Chapter 2

Economic Cost of Alternative Fuels

Imported natural gas can substitute coal and uranium for power generation, naphtha and fuel oil for fertilizer plants and diesel for the transport sector. Substituting diesel in the agriculture sector is not easily possible, though it can be expected that use of diesel for irrigation will gradually be substituted by use of electricity, which in turn may increase use of gas. We need to examine the economic benefit of natural gas in the power generation, fertilizer and transport sectors as compared to coal, uranium, naphtha and petroleum.

2.1: Cost of Various Fuels

There are several points of view for examining the cost of a form of fuel. The end user is concerned with the delivered price of fuel at his doorstep per unit calorific value, apart from the capital cost of equipment needed for utilizing the fuel and mitigating the environmental impact in order to attain statutorily acceptable limits. The cost of waste disposal is also a relevant factor.

Delivered price of fuel depends on a large number of factors including processing costs, taxes and transportation tariffs. Fluctuations in import parity prices[23], currency exchange rates and domestic production also affect prices of fuel. Prices also vary from one State of the country to another, depending on local taxes such as VAT, entry tax etc. levied by State Governments.

[23] The reference price for domestically produced crude oil is calculated on import parity price basis. The import parity price (IPP) is the price at the border of a good that is imported, which includes international transport costs and tariffs.

From a national perspective, the foreign exchange outgo on account of import of fuel is a critical factor which has to be taken into account for policy formulation. India imports a very large portion of its energy requirement from abroad, almost 26% at present, and this dependence is projected to grow to 53% by 2030. Our energy policy, therefore, has to be designed in a manner that is conducive to reducing the cost incurred by the country in importing fuel.

Another critical dimension is the environmental impact of the fuel imported. Although the Kyoto Protocol does not impose any binding targets on India for reduction of Green House Gases (GHGs), voluntary commitments may be required in future for demonstrating support to the cause of sustainable development. Rapid economic development requires huge additions to power generation capability and industrial output in the country, which would only worsen the problem of GHG emissions. Any attempt in reducing GHG emissions would require that use of clean fuels is encouraged and green fuels are made available at reasonable prices in India. Reasonable pricing will have to take into account the environmental cost of each type of fuel which can be imported.

Renewable sources of energy offer freedom from dependence on imports. India is blessed with good potential for micro hydel, solar and wind energy. There is no doubt that such sources of energy must be aggressively pursued to ultimately achieve self-sufficiency. However, the scope of such efforts is rather limited at present by the high cost of present technology harnessing renewable energy sources. The Integrated Energy Policy, 2006 had stressed the importance of solar energy in particular in order to diversify supply sources, but had estimated that only 5 to 6 % of India's energy mix would come from renewable sources of energy by the year 2031-32:

> *From a longer-term perspective and keeping in mind the need to maximally develop domestic supply options as well as the need to diversify energy sources, renewables remain important to India's energy sector. It would not be out of place to mention that solar power could be an important player in India attaining energy independence in the long run. With a concerted push and a 40-fold increase in their contribution to primary energy, renewables may account for only 5 to 6% of India's energy mix by 2031-32. While this figure appears small, the distributed nature of renewables can provide many socio-economic benefits.*

The Policy also estimates that even if India succeeds in achieving its full hydro potential of 1,50,000 MW, the contribution of hydro energy to the energy mix will only be around 1.9 - 2.2% by 2031-32. Similarly, the contribution of nuclear energy to the energy mix by 2031-32 is at best, expected to be 4.0 to 6.4%. Clearly, renewable sources and hydro/ nuclear power may expand rapidly in coming years, but the lions' share of our energy mix would still come from coal, natural gas and petroleum.

India has traditionally been importing crude oil to meet domestic requirements. Inspite of the high cost of transportation depending upon location of use, imports of coal are now gradually picking up in the face of unavailability of high quality coal in the country coupled with inadequate extraction of coal due to a variety of constraints faced by Coal India Limited. Some data regarding the price at which imports of coal, nuclear fuel and natural gas are taking place is available now. Since all the imported fuels differ in calorific value, their prices should be compared in terms of cost per unit of energy imported.

2.2: Cost of Importing Coal

Coal Controller of India, Kolkata, publishes statistics regarding production, imports and consumption of coal each year. The Provisional Coal Statistics published for the year 2012 state that data for coal imports is available only upto October 2012 from Director General, Commercial Intelligence and Statistics and have extrapolated data to estimate imports for the whole of 2011-12. Imported coal mainly consists of high quality coking coal used mainly in the steel industry, and non-coking coal used by the power sector. South Africa and Indonesia provide the bulk of Indian requirement of non-coking coal. Year wise imports of non-coking coal are as given in Table 2.1 below:

Table 2.1:Year wise imports of non-coking coal in India

Year	Quantity (Million Tonnes)	Value (Million Rs.)	Average Annual Exchange Rate (Rs. Per US$)	Average Price (US$ per MMBTU)
2002-03	10.313	16325	48.3953	1.374
2003-04	08.691	13385	45.9516	1.408
2004-05	12.025	30228	44.9315	2.350
2005-06	21.695	53722	44.2735	2.349
2006-07	25.204	65080	45.2849	2.395
2007-08	27.765	86358	40.2410	3.246
2008-09	37.923	187268	45.9170	4.517
2009-10	48.565	190489	47.4166	3.474
2010-11	49.434	206875	45.5768	3.856
2011-12 (Apr-Oct)	43.300	215559	47.9229	4.363

Source: Provisional Coal Statistics 2012, Coal Controller of India. Average Annual Exchange Rate taken from web-site of Reserve Bank of India. 1 MMBTU = 252,000 Kcal. Annual average exchange rate for the whole of 2011-12 used for calculating April-October 2011 import price in US$/MMBTU.

The above calculation is based on the assumption that average calorific value of imported coal is 6000 Kcal per Kg of coal. In contrast, the average calorific value of Indian coal is about 4000 Kcal per Kg of coal. They are not strictly comparable over time as they are at current prices and current exchange rates.

2.3: Cost of Importing Crude Oil

Indian crude oil imports during 2010-11 stood at 163.595 million tonnes procured from 30 countries. The composition of Indian basket of crude oil is based on the total crude oil processed by refiners in the country, including imported sour and sweet crude oil as well as domestic production.

Crude oil is classified by the location of its origin and often by its relative weight or viscosity (light, intermediate or heavy). Sweet crude oil has relatively low amounts of sulphur, while sour crude oil has substantial amounts of sulphur and requires more refining to meet product standards.

There are three primary benchmarks for crude oil: WTI (West Texas Intermediate), Brent blend, and Dubai (Fateh). WTI crude oil is of very high quality, being light and sweet (API[24] gravity 39.6 degrees, sulphur content 0.24%), which makes it ideal for production of petrol and diesel. It is used primarily in the U.S.A. which is the largest petrol consumer in the world. Brent blend (API gravity 38.3 degrees, sulphur content 0.37%) is a combination of crude oil from 15 different oil fields in the Brent and Ninian systems located in the North Sea. Though it is not as high in quality as WTI, it is still ideal for making gasoline and middle distillates. The third benchmark crude, known as

[24] API = American Petroleum Institute

Dubai Crude or Fateh is a light, sour crude oil (API gravity 31 degrees, sulphur content 2.13%) extracted from Dubai. As the production of oil in Dubai region is declining now, the Oman benchmark (API gravity 33.34 degrees, sulphur content 1.04%) is emerging as the new benchmark for sour crude. A summary of these benchmarks is presented below in Table 2.2.

Table 2.2: Crude Oil Benchmarks

Benchmark	Characteristics	API Gravity (Degrees)	Sulphur Content
WTI	Light and sweet	39.6	0.24%
Brent	Light and sweet	38.3	0.37%
Dubai	Light and sour	31.0	2.13%
Oman	Light and sour	33.3	1.04%

Nearly two thirds of our total imports of crude oil come from West Asia. As Indian refineries have improved their capability to refine sour crude oil, the Brent Blend content in the Indian crude basket has gradually come down from around 43% in 2006 to 37% in 2010, while the percentage of sour grades represented by Dubai and Oman grades has gone up from 57% to 63%.

Table 2.3:Year wise imports of crude oil in India

Year	Quantity (Thousand Tonnes)	Value (Million US$)	Average Price (US$ per MMBTU)
2002-03	81,989	15,759	4.703
2003-04	90,434	18,268	4.943
2004-05	95,861	25,990	6.634
2005-06	99,409	38,776	9.544
2006-07	111,502	48,389	10.618
2007-08	121,672	67,988	13.672
2008-09	132,775	76,876	14.167
2009-10	159,259	79,553	12.222
2010-11	163,595	100,080	14.968
2011-12 (Provisional)	171,729	139,690	19.903

Source: Policy Planning and Analysis Cell, Ministry of Petroleum and Natural Gas, GoI data

Import prices of crude oil from 2002-03 to 2011-12 are shown in Table 2.3. Statistical data about imports of crude oil is available on the web-site of Petroleum Policy & Analysis Cell, MoPNG (ppac.org.in). Brent blend, Dubai and Oman benchmarks have slightly different gross calorific values associated with them. However, in order to calculate the price per unit of energy, we have taken the average value of 10,300 Kcal/kg or 40,870 BTU/Kg given in the statistics published by MoPNG[25].

2.4: Cost of Indian Imports of LNG

Imports of LNG began around 2004 in India. PPAC data regarding the total quantity of LNG imported into the country is shown in Table 2.4.

Table 2.4:Year wise imports of LNG in India

Year	Quantity (Million Tonnes)	Quantity (Million MMBTU)
2003-04	0.25	12.68
2004-05	2.50	128.35
2005-06	5.06	256.62
2006-07	6.81	352.35
2007-08	8.25	425.10
2008-09	7.96	410.28
2009-10	8.92	459.95
2010-11	8.86	454.07
2011-12 (Provisional)	10.13	524.951

Source: Policy Planning and Analysis Cell, Ministry of Petroleum and Natural Gas, GoI data

Most of these imports were taking place through Petronet LNG Ltd. and Hazira LNG Pvt. Ltd. earlier. In later years, however, the State of Gujarat started importing LNG through its own public sector enterprises. GAIL (India) Limited has also started importing spot LNG and has tied up a long term LNG import agreement with a U.S. based company. PPAC data in Table 2.4 above

[25] Ministry Of Petroleum & Natural Gas, Economic Division, *Indian Petroleum & Natural Gas Statistics 2010-11*, page 176

does not reflect all these sources of import. The price at which imports are taking place is also not available, perhaps in view of the commercial sensitivity of this data in a situation where Indian companies are competing against each other for the same cargo at times.

As has been mentioned earlier in the introductory chapter, LNG can be sourced through long term contracts and through spot market purchases. The pricing formula in long term contracts generally has a cap on the maximum crude oil price and LNG becomes cheaper than oil in energy equivalent terms if crude oil prices exceed the specified cap. Spot market prices of LNG are unaffected by any such considerations and broadly used to move in line with crude oil prices, although there are violent fluctuations at times.

Data from Shell Hazira LNG Private Ltd. about import of LNG is not readily available. Data from GSPC Gas Ltd. annual reports shows that they imported LNG at rates between US$ 6 to 7 per MMBTU from 2007-08 to 2010-11. Petronet LNG Ltd., the largest importer of LNG in the country, provides data about their imports in their annual reports. An analysis of data provided in their annual reports reveals the following picture:

Table 2.5: Year wise imports of LNG by Petronet LNG Ltd.

Year	Quantity (TBTU)	Value (Rs. Crores)	Average Annual Exchange Rate (Rs./US$)	Average Price (US$ per MMBTU)
2005-06	247.76	3,253.48	44.2735	2.966
2006-07	292.80	4,746.47	45.2849	3.580
2007-08	321.95	5,566.42	40.2410	4.297
2008-09	321.33	7,375.62	45.9170	4.999
2009-10	384.41	9,664.76	47.4166	5.302
2010-11	412.21	11,801.20	45.5768	6.282
2011-12	548.00	20,586.74	47.9229	7.839

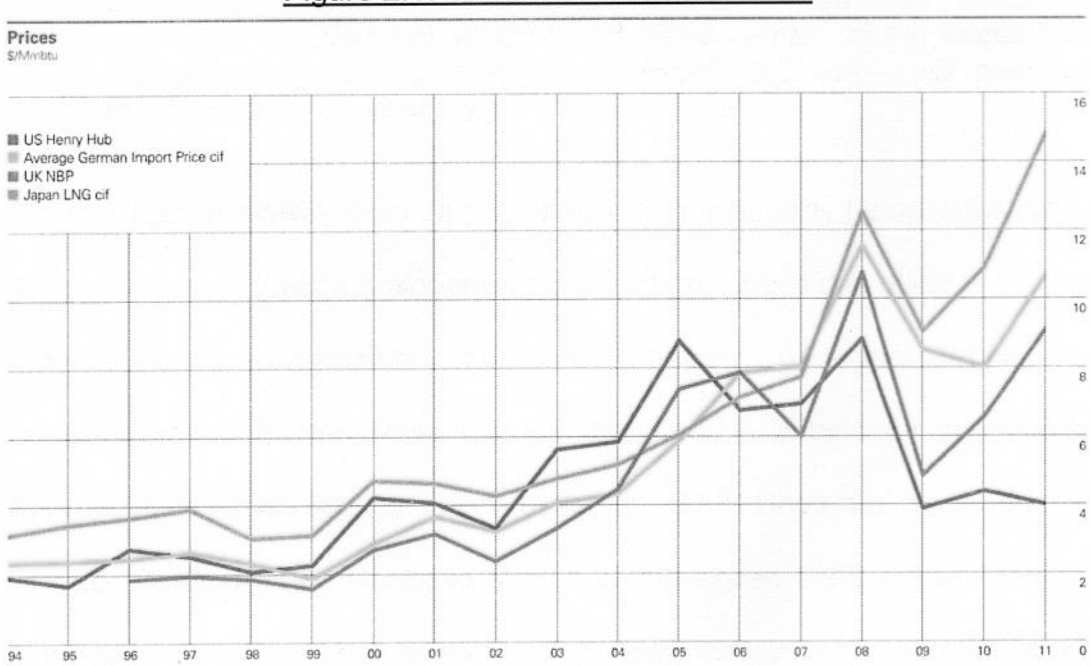
Source: Annual Reports of Petronet LNG Ltd.. Average Annual Exchange Rate taken from web-site of Reserve Bank of India. 1 TBTU = 1 Tera BTU = 1 million MMBTU.

However, it has to be noted that India was not a major importer of LNG so far and most LNG imports have been coming through long term contracts, leading to somewhat lower prices than spot market rates. As our imports grow, LNG rates will get more closely aligned to world market rates.

2.5: International LNG Prices

The linkage between crude oil and LNG prices has been weakening during the past three years after vast quantities of commercially recoverable Shale gas have been found in the USA. American gas prices have been quite stable even as crude oil prices continue to soar. Exports of LNG from U.S. may contribute to keeping LNG cheap as compared to oil in future. World market rates of LNG in the past are available in the *BP Statistical Review of World Energy, June 2012*. Figure 2.1 below is reproduced from this publication, showing the movement of LNG prices from 1994 to 2011.

Figure 2.1: Variation in Prices of LNG



Note: cif = cost + insurance + freight. Source: *BP Statistical Review of World Energy*, June 2012

It can be seen that Henry Hub prices continue to be at around 4 US$/MMBTU. The average German import price and Japan LNG import price has steadily gone up during the past two years. Japan is the world's largest importer of LNG, and a rise in Japanese imports of LNG after the Fukushima disaster has led to some recovery in the natural gas trading market which was facing a problem of over capacity after successful commercial exploitation of Shale gas in America. The *World Energy Outlook 2010* published by International Energy Agency, looking at the New Policy Scenario (wherein new policies to mitigate climate change will be adopted by governments worldwide), says:

> *The glut of global gas-supply capacity that has emerged as a result of the economic crisis (which depressed gas demand), the boom in US unconventional gas production and a surge in liquefied natural gas (LNG) capacity, could persist for longer than many expect. Based on projected demand in the New Policies Scenario, we estimate that the glut, measured by the difference between the volumes actually traded and total capacity of inter-regional pipelines and LNG export plants, amounted to about 130 bcm in 2009; it is set to reach over 200 bcm in 2011, before starting a hesitant decline. This glut will keep the pressure on gas exporters to move away from oil-price indexation, notably in Europe, which could lead to lower prices and to stronger demand for gas than projected, especially in the power sector. In the longer term, the increasing need for imports — especially in China — will most likely drive up capacity utilisation.*

Some movement away from oil price indexation is already being witnessed in our country also now. In a pioneering effort, state-owned gas utility GAIL India recently signed an agreement to import 3.5 million tons a year of LNG from Lousiana-based Sabine Pass Liquefaction LLC, a subsidiary of Cheniere Energy. With India's energy needs galloping, GAIL Chairman and Managing Director B. C. Tripathi wants to tap all of the seven LNG export terminals planned in the US and has written to Petroleum Ministry as well as Ministry of

External Affairs (MEA) to persuade the U.S.A. to allow other terminals to sell gas to India. On his prod, MEA has taken up the matter with the US.

Gas from the USA and new sources like the proposed Turkmenistan – Afghanistan–Pakistan–India (TAPI) pipeline may be available in future at rates between US$ 10 and 14 to India. It will be beneficial for the country if we are able to procure cheap gas in future years. Prudence demands, however, that while evaluating the economic benefit of natural gas over other fuels, we take the price of imported gas available in the spot market to large consumers, so that the analysis is not unduly optimistic.

Table 2.6: Prices of natural gas and crude oil (US$/MMBTU)

Year	LNG	Natural Gas				Crude Oil
	Japan cif	Average German Import Price	UK (Heren NBP[26] Index)	US Henry Hub	Canada (Alberta)	OECD countries cif
2002	4.27	3.23	2.37	3.33	2.57	4.17
2003	4.77	4.06	3.33	5.63	4.83	4.89
2004	5.18	4.32	4.46	5.85	5.03	6.27
2005	6.05	5.88	7.38	8.79	7.25	8.74
2006	7.14	7.85	7.87	6.76	5.83	10.66
2007	7.73	8.03	6.01	6.95	6.17	11.95
2008	12.55	11.56	10.79	8.85	7.99	16.76
2009	9.06	8.52	4.85	3.89	3.38	10.41
2010	10.91	8.01	6.56	4.39	3.69	13.47
2011	14.73	10.61	9.03	4.01	3.47	18.56

Note: cif = cost + insurance + freight

Historical prices as extracted from *BP Statistical Review 2012* are placed below in Table 2.6 above for ready reference. Henry Hub prices, the lowest amongst all, are not appropriate for calculating the LNG import price in India due to large transportation costs involved. An appropriate benchmark for comparison can be the average price paid by Japan for LNG imports, since

[26] NBP = New Balancing Point, a notional hub for gas trade in U.K.

the volumes imported by Japan are very large and similar rates should ultimately prevail as our imports grow in size. It can be seen that the price of LNG imports in Japan has almost consistently lower than the price of crude oil (the year 2002 was the only exception to this).

2.6: Cost of Importing Nuclear Fuel

One more alternative for power generation is to go for nuclear power. India has vast reserves of Thorium. Our nuclear energy programme aims to construct reactors that can use Thorium in the third phase of development. India has done reasonably well in the second phase of the programme in constructing Fast Breeder Reactors, but the first Advanced Heavy Water Reactor (AWHR) that can use Thorium has still not been commissioned. At the moment, India still depends on import of Uranium for nuclear power.

Only 10 countries are responsible for 94% of uranium production in the world. Uranium producing countries came together as a cartel in 1972 that has been controlling prices since then. There have been wild fluctuations in prices, beginning from US$ 10 per pound in 1989, falling to a record low of US$ 7 per pound in 2001, moving to a bubble of US$ 137 per pound in 2007 when new prospecting and mining operations began to reduce prices. Current prices stand at around US$ 43 per pound.

Due to the limited numbers of buyers and suppliers, there is no transparent market based mechanism for sale of Uranium. Most sales are affected through individual negotiations. Uranium fuel has to pass through a number of intermediary processing steps before it can be used in reactors, which form the front end of the nuclear fuel cycle. The first step is mining of raw Uranium.

The second stage is of milling, which converts naturally available Uranium into yellowcake made of uranium oxide (U_3O_8). The third stage is of enrichment, to increase the percentage of U_{235} isotope to around 3.75% in the yellowcake. The fourth stage is fuel fabrication to produce fuel assemblies that can be used in reactors.

Enrichment and processing of Uranium fuel requires large amounts of electricity and other inputs. The resources used to enrich fuel are measured in Separative Work Units (SWUs). For instance, a 1300 MW power plant typically needs 25,000 Kg of enriched Uranium annually with U_{235} concentration of 3.75%. This amount of fuel would be manufactured from 210,000 Kg of raw uranium using about 120,000 SWUs.

Buyers usually do not buy only fuel bundles, but go for procurement at all stages of the front end of the nuclear fuel cycle. They engage multiple suppliers at each stage of the cycle in the hope that overall fuel costs can be minimized this way. The exact cost of imports would depend on the mix of all four stages of fuel that is used in Indian reactors and is not readily available on the websites of the Department of Atomic Energy. However, we get data about the rates of uranium from various websites.

For comparing the import cost of nuclear fuel, the commonly used data is the price of yellowcake. According to the web-site of World Nuclear Association[27], the calorific value of natural uranium is 500 GJ per Kg, or around 215.10 MMBTU per pound. This has been used as a conversion factor in Table 2.7 to

[27] http://www.world-nuclear.org/info/energy-conversion-heat-values-fuels.html

get an idea of the foreign exchange outgo for nuclear fuel. Variation in prices from 2002 to 2012 is shown in Table 2.7 below:

Table 2.7: Year wise rate of Uranium (U_3O_8)		
Year	Price (US$ per pound)	Price (US$ per MMBTU)
2002	10.30	0.048
2003	15.50	0.072
2004	21.00	0.098
2005	37.50	0.174
2006	75.00	0.349
2007	78.00	0.363
2008	50.00	0.232
2009	42.50	0.198
2010	72.00	0.335
2011	52.00	0.242

Source: http://www.uraniumminer.net/market_price.htm, month end prices for next year January taken for each year.

It needs to be noted that this is only a small part of the total cost incurred in nuclear power generation and substantial fixed and variable costs need to be added in local currency to determine the actual cost of generation.

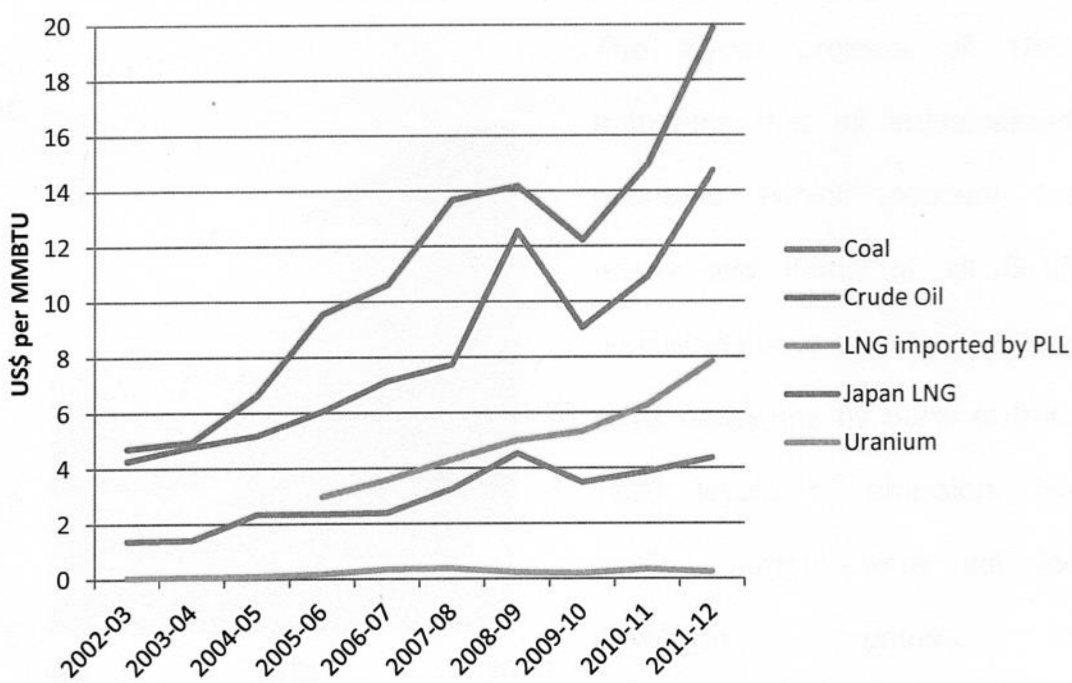
2.7: Comparison of Cost of Importing Coal, Crude Oil, Uranium & LNG

We can now compare the import price of coal, crude oil, natural gas, and uranium into India over the past ten years. The results are shown in Table 2.8.

Table 2.8: Year wise prices of coal, crude oil, LNG and natural uranium imports (US$ per MMBTU)					
Year	Coal	Crude Oil	LNG imported by PLL	Japan LNG	Uranium
2002-03	1.374	4.703		4.27	0.048
2003-04	1.408	4.943		4.77	0.072
2004-05	2.350	6.634		5.18	0.098
2005-06	2.349	9.544	2.966	6.05	0.174
2006-07	2.395	10.618	3.580	7.14	0.349
2007-08	3.246	13.672	4.297	7.73	0.363
2008-09	4.517	14.167	4.999	12.55	0.232
2009-10	3.474	12.222	5.302	9.06	0.198
2010-11	3.856	14.968	6.282	10.91	0.335
2011-12	4.363	19.903	7.839	14.73	0.242

This trend, shown pictorially in Figure 2.2, is broadly in line with the historical data analysis contained in the *World Energy Outlook 2010* published by the International Energy Agency (IEA). IEA has also predicted that in all policy scenarios analysed, natural gas will continue to be cheaper than crude oil in energy equivalent terms upto 2035, and that coal will continue to be cheaper than both these.

Figure 2.2: Cost comparison of imported fuels



2.8: Climate Change Mitigation Efforts in India

All these fuels have some environmental impact. The financial cost of mitigating environmental impact depends on the degree of mitigation required. For instance, the total pollution caused by a coal based power plant may be brought down to some extent by using superior quality of coal with lower sulphur content. This would not require much capital investment. If further improvement is required, then equipment like electric precipitators have to be installed, needing heavy capital investments. Even lower environmental impact can be achieved by Carbon Capture and Storage (CCS) technology.

The total Greenhouse Gas (GHG) emissions in the world stood at about 22 billion tonnes of carbon dioxide equivalent[28] in the year 1990. They have been increasing over the past two decades and have contributed to global warming. Growth of GHGs in the world is shown in Figure 2.3, which is taken from BP Energy Outlook 2030.

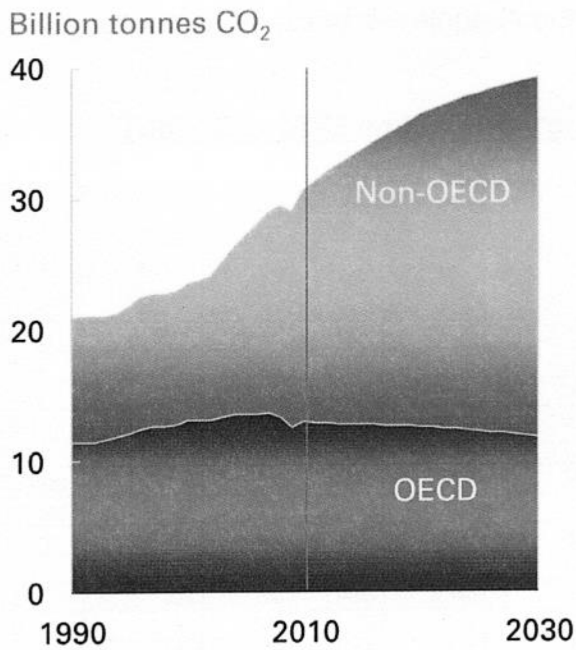


Figure 2.3: World GHG emissions

The Kyoto protocol of 1997 mandates that all industrialized countries (which account for nearly two thirds of all GHG emissions) have to cut down their GHG emissions by 5.2% of their 1990 levels of emission. No binding targets were set for developing countries. In December, 2009, there was broad agreement during the Copenhagen conference that efforts should be made to contain global temperature rise to less than 2 degrees centigrade. No other specific agreement has been reached so far, with all countries only agreeing to extend Kyoto protocol upto 2020 at the recently concluded negotiations at Doha.

[28] GHGs are traditionally measured in terms of CO_2 equivalents. This is done taking into account the Global Warming Potential (GWP) of various GHGs. For example, GWP of CH_4 is 21 times CO_2, so one unit of CH_4 would be multiplied by 21 to get the related CO_2 equivalent.

IEA data for GHG emissions from selected countries is reproduced in Table 2.9 for reference. It can be seen that India contributes only about 4% of the total GHG emissions in the world, although it has almost one sixth of the population of the world. Per capita CO_2 emissions from India at 1.18 tonnes are much lower than the world average of 4.38 tonnes. Inspite of the low emission intensity per capita, India has shown willingness to be a part of the solution to the world's efforts to mitigate climate change and is determined to see that her per capita emissions will never exceed the average per capita carbon emission levels of developed countries.

Table 2.9: GHG emissions from selected countries, 2008

Region / Country	Population (million)	GDP (billion 2000 US$)	GDP ppp (billion 2000 US$)	Energy Cons. (MTOE)	CO_2 Emissions MT CO_2	Per-capita Energy Cons. (kgOE)	Energy Intensity KgOE/ $GDPppp	Kg CO_2 / $GDP ppp	Per-capita Electricity Cons. (kwh)	Per-Capita CO_2 Emission (tonnes)
World	6609	39493	61428	12029	28962	1.82	0.20	0.47	2752	4.38
China	1327	2623	10156	1970	6071	1.48	0.19	0.60	2346	4.58
Brazil	192	808.95	1561	235.56	347	1.23	0.15	0.22	2154	1.80
India	1123	771	4025	421	1146	0.53	0.10	0.28	543	1.18
Japan	128	5205	3620	513.5	1236	4.02	0.14	0.34	8475	9.68
S. Africa	48	178	517	134.3	346	2.82	0.26	0.67	5013	7.27
Thailand	64	173	548	104	226	1.63	0.19	0.41	2157	3.54
Turkey	74	372	821	100	265	1.35	0.12	0.32	2210	3.59
UK	61	1766	1833	211	523	3.48	0.12	0.29	6142	8.60
USA	302	11468	11468	2340	5769	7.75	0.20	0.50	13616	19.10
France	64	1506	1738	264	369	4.15	0.15	0.21	7573	5.81
Germany	82	2065	2315	331	798	4.03	0.14	0.34	7185	9.71
Russia	141.79	429.55	1651.17	786	1593.83	5.54	0.48	0.97	6443	11.24

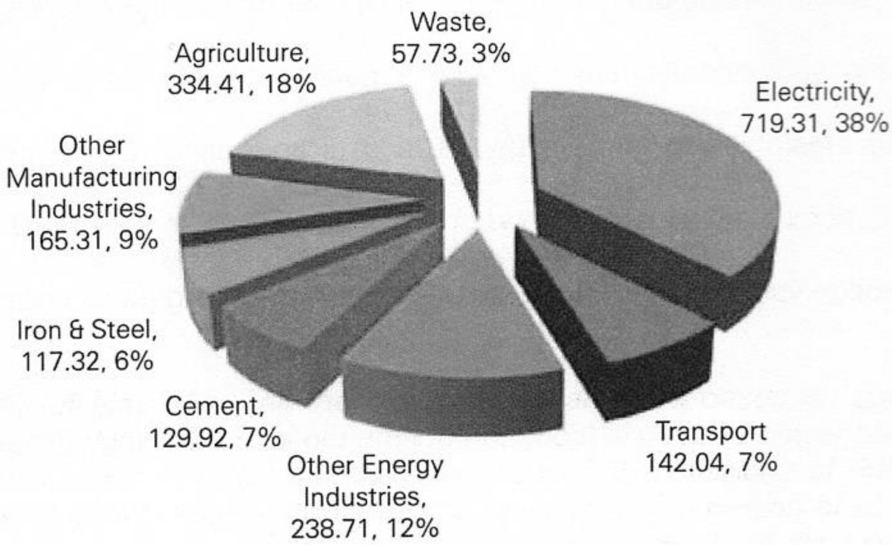
Source: Planning Commission, Government of India (May 2011) *Interim Report of The Expert Group on Low Carbon Strategies for Inclusive Growth*

Government of India adopted the Policy for Abatement of Pollution in 1992, which provided multi-pronged strategies in the form of regulations, legislations, agreements, fiscal incentives and other measures to prevent and abate pollution. The Government also adopted a National Conservation Strategy and Policy Statement on Environment and Development, 1992.This was followed by adoption of the National Environment Policy, 2006 which sought to extend the coverage, and fill in the gaps that still existed, in the light of latest knowledge and accumulated experience. The Ministry of Petroleum and Natural Gas, Government of India has enunciated an Auto Fuel Policy (2002) which aims to comprehensively and holistically address the issues of vehicular emissions, vehicular technologies and auto fuel quality in a cost-efficient manner while ensuring the security of fuel supply. Integrated Energy Policy, 2006 also addressed the issue of balancing growth with low carbon emissions.

As a result of government policies that encourage energy efficiency in various sectors of the economy, energy intensity of GDP has fallen from 66.8 grams of CO_2 equivalent per Rupee in 1994 to 56.21 grams in 2007. In December 2009, India announced that it would aim to reduce the emissions intensity of its GDP by 20-25 percent from 2005 levels by 2020. The Planning Commission has set up an Expert Group on Low Carbon Strategies for Inclusive Growth under the Chairmanship of Dr. Kirit Parikh which has published an interim report in May, 2011.

The Indian Network for Climate Change Assessment (INCCA) programme has made a rapid assessment of GHG emissions for the year 2007. As per this assessment, total emissions amounted to 1904.73 MT of CO_2 equivalent as shown in Figure 2.4. These emissions include emissions from the Energy sector, agriculture sector, industries and waste. The energy sector emissions comprise of emissions due to fuel combustion in electricity generation, petroleum refining, transport, residential & commercial activities, agriculture & fisheries. It also includes the fugitive emissions due to coal mining, and handling of oil and natural gas. The energy sector emitted 1100.06 million tons of CO_2-eq in 2007, which is 58 percent of the total CO_2-eq emissions in that year.

Figure 2.4: GHG Emissions Across Sectors in 2007 (MT CO_2 equivalent)



Source: *INCCA assessment report*

The biggest contributors in the energy segment were electricity generation (719.31 MT, 38%) followed by transport sector (142.04 MT, 7%). In view of the fact that fertilizer, electricity generation and transport sector are major potential users of natural gas, it makes sense to focus on these three segments and assess the economic benefit of switching over to gas in these areas.

2.9: Cost Comparison of Fuels for the Power Sector

As we have seen earlier, the import price of coal is much less than of imported LNG. Demand side management is being undertaken to reduce the rate of growth of electricity demand. On the supply side, the question we have to examine for the power sector is whether it is beneficial to import LNG and supply it to power manufacturers?

Integrated Energy Policy 2006 has clearly recognized that coal will continue to be the pre-eminent fuel for electricity generation in the country in the years to come. If that be the case, then a look at various technology options for mitigating carbon emissions in coal based thermal power plants would be useful. The following extract from the *Interim Report of the Expert Group on Low Carbon Strategies for Inclusive Growth* explains technology options:

> *As of May 2010, all the coal based plants are based on sub-critical technology. The total generation from coal and lignite power plants was 461 billion kWh (at bus-bar) leading to CO_2 emissions of 508 million tons during 2008 – 09. Thus, the specific CO_2 emission of all existing coal and lignite power plants is 1.1 kg per net kWh for this period. Some of the old and less efficient coal power plants emit as high as 2 kg per kWh. However, the new 500 MW sub-critical power plants have net heat rates of 2450 kCal/kWh leading to specific emission of 0.93 kg per net kWh.*
>
> *There are several technology options to improve the combustion efficiency and lower CO_2 emissions. Super critical plants operate at higher temperatures leading to net heat rate of 2235 kCal per kWh and specific emission of 0.83 kg per net kWh. The technology is available globally and the cost is almost the same as sub-critical plants. As per recent guidelines and projections, super-critical power plants would account for 60 percent of thermal capacity to be built in 12th Plan and 100 percent in 13th Plan. Super critical units could thus contribute up to 50 GW by 2020.*
>
> *Ultra super critical power plants operate at still higher temperatures leading to net heat rate of 1986 kCal per kWh and specific CO_2 emissions of 0.74 kg per kWh. However, the technology is still not ready for large scale adoption. The high temperatures impose stringent materials challenges. It is unlikely that such plants would be installed before 2020.*
>
> *Integrated Coal Gasification Combined Cycle (IGCC) is another promising technology, which can attain higher efficiencies and lower CO_2 emissions and also produce synthetic chemical fuels such as diesel and hydrogen. However, initial estimates under Indian conditions of high ash coal show very high auxiliary power consumption and hence the overall efficiency is comparable with sub critical units at*

almost double the cost. While we should pursue research in IGCC, commercial deployment of IGCC is unlikely before 2020.

Carbon Capture and Sequestration (CCS) is being considered in several countries with large coal based power. However, there are several technical, economic and regulatory challenges in its role as a commercially viable low carbon option. The government should watch the development of this technology in USA and EU, where a number of commercial plants are under implementation/consideration and also undertake a few studies to examine the issues of potential and feasibility both technical and economic.

Gas based power is an attractive power generation option as the capital cost is low and the CO_2 emissions are only 0.4 kg per kWh. However, the cost of gas is usually much more than the cost of coal to generate one unit of electricity. Also there is considerable uncertainty about availability of gas for power given the limited reserves and also its alternate use in fertilizer production and other sectors. It is therefore unlikely that gas can contribute a large share of electricity generation. We have assumed that gas capacity could grow to 25,000 MW by 2020.

The potential of CCS has been discussed in detail in the World Energy Outlook 2010. It has been predicted that use of natural gas for power generation will grow initially in the USA on the back of cheap shale gas, but coal based generation will again start increasing after that with CCS technology. As the cost of carbon emissions goes up, almost 20 – 40% of total abatement efforts are predicted to come from CCS alone in the power and industry sectors.

The European Union and New Zealand have already introduced cap-and-trade schemes, which set caps on carbon dioxide emissions and provide for trading of CO_2 certificates, yielding prices of CO_2 for specific time periods. Current prices are around US$ 30 per tonne, and these are predicted by IEA to go up substantially in future. As per IEA estimates, they may range between US$ 42 and US$ 120 per tonne in 2035 (at 2009 prices) depending on the level of mitigation effort in the world, with the higher figure representing the figure that would be reached if global temperature rise is to be contained within 2 °C (the 450 scenario, wherein carbon dioxide concentration is contained within 450 ppm). Carbon prices are set by the most expensive abatement option, which is CCS for OECD countries in 2035. IEA estimates for carbon prices are reproduced in Table 2.10, where the 450 scenario is for restricting global temperature rise to 2 °C, Current Policies scenario is business as usual, and New Policies represents a scenario in between these two scenarios.

Table 2.10: CO_2 Prices by main region and scenario (US$ 2009 per tonne)

	Region	2009	2020	2030	2035
New Policies	European Union	22	38	46	50
	Japan	n.a.	20	40	50
	Other OECD	n.a.	-	40	50
Current Policies	European Union	22	30	37	42
450	OECD+	n.a.	45	105	120
	Other Major Economies	n.a.	-	63	90

Note: OECD+ includes all the OECD countries plus non-OECD EU countries. The CO_2 price in the European Union is assumed to converge with that in OECD+ by 2020 in the 450 Scenario. Other Major Economies comprise Brazil, China, the Middle East, Russia and South Africa.

Source: *World Energy Outlook 2010,* IEA

Carbon emissions of coal and gas based power plants have been analysed by several organizations. One of these studies[29] reports figures of 72.3 kg CO_2 equivalent per MMBTU of natural gas and 99.9 kg CO_2 equivalent per MMBTU for coal as life cycle emissions. Using IEA estimates of efficiency (49% or 6,988 BTU/kWh for new gas combined cycle plants and 38% or 8,970

[29] Fulton, Mark and Others (August 25, 2011) *Comparing Life-Cycle Greenhouse Gas Emissions From Natural Gas and Coal,* Worldwatch Institute, downloaded from the website http://www.worldwatch.org/system/files/pdf/Natural_Gas_LCA_Update_082511.pdf

BTU/kWh for new supercritical coal plants), the study concludes that these emissions amount to 582 kg of CO_2 equivalent per MWh for natural gas and 1,103 kg of CO_2 equivalent for coal. Using these figures and the estimates of CO_2 prices provided by IEA in the World Energy Outlook 2010, we can now estimate the cost of electricity generation including the import cost and environmental cost of natural gas and coal in the three policy scenarios projected by IEA. The results are shown in Table 2.11. Prices of natural gas have been taken to be the weighted average of Japanese imports, and the calorific value of coal has been assumed to be 6,000 Kcal/Kg.

Table 2.11: Cost comparison* of coal and natural gas power plants

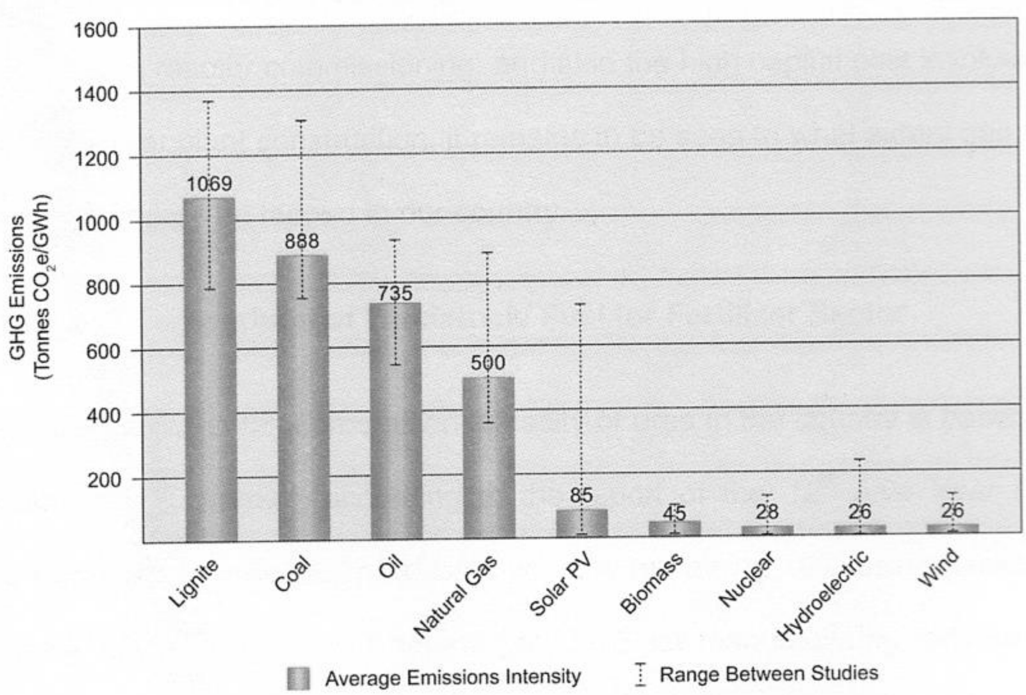
		Super-critical Coal Plant	Gas Combined Cycle Plant
Carbon emission	Kg CO_2 eq/ kWh	1103	582
Efficiency	%	38%	49%
Fuel needed	MMBTU/MWh	8.970	6.988
2009 costs per MWh	Fuel cost	33.66 @ 97.3 per tonne	65.69 @ 9.4 per MMBTU
	CO_2 cost @ US$ 30 per tonne	33.09	17.46
	Total cost US$/MWh	**66.75**	**83.15**
2035 cost per MWh, Current Policies Scenario	Fuel cost	43.33 @ 115 per tonne	97.13 @ 13.9 per MMBTU
	CO_2 cost @ US$ 42 per tonne	46.33	24.44
	Total cost US$/MWh	**89.66**	**121.57**
2035 cost per MWh, New Policies Scenario	Fuel cost	50.00 @ 106.5 per tonne	106.92 @ 15.3 per MMBTU
	CO_2 cost @ US$ 50 per tonne	55.15	29.10
	Total cost US$/MWh	**105.15**	**136.02**
2035 cost per MWh, 450 Scenario	Fuel cost	23.40 @ 62.10 per tonne	88.05 @ 12.6 per MMBTU
	CO_2 cost @ US$ 30 per tonne	99.27	52.38
	Total cost US$/MWh	**122.67**	**140.43**

*This comparison takes into account only the cost of importing fuel and the environmental cost of GHG emissions. Other factors like cost of capital etc. are not included. All calculations are at 2009 prices.

It can be seen that the cost of using gas for power generation is higher than the cost of using coal in 2009 and in all the three scenarios for which estimates have been made by the IEA. In the Indian context, this means that we should attempt to import coal and set up high efficiency thermal power plants with effective pollution control measures and divert natural gas to other uses in the national interest.

As far as nuclear energy is concerned, the cost of importing fuel is extremely low in energy equivalent terms. Nuclear energy is also a clean source of power from the environmental point of view. A comparison of the life-cycle emissions from coal, gas and nuclear electricity generation is shown in Figure 2.5 as evaluated by the World Nuclear Organization[30] on the basis of several publications in this regard.

Figure 2.5: Lifecycle GHG Emissions Intensity of Electricity Generation Methods



[30] World Nuclear Association Report (July 2011) *Comparison of Lifecycle Greenhouse Gas Emissions of Various Electricity Generation Sources*

COMPARISON OF A COAL PLANT AND A NUCLEAR PLANT

For a standard 1000 MW coal plant...

1. Amount of coal consumed per day (average load) = **7,800 tonnes**
2. Amount of coal consumed per year (average load) = **2.86 million tonnes**[xxi]
3. CO_2 generated from this coal per year = **8.37 million tonnes**[xxii]
4. Death attributable to this emission every year
   a. Due to air pollution (annually) = **362**[xxiii]
   b. Due to climate change mitigation (annually) = **39**[xxiv]
5. Economic loss due to climate change mitigation which would be needed to cope with the CO_2 effect (for this plant alone) = **$83.7 million every year**
6. Uranium (natural) needed to convert this coal plant to equivalent nuclear power plant = **about 52 tonnes**[xxv]
7. Thorium needed to convert this coal plant to equivalent nuclear power plant = **10.4 tonnes**
8. In effect, the savings if we used a nuclear plant (Uranium or Thorium) of the same size,
   a. Lives saved = **401 (annually)**
   b. Economic savings due less climate change impact (and hence reduced need for adaptation) = **$83.7 million every year**

It can be seen that apart from the low cost of fuel, greenhouse gas emission from nuclear power generation is also almost as low as renewable sources of energy. A comparison between coal and nuclear plants made by A.P.J Abdul Kalam and Srijan Pal Singh[31] is reproduced alongside, showing economic savings of US$ 83.7 million every year in a 1000 MW power plant based on nuclear energy as compared to coal. Given the fact that India has huge reserves of Thorium and the third phase of Indian nuclear energy programme focusses on Thorium based reactors, nuclear energy represents an attractive option for achieving energy security and self-sufficiency for India. However, in the aftermath of the Fukushima disaster and going by the extent of opposition witnessed to the Kudankulam reactor commissioning, and also the high capital cost involved in nuclear power plant construction, it remains to be seen to what extent can this source of energy be tapped in our country.

2.10: Cost Comparison of Feedstock/ Fuel for Fertilizer Sector

Almost 81% of the total production capacity of urea in the country is based on natural gas at present, according to the report of the *12th Five Year Plan Working Group on Fertilizer Industry*, with the remaining 19% being based on naphtha and fuel oil. Use of natural gas/ LNG for manufacturing fertilizers is

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[31] Kalam, A.P.J Abdul and Singh, Srijan Pal (November 6, 2011) *Nuclear power is our gateway to a prosperous future*, The Hindu

cleaner, cheaper and more energy efficient. One of the most important facts to be borne in mind while deciding priorities for gas allocation is that urea manufacture utilizes both, heat value and chemical composition of natural gas. Other industrial uses of natural gas including power generation utilize only the heat value of gas.

In view of the fact that using natural gas to substitute naphtha and fuel oil for manufacturing urea is both cheaper and cleaner in terms of environmental impact, there can be no doubt that fertilizer industry should be given top priority while allocating gas. Total requirement of gas has been projected to be more than 100 MMSCMD by the end of the 12th five year plan by the working group on fertilizer industry. The Working Group's report bemoans lack of availability of gas as a major constraint for expansion of fertilizer industry. It says that the policy of not allocating natural gas to new fertilizer units is a major hurdle for setting up new capacity in the sector. Options being explored by fertilizer units include coal based gas options like Syn Gas, Underground Coal Gasification and Coal Bed Methane apart from long term LNG import contracts and setting up plants in foreign countries where raw materials including natural gas are available.

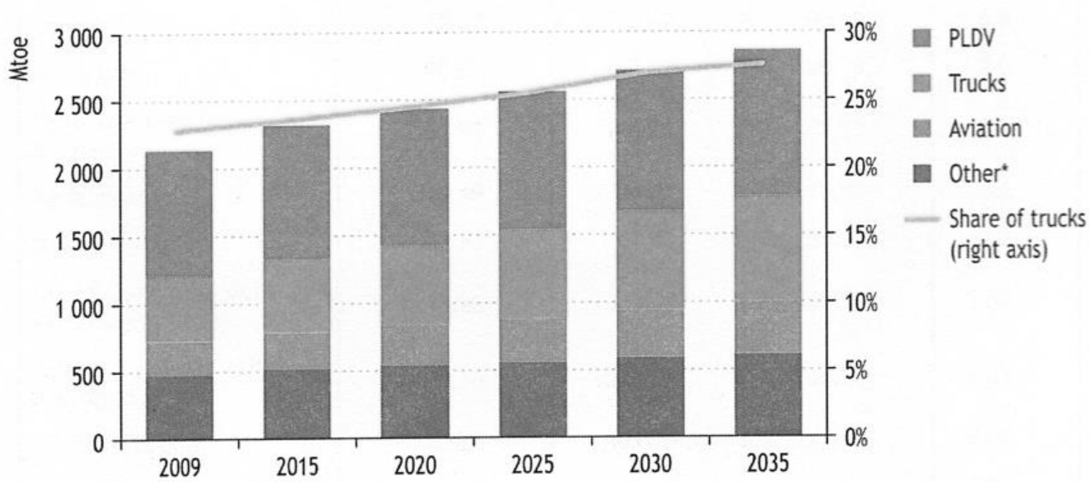
2.11: Cost Comparison of Fuels in the Transport Sector

Another major sector where natural gas can be used to substitute crude oil based products is the transport sector. According to a Central Pollution Control Board report[32], of all human activities, driving motor vehicles produces the most intensive CO_2 emissions and other toxic gases per capita. This may

[32] Central Pollution Control Board (March, 2010) *Status Of The Vehicular Pollution Control Programme In India*

suggest that non-motorized transport should be a priority for mankind, but the fact is that as standards of living in developing countries improve, more and more vehicles for passenger and freight transport are expected to crowd roads. The *World Energy Outlook 2010* also says that the Transport sector is expected to continue to drive the growth in global oil demand. Demand for road transport fuels is set to continue to expand rapidly in the emerging economies in line with rising incomes, which boost car ownership and usage as well as freight, and expanded road networks. Trucks and passenger light-duty vehicles (PLDVs) account for most of the increase in transport-related oil use. IEA predictions regarding share of different types of vehicles in the transport sector in the New Policies Scenario are reproduced in Figure 2.6.

Figure 2.6: Share of transport oil consumption by vehicle type under New Policies Scenario



*Includes other road, rail, pipelines, navigation and non-specified.

Source: *World Energy Outlook 2010,* IEA

IEA predictions indicate that the percentage share of trucks world-wide is expected to grow from around 22% at present to about 27% in 2035.

As we have seen earlier, transport sector is the second largest contributor to carbon emissions in India, accounting for 142.04 MT or almost 7% of the total CO_2 equivalent emissions of GHGs in the country in 2007. Amongst all modes of transport, road transport alone emitted 87 percent of the total GHG emissions or 123.55 million tons of CO_2-eq. Civil aviation emitted 7 percent of the total transport emissions and in absolute terms, 10.21 million tons of CO_2-eq. Railways emitted 6.84 million tons of CO_2-eq or 5 percent of the total transport emissions (excluding electricity consumed for traction).

Table 2.12: Trends of CO_2 –eq and Emission Intensities in India

(1994 and 2007 figures in Million Tonnes of CO_2 –eq)

Sector	1994	2007	Change	CAGR
Electricity	355.04	719.31	364.27	5.6
Transport	80.29	142.04	61.75	4.5
Residential	78.9	137.84	58.94	4.4
Other Energy	78.92	100.87	21.96	1.9
Cement	60.87	129.92	69.05	6.0
Iron & steel	90.53	117.32	26.79	2.0
Other manufacturing Industries	101.98	165.31	63.33	3.8
Agriculture	344.49	334.41	-10.08	-0.2
Waste	23.23	57.73	34.50	7.3
Total CO_2-eq emissions excluding LULUCF	1214.25	1904.75	690.50	3.52
Total excluding LULUCF and Agriculture	869.76	1570.34	700.58	4.65
GDP (Rs. Billion)*	12,825	30,619	17,794	6.92
Emission intensity**	66.8	56.2	10.2	-1.34

**@1999-00 prices (Central Statistical Commission, India)*

***in grams of CO_2 equivalents per Rs. of GDP*

Source: Planning Commission, GoI (May 2011) Low Carbon Strategies for Inclusive Growth: An Interim Report.

Table 2.12 shows the trend of sector-wise growth of carbon emissions from 1994 to 2007 as analysed by the Expert Group for Low Carbon Strategies for

Inclusive Growth. The analysis indicates that transport sector is also the *second fastest growing* contributor with a CAGR of 4.5%, after electricity generation which has a CAGR of 5.4%.

Natural gas is a clean fuel which has no solid particles and sulphur. Using CNG or LNG for road transport effectively cuts down Particulate Matter (PM) and SO2[33] emissions. Apart from this, natural gas has lower carbon intensity as compared to petrol and diesel and therefore helps in reducing GHG emissions also. The city of New Delhi has witnessed a remarkable improvement in air quality after the Supreme Court of India enforced conversion of all public transport to CNG and is a successful case study. A quantitative comparison of emissions from petrol and CNG is given in Table 2.13, from the CPCB Report on Status of Vehicular Pollution Control Programme in India.

Table 2.13: Weighted Emissions from Petrol and Alternative Fuels (Unit : Moles of CO_2 -eq per Vehicle Mile Travelled)

Greenhouse Gas	Petrol	Compressed Natural Gas	Liquefied Petroleum Gas
Carbon Dioxide (CO_2)	7.90	5.64	6.00
Methane (CH_4)	0.22	0.91	0.17
Nitrous Oxide (N_2O)	0.54	0.54	0.54
Nitrogen Oxide (NO_x)	1.06	0.97	0.92
Carbon Monoxide (CO)	0.99	0.97	0.96
Total	10.71	9.03	8.61

Source: Central Pollution Control Board (March, 2010) *Status Of The Vehicular Pollution Control Programme In India.*

Improvements in vehicular emission levels are being made by progressively improving pollution norms for vehicles in India. Metros in the country are following Euro IV norms. It needs to be examined how CNG driven vehicles

[33] SO_2 = Sulphur Dioxide, a gas which is a major source of local pollution

compare with petrol and diesel vehicles following stringent emission norms. In this regard, a study was carried out to evaluate the emissions from Indian CNG buses in comparison with diesel bus with Euro II, III & IV emission norms. The test results are given in Table 2.14. Results show that a stoichiometric CNG bus with a three-way catalyst is far ahead of a comparable diesel bus. It meets the Euro-IV norms for both PM and NOx. Even CO emissions are better than Euro-II norms.

Table 2.14: Emission comparison of CNG with Euro norms

Euro Norms	Emissions in g/ KWh			
	HC	NO_x	CO[34]	PM
Euro II	1.1	7	4.0	0.15
Euro III	0.66	5.0	2.10	0.10
Euro IV	0.46	3.5	1.50	0.02
Indian CNG Bus	0.04	3.24	3.12	0.014

Source: R.Ramakrishnan 2001, *CNG -The clean and cost effective fuel for Delhi vehicles*, Mimeo. HC = Hydrocarbons, NO_x = Oxides of Nitrogen, CO = Carbon Monoxide, PM = Particulate Matter

It is clear that CNG offers clear advantages over petrol and diesel in reducing GHG emissions (HC in Table 2.14) as well as SO2 and PM emissions. A question arises at this point regarding the segments of road transport traffic that must become a priority for conversion to CNG/ LNG in order to reduce harmful environmental impact.

Over 72% of the total vehicles registered in India are two wheelers, which are not easily amenable to being converted to CNG. The Annual Report of the Ministry of Road Transport and Highways provides details of all registered vehicles which are shown in Table 2.15.

[34] Carbon Monoxide molecules are short-lived in the atmosphere due to their reactivity and solubility. They do not contribute significantly to greenhouse effect.

Table 2.15 : Total Registered Motor Vehicles in India (thousands)

Year	All Vehicles	Two Wheelers	Cars, Jeeps and Taxis	Buses	Goods Vehicle	Others*
2001	54,991	38,556	7,058	634	2,948	5,795
2002	58,924	41,581	7,613	635	2,974	6,121
2003	67,007	47,519	8,599	721	3,492	6,676
2004	72,718	51,922	9,451	768	3,749	6,828
2005	81,501	58,799	10,320	892	4,031	7,457
2006	89,618	64,743	11,526	992	4,436	7,921
2007	96,707	69,129	12,649	1,350	5,119	8,460
2008	1,05,353	75,336	13,950	1,427	5,601	6,039
2009	1,14,951	82,402	15,313	1,486	6,041	9,710

*Others include tractors, trailers, three wheelers, LMV and other miscellaneous vehicles. Source: Ministry of Road Transport & Highways, *Annual Report 2012*

Although the number of two wheelers is the largest amongst all segments, they are not the biggest contributors to vehicular emissions. The CPCB Report cited earlier provides some data about segment-wise emissions for the year 2003-04. This data is reproduced in Table 2.16.

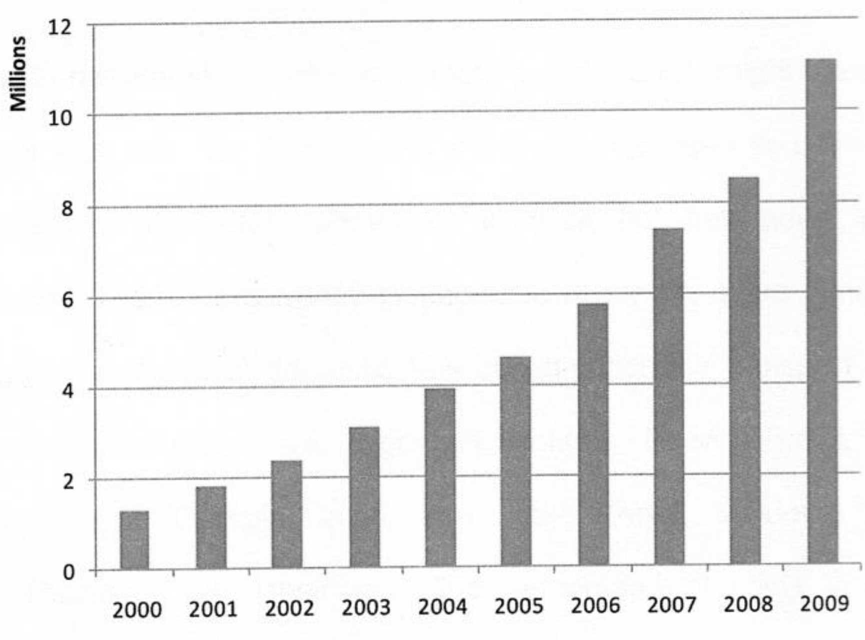
Table 2.16 : Emissions from different vehicle type of India (1000 Tonnes)

Categories	CO_2	CO	NO_x	CH_4	SO_2	PM	HC
Bus	28748.16	207.26	679.73	5.02	79.24	31.36	51.72
Omni buses	8508.42	60.94	200.53	1.49	23.45	9.28	15.11
Two wheelers	8701.08	719.64	62.15	58.88	4.25	16.36	464.49
Light motor vehicles (Passenger)	4378.10	370.29	92.93	13.07	2.11	14.52	10.16
Cars and jeeps	23901.22	212.30	22.14	18.17	5.67	3.22	28.01
Taxi	2367.08	10.23	5.68	0.11	117.05	0.80	1.48
Trucks and lorries	70288.92	491.15	859.51	12.28	193.73	38.20	118.69
Light motor vehicles(Goods)	44654.58	442.04	110.94	7.80	123.08	17.33	12.13
Trailers and tractors	46563.85	460.94	115.69	8.13	128.34	18.08	12.65
Others	5705.22	57.41	64.54	1.83	32.19	3.98	8.96

Source: Central Pollution Control Board (March, 2010) *Status Of The Vehicular Pollution Control Programme In India.*

Buses and Trucks contribute almost 40% of the total CO_2 emissions although their number is not large. They emerge as the natural choice for retrofitting and OEM adaptation for CNG/ LNG. Although use of CNG for vehicular propulsion is not new, it has begun showing a strong growth in the past one decade according to an IEA study[35], from only around a million vehicles to about 11 million vehicles currently estimated. The total number of natural gas vehicles world-wide is shown in Figure 2.7.

Figure 2.7: Total Number of NG Vehicles in the World



Source: NGV Global, NGV Communications Group.

India is already one of the countries that have taken a lead in propagating CNG vehicles, along with Pakistan, Iran and China. Growth of NG vehicles in these countries as reported in the same IEA publication is shown in Figure 2.8, which shows a strong growth performance in India.

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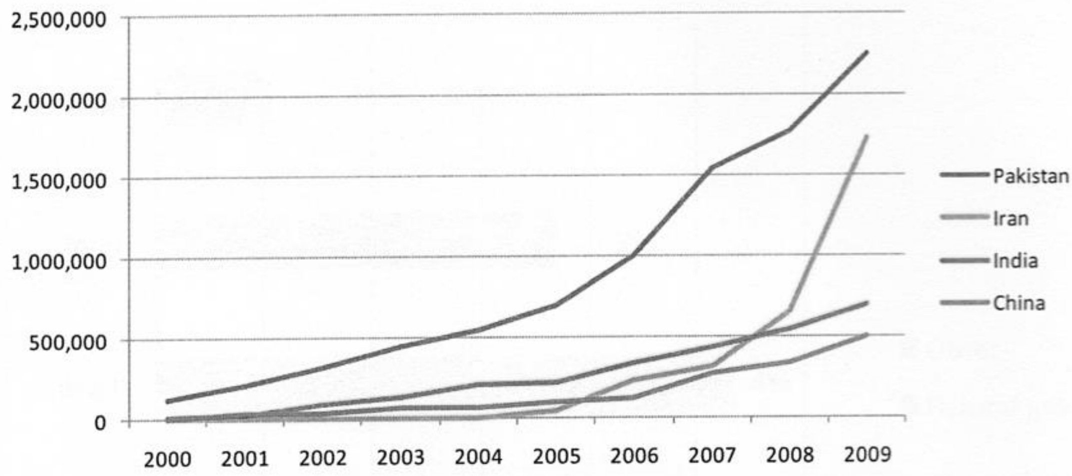
[35] Nijboer, M. (2010) *The Contribution of Natural Gas Vehicles to Sustainable Transport* International Energy Agency

Figure 2.8: Growth of NG vehicles in select countries

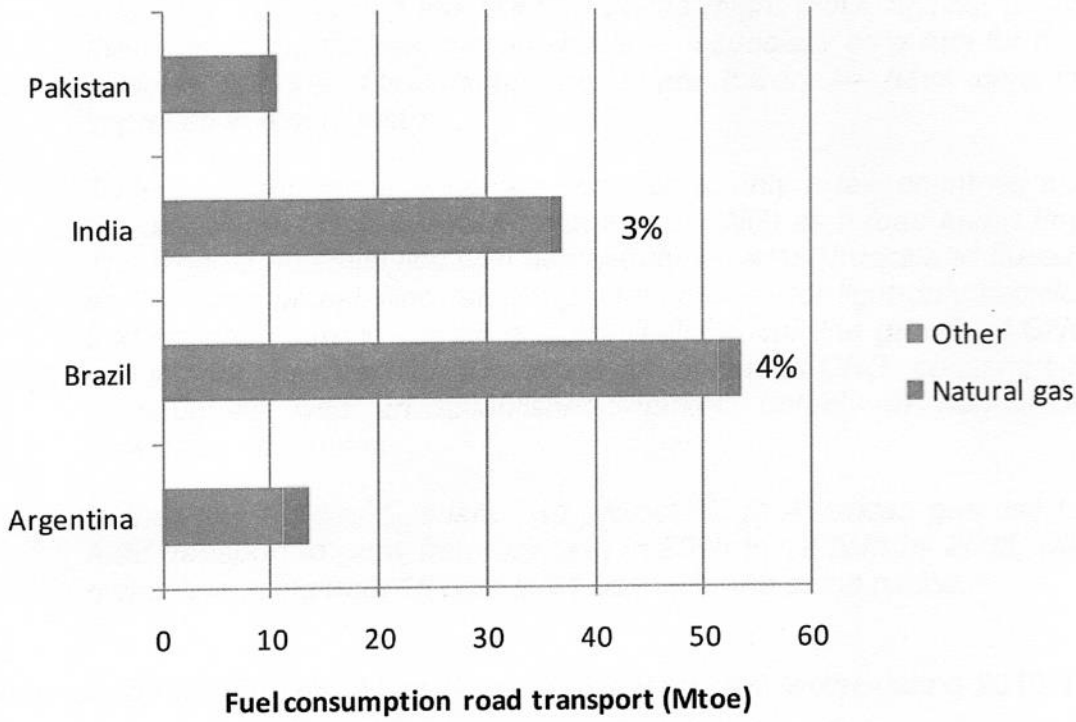


Source: NGV Global, NGV Communications Group.

This growth has translated into consumption of CNG for freight transport and passenger buses in the Asia Pacific region, as opposed to Latin America which leads in the total number of vehicles but has quite low CNG consumption. There are currently 17 countries where the share of natural gas consumption in the total domestic fuel consumption for transport is 1% or greater. These countries are: Argentina, Belarus, Bolivia, Brazil, Bulgaria, Colombia, Egypt, Georgia, India, Iran, Italy, Korea, Moldova, Pakistan, Russia, Thailand and Uzbekistan. The percentage of CNG in the total transport fuel consumption is shown in Figure 2.9 for some selected countries out of these. For India, the figure currently stands at 3%, which is next to Brazil which relies on CNG for about 4% of the total transport fuel. The total quantum of fuel used for transport in the country stands at about 37 MToe[36], which is next to Brazil which spends about 54 MToe fuel on transport.

[36] MToe = Million Tonnes of Oil Equivalent

Figure 2.9: Share of CNG in transport fuel in selected countries (MToe)



The *World Energy Outlook 2010* has discussed the question of substituting oil by CNG for the transport sector in detail. According to the IEA, gas demand is set to expand rapidly in two emerging sectors: as feedstock for gas-to-liquids plants and as a road-transport fuel. The primary driver for this phenomenon is said to be the low price of natural gas as compared to crude oil, a factor that is applicable to India also in some measure. Some relevant excerpts from *World Energy Outlook 2010* are given below:

> *The recent fall in gas prices relative to oil prices, especially in North America, has led to greater interest in promoting compressed natural gas (CNG) as a road fuel for fleet vehicles, including lorries, trucks and buses, as a way of reducing costs, improving energy security and reducing emissions of local pollutants and, to a limited degree, greenhouse gases. CNG already makes a significant contribution to meeting road-transport fuel needs in several countries, notably in Pakistan and Argentina, but in most major economies CNG use is marginal. This could change, especially if gas prices remain low relative to oil prices. However, there are major*

barriers to the expansion of natural gas use, including the cost and practicalities of on-board fuel storage, the cost of installing the infrastructure for delivering and distributing the fuel at existing refuelling stations and the risk that prices might move against gas in the future. Nonetheless, the prospects — especially as a fuel for fleet vehicles (as the infrastructure costs are lower) — have certainly improved in recent years.

Today, natural gas vehicles are common in only a few countries and the global use of compressed natural gas (CNG) as a road fuel is tiny. The biggest potential lies with heavy-duty vehicles (trucks and buses), as the costs of installing refuelling infrastructure for light-duty vehicles and adapting cars to run on gas are likely to limit the growth of CNG use in light vehicles. There is scope for increased CNG consumption in countries with an established market, notably in non-OECD Asia and Latin America.

In the New Policies Scenario, we project North American gas use for road transport to grow from 0.9 bcm in 2008 to 12 bcm by 2035, with global use rising from 18 bcm to 61 bcm over the same period.

India consumed 58.765 MT of diesel ~~in the transport sector~~ during 2010-11 according to the statistics published by Ministry of Petroleum and Natural Gas. Further breakup of this total consumption as provided in the *Report of The Expert Group on A Viable and Sustainable System of Pricing of Petroleum Products* headed by Dr. Kirit Parikh is shown in Figure 2.10.

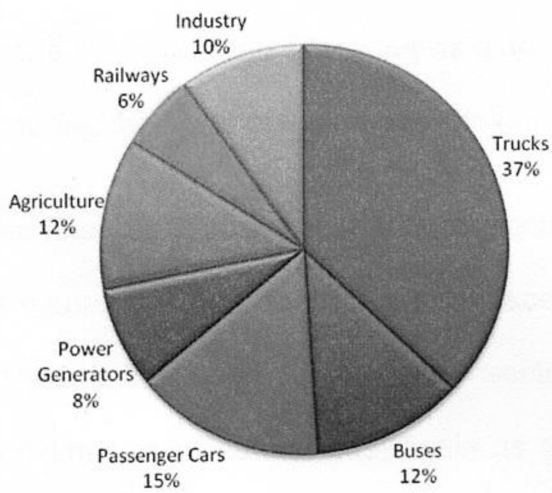


Figure 2.10: User-wise percentage share in total diesel consumption, 2008-09

Trucks and Buses together account for 49% of the total usage, which would amount to 28.79 MT of diesel in 2010-11. This corresponds to 32 billion cubic metres of natural gas, or 87.64 MMSCMD. There is thus a huge opportunity for India as a nation to switch over from diesel to CNG for road freight and passenger transport, and the transport sector should become a high priority instead of power sector for allocation of natural gas and channelizing of funds for infrastructure construction.

The comparison of costs made in this chapter focusses only on the foreign exchange expenditure incurred on importing fuel and the environmental impact of various fuels. Fixed costs and other expenses in domestic resources have deliberately not been added to the criterion for comparison, since they would tilt the balance away from renewable and clean sources of energy towards sources which can be used at a lower capital cost today. Going for low capital cost solutions may seem to be a good option in the short term, but would lead to a gradually worsening balance of payments situation in future in view of India's high dependence on energy imports and may lead to high levels of carbon emissions, adding costs of climate change mitigation at the national level. The analysis is to determine the best choice of fuels for lowering the costs of import and climate change impact.

Our analysis indicates that fertilizer sector is the most preferred sector for use of natural gas as a feedstock to replace crude oil based feed-stocks such as naphtha. Transport and industry sectors emerge as the next priority for consumption of natural gas, again as a substitute for crude oil based fuels. Power sector has to continue to depend on coal as the major fuel, while also focussing on nuclear energy and renewable sources of energy to the extent possible. Use of natural gas as a fuel for power generation has to assume lower priority than the fertilizer, transport and industry sectors.