGL, MNGL	647,790	28.67	1990	11.6	98	1.8
Gujarat	Ahmedabad, Baroda, Surat, Ankeleswar	GSPC, Sabarmati Gas, Gujarat Gas, HPCL, VMSS, Adani Gas	1,144,424	50.65	12,693	73.9	3686	68.5
Uttar Pradesh	Agra, Kanpur, Bareilly, Lucknow	Green Gas Ltd. (Lucknow), CUGL(Kanpur)	7090	0.31	55	0.3	430	8.0
Tripura	Agartala	TNGCL	11,431	0.51	256	1.5	41	0.8
Madhya Pradesh	Dewas, Indore, Ujjain, Gwalior	GAIL Gas, AGL	1775	0.08	6	0.0	49	0.9
Rajasthan	Kota	GAIL Gas	177	0.01	0	0.0	16	0.3
Assam	Tinsukia, Dibrugarh, Sibsagar, Jorhat	Assam Gas Co. Ltd.	23,632	1.05	759	4.4	366	6.8
Andhra Pradesh	Kakinada, Hyderabad, Vijaywada, Rajmundry	BGL	1802	0.08	15	0.1	1	0.0
Haryana	Sonepat, Gurgaon, Faridabad	GAIL Gas, Adani Gas, Haryana City Gas	11,508	0.51	43	0.3	123	2.3
Total			2,259,629	100	17,187	100	5380	100

Source Kar et al. (2015)

Table 17 Status of CNG stations and vehicles (as of 31 March 2013)

State	Entity	Number of CNG stations	Share (%)	Number of CNG vehicles	Share (%)
Gujarat	GAIL Gas/Adani Energy/Gujarat Gas, GSPC, GGCL, SGL, HPCL	313	34.51	638,422	34.08
Delhi/NOIDA, Gr. NOIDA/Ghaziabad	Indraprastha Gas (IGL) New Delhi	290	31.97	720,000	38.43
Maharashtra	Mahanagar Gas Ltd. (MGL) Mumbai, MNGL Pune	203	22.38	334,810	17.87
Andhra Pradesh	Bhagya Nagar Gas Ltd. (BGL) Hyderabad.	29	3.20	19,958	1.07
Rajasthan	GAIL Gas	2	0.22	1085	0.06
UP	Green Gas Ltd. (Lucknow), CUGL (Kanpur)	30	3.31	56,857	3.03
Tripura	Tripura Natural Gas Co. Ltd. (TNGCL) Agartala	3	0.33	4682	0.25
MP	Avantika Gas (Indore)/GAIL Gas Ltd.	16	1.76	10,878	0.58
Haryana	Haryana City Gas Ltd.	14	1.54	85,560	4.57
West Bengal	GEECL	7	0.77	1201	0.06
All India		907	100.00	1,873,453	100.00

Source Kar et al. (2015)

on the green environment in India. In the USA, natural gas currently accounts for 13 % of energy used in commercial cooling and this percentage is expected to increase due to technological innovations in commercial natural gas cooling techniques.

In India, use of natural beyond cooking should be pushed through. As per the existing economics of alternative fuels and availability of affordable electricity, viability of natural gas for wider use seems to be a distant dream. One of the ways to increase penetration of natural gas in the commercial sector is to promote tri-generation technologies to generate electricity, heating, or cooling.

Most promising areas of tri-generation application include hospitals, hotels, departmental stores, mall, data centres, industries, and large residential complexes. According to Trigen India Portal, it is estimated that there are several thousands of potential sites in India, where tri-generation could be applied economically

within a range of 200 kWel to several MWel per installed system. Tri-generation technology working well in Jai Prakash Narayan Apex Trauma Center (JPNATC), AIIMS, New Delhi, and can be presented as a model case to promote the technology. Tri-generation technology offers benefits such as energy savings, economic savings, environmental savings, and increased reliability and interdependence from traditional forms of electricity supply.

Others

Research has been started in the USA to run locomotives on natural gas. Recently, CSX Corporation and GE transportation announced that natural gas-fuelled locomotives can travel longer distances without refuelling stops, as well as provide environmental and economic benefits. Adoption of natural gas-fuelled locomotives could make freight rail as a more attractive transportation solution (LNG Global 2013). Possibly an extensive Indian rail network could reduce load on the nation's highways in an environmentally efficient way.

Inland water transport seems to be another potential area where the use of natural gas/LNG/CNG could be very productive. According to the Planning Commission (2012, p. 231), the total external costs of inland navigation after accounting for all externalities, including accidents, congestion, noise emissions, air pollution and other environmental impacts are seven times lower than that of road transport. To reduce GHGs emissions, Indian coastal vessels could be converted to CNG/LNG fuel powered.

LNG-driven tugboats offer greater efficiency and less pollution could be better for external environment and even for the boat operators. The LNG tugboat is designed for the green future, so some of the countries in Europe and even Asian countries like China are developing LNG tugboat for preserving aquatic environment. So, LNG-driven tugboats may be tried in India.

7 Discussions

The position of India in Energy Sustainability Index Ranking (Table 18) is very uncomfortable and embarrassing one. Considering renewable resource richness, India should improve its score in the areas of energy security, energy equity, and environmental sustainability. The economic prosperity of the country is highly dependent on energy availability, and green development requires green energy. Natural gas along with other green forms of energy such as solar, wind, and biomass expected to play a crucial role. The areas where natural gas could contribute significantly are transport sector, cooling and heating, electricity generation, fertilizer production, green supply chain, petrochemical production, LPG production, and green production in industries such as chemical, steel, pharmaceutical, and ceramic. Various consuming industries such as fertilizer, chemical, and

Table 18 India's energy sustainability index ranking

	2011	2012	2013	Ranking
Energy performance	124	124	124	
Energy security	87	86	76	C
Energy equity	110	110	110	D
Environment sustainability	123	123	121	D
Contextual performance	67	77	76	
Political strength	90	97	93	
Societal strength	76	80	80	
Economic strength	44	54	54	
Overall rank and balance score	115	117	115	CDD

Source World Energy Council (2013, p. 59)

pharmaceutical can produce derivatives from natural gas and contribute towards green developments in India. Similarly, the transport sector may gradually switch to green fuel such as natural gas to reduce impact on the environment.

The enabling factor for faster adoption of natural gas could be availability of gas, development of suitable cross-country gas pipeline with better spread for equitable distribution, and investor friendly policy for infrastructure development. Currently the western and northern states have the combined coverage of 60 % of total pipeline network in India. The eastern states such as Bihar, Jharkhand, Odisha, and West Bengal have almost no operational cross-country gas pipeline network. Therefore, gas distribution and consumption found to highly skewed. By 2030, all states in India will be connected through National Gas Grid and will have access to domestic or imported natural gas.

8 Conclusion

It is very clear that for green economy, clean energy would play the most important role. United Nations Millennium Development Goal and Climate Change initiatives are the prime drivers of clean energy policies across the globe. But due to financial and other constraints, many of the governments are not able to meet their own target. Therefore, public stakeholders encourage the private sector to come forward to participate in the cleaner and greener environment building measures. For green development, green manufacturing and production, transport, green supply chain, and green consumption need to be given priority.

Natural gas is considered as one of the important green fuels for driving green growth in India. By 2030, India will have a fully functional National Gas Grid and provide a green fuel option to industry, transport sector, residential and commercial buildings, and other consuming industries or individual consumers. Shale gas access to Indian companies at competitive price could prove as a game changer for green developments in India. Shale gas has already changed the global gas pricing

dynamics and likely to push LNG price further down. This essentially means more LNG flowing to India leading to greater LNG infrastructure development in the country. Such developments could improve gas supply and availability in coastal states such as Tamil Nadu, Kerala, Andhra Pradesh, Odisha, and West Bengal. New gas corridor will be developed in some of these gas-starved states and driving green manufacturing, distribution, transport, and consumption.

Also, transmission of natural gas from Turkmenistan through TAPI is going to be a landmark achievement. This would enhance much needed supply security and enrich the gas sourcing mix of India. Availability of ready to feed in and use of dry gas could bring green growth revolution in India, especially in north Indian states such as Punjab, Haryana, Delhi, Uttar Pradesh, and Rajasthan.

Evolution of natural gas market in India is going to drive socio-economic transformation, green growth, and environmental preservation through reduction in GHGs, eradication of energy poverty, and reduction in death arising out of pollution.

Annexure

Table 19 Key task of PNGRB

Tasks	Details
1 To protect consumer interest by fostering fair trade and competition amongst entities by creating an environment for level playing field in downstream oil and the gas sector by:	<p>Addressing issues of continuing anomalies in pricing and subsidies which affects the competitive positions of downstream sector</p> <p>Addressing access to infrastructure on principles of contract carriage or common carrier to be applied on non-discriminatory principles. These principles include specifying pipeline access code. The PNGRB's task is to evolve an access code for non-discriminatory third party access to common infrastructure after meeting own genuine requirements</p> <p>Facilitating creation of a trading platform for crude oil, petroleum products, natural gas and pipeline capacities</p> <p>Ensuring competitive environment and transparent bidding process with selection criteria that incentivizes infrastructure (pipeline) investment</p> <p>Ensure that the ownership of infrastructure by any CGD or any company does not become a barrier to competition and disincentivize creation of vertically integrated monopolies</p>
2 Register entities so as to elicit serious participation from industry in all segments of downstream energy value chain on such terms which are fair, encourage competition and create adequate and efficient infrastructure. PNGRB registers entities to:	<p>Market petroleum products and establish storage facilities. The storage facilities can be for storage of any petroleum product or for natural gas storage. Also, PNGRB ensures adequate availability, display of prices, equitable distribution of petroleum products along with enforcement of retail service obligations and continuous monitoring of transportation rates</p> <p>Establish and operate Liquefied Natural Gas (LNG) terminals in order to receive LNG from ships and regasify the LNG to natural gas for further transmission through the pipeline</p>
3 Authorize entities to:	<p>Lay, build, and operate or expand a common carrier or contract carriage for optimal and efficient use of resources such as pipeline network</p> <p>Lay, build, and operate or expand city gas distribution network for better utilization of pipeline networks and avoidance of duplicity of infrastructure</p>
4 Regulate by regulations	<p>Transportation rates for common carrier or contract carriage</p> <p>Access to city gas distribution network would allow operators to optimally use the existing infrastructure and reduce additional investment leading higher return on investment</p> <p>Tariffs to be reasonable and allowable. Also, tariffs have to eventually move from a "fixation regime" to a "traded regime". Fixation regime means that the tariff rates are fixed by the entity on a bidding basis and is fixed for any entity using that pipeline or CGD infrastructure. Traded regime includes the system followed in developed economies where the tariff for the pipelines is charged on an entry-exit model based on the total number of in and out pipelines located in a region</p>

Source Partially Adapted from Kar et al. (Forthcoming)

References

- Airy A (2014) Easing of N-curbs to revive India-Iran gas pipeline talks. *Hindustan Times*, New Delhi, January 20
- BP Statistical Review of World Energy, June 2013
- BP Statistical Review of World Energy, June 2014
- CCEA (2014). Revision of domestic gas prices. Available on <http://pib.nic.in/newsite/pmreleases.aspx?mincode=20>. Accessed on 28 Oct 2014
- Cesur R, Tekin E, Ulker A (2013) Air pollution and infant mortality: evidence from the expansion of natural gas infrastructure. Discussion Paper No. 7179
- Chandrasekhar CP (2013) The cost of reliance on gas. *Frontline*, July 12
- Chen Y, Ebenstein A, Greenstone M, Li H (2011) The long-run impact of air pollution on life expectancy: evidence from China's Huai river policy. Mimeo
- DoF (Department of Fertilizers) (2014) Subsidy given to farmers of Uttar Pradesh. Parliament questions, Rajya Sabha, winter session, February 21. Available at <http://fert.nic.in/node/1529>
- Green Peace India (2014). Coal Kills: an assessment of death and diseases caused by India's dirtiest energy source. Available at http://www.greenpeace.org/india/Global/india/report/Coal_Kills.pdf. Accessed on 26 June 2014
- IGU (2011) World LNG Report, June 2011
- IGU (2013) World LNG Report-2013
- Jayaswal R (2013) Government plans 15,000-km Asian Gas Grid to connect with producers in Iran, Myanmar. *Economic Times*, 25 November. Available at http://articles.economictimes.indiatimes.com/2013-11-25/news/44449908_1_tapi-project-pipeline-project-india-importing-gas. Accessed on 21 Jan 2014
- Kar S, Sahu S (2012) Managing natural gas business: a case of Bharat Natural Gas Company limited. *Emerg Markets Case Stud* 2(1):1–22
- Kar SK, Mishra SK, Bansal R (2015) Drivers of green economy: an indian perspective. In: Thangavel P, Sridevi G (eds) *Environmental sustainability: role of green technologies*. Springer, Berlin
- Kar SK, Sinha PK, Mishra S (Forthcoming) Sabarkantha gas limited: challenges of marketing natural gas. *Asian Case Res J*
- LNG Global (2013) LNG for fuel. Available at <http://www.lngglobal.com/lng-for-fuel/>. Accessed on 19 Nov 2013
- Ojha K, Karmakar B, Mandal A, Pathak AK (2011) Coal bed methane in India: Difficulties and Prospects. *Int J Chem Eng Appl* 2(4):256–260
- Petroleum and Natural Gas Regulatory Board Act (2006) No. 19 of 2006. Ministry of Law and Justice, 31 Mar 2006
- Petroleum Statistics (2012, 2013) Ministry of Petroleum and Natural Gas, India
- PIB (Press Information Bureau) (2014) Government of India, Ministry of Petroleum and Natural Gas. Allocation of gas from KG-D6 Block. 21 February 18:22 IST
- Planning Commission (2012) Twelfth Five Year Plan (2012–2017). *Economic Sectors*, vol II
- Platts (2013) *LNG Daily*, vol 10, issue 132, July 11
- PNGRB (2013) “Vision 2030”—natural gas infrastructure in India. Available at <http://www.pngrb.gov.in/newsite/pdf/vision/vision-NGPV-2030-06092013.pdf>. Accessed on 23 June 2014
- Rangarajan Committee (2012) Report of the committee on the production sharing contract mechanism in Petroleum Industry
- Ranjan A (2014) Suresh Prabhu to head panel to review gas price. *Indian Express*, July 24, Available at <http://indianexpress.com/article/business/business-others/suresh-prabhu-to-head-panel-to-review-gas-price/>. Accessed on 8 Oct 2014
- Standing Committee on Petroleum & Natural Gas (2013–2014) Allocation and pricing of gas. Nineteenth Report, pp 1–80

TOI (2014) Govt postpones decision on revision of natural gas prices. Available at <http://www.timesnow.tv/Govt-postpones-decision-on-revision-of-natural-gas-prices/articleshow/4465187.cms>. Accessed on 8 Oct 2014

World Energy Council (2013) World Energy Trilemma: 2013 energy sustainability index