Questionable Economics of LNG-based Power Generation: Need for Rigorous Analysis

By Amol Phadke, (Prayas Energy Group)
Prayas, Pune, Maharashtra, **India**

Abstract

Though, coal-based generation continues to be the mainstay of power generation in India, large scale capacity addition based on oil and / or gas has been preferred in the last decade. Now this shift is further consolidating on liquefied natural gas (LNG)-based capacity addition. The main reasons for this shift are said to be favorable economics of LNG and the problems related to Indian coal supply and its quality. But little reliable information is available in the public domain about the cost of LNG-based generation, while many experts have expressed concern over viability of LNG-based generation. Problems related to coal that are sited as excuses for this shift to LNG are not new and inaction on the part of authorities has been the primary reason for their continuation.

In this context, the paper compares LNG-based generation with its competing options, viz., domestic and imported coal-based generation. The paper first discusses the scale and the revels process of shift towards oil/gas-based generation. This is followed by economic comparison of LNG-based generation with its competing options. Major cost components such as capital cost of projects, fuel cost, and the transmission cost are estimated on the basis of available data. The past and future trends of these costs are also discussed. A base-case scenario shows the total cost of electricity at the load center for different options for base-load generation. Considering the cost trends, a sensitivity analysis is carried out to see the effect of variations in major cost components on the economics of the competing options. The sensitivity analysis shows that, in most of the cases, coal-based generation is cheaper than LNG-based generation. At the prevailing prices, the annual financial loss due to choice of a 2,000 MW LNG-based plant instead of a coal-based plant is in the range of Rs.1, 000 to 1,800 Crores[1]

The paper concludes that there is little economic justification for LNG-based capacity addition on a large scale, especially in a country like India that has huge coal reserves. The paper also discusses in brief the related issues of cost stability, foreign exchange outgo, and environmental impacts. Apart from the economic disadvantage of LNG-based generation, other factors like, price stability, foreign exchange outgo, and risk of import dependence of strategic sector also cast serious doubt over the policy of large-scale shift to LNG-based power generation.

1 Review of the Debate

In 1991, During the first phase of reforms and liberalization in the Power Sector, Independent Power Producers (IPP) were invited to add generation capacity. This was also accompanied with a liberal attitude towards import of fuels. For example, till 1999,

---

[1] *1 crore = 10 million*

about 2,746 MW of imported oil/gas-based IPP plants have been commissioned and 3,343 MW plants are under construction. Compared to this, only 411 MW IPP plants-based on coal are commissioned and another 500 MW are under construction (MOP 1999 b). This change in fuel policy now seems to be consolidating with a focus on imported LNG-based power generation. A study by a high-level committee appointed by Prime Minister's Office (PMO) concludes that LNG-based capacity addition of 23,000 to 30,000 MW by 2007 would be economical (PMO 1999).

Enron Corporation's Dabhol project, that achieved financial closure in May 1999, would be the first LNG-based power project in the country. The project is expected to start using LNG by early 2002. Apart from a facility with the capacity of 4 MTPA (Million Tons Per Annum) for LNG import for this 2000 MW project, four additional LNG import facilities of 5 MTPA each are being planned in the state of Gujrat alone. A sizable component of LNG is expected to be used for power generation. The Indian embassy estimates that in next decade or so India will import LNG to the tune of 35 MTPA (Embassy of India Doha-Quatar, 2000). This implies a foreign exchange outgo of $ 7 billion (Rs. 31,500 crores) per year Crores/year (at LNG price of $ 4.5 /MMBTu). This is comparable to India's total oil import bill for the year 1999. Even if all the planed LNG terminals do not come on line, this is a clear indictor of rapid increase in LNG use for power generation.

The emphasis on LNG is often said to be due to its (expected) economic advantage over coal-based generation and also due to the problems related to availability and quality of India coal. The LNG is also seen as a cleaner fuel. But there are contradictory viewpoints about the economics of LNG as well as rationality of this fuel shift. The following section takes an overview of coal-related problems and the debate on economics of LNG.

Coal Related Problems

Coal-based generation is the mainstay of power sector in India with over 60% of the generation capacity being coal-thermal. Even though India has coal reserves sufficient to last for two centuries, the problems relating to rate of production, transportation and quality of coal have resulted in substantial difficulties in expanding coal-based generation.[2] In addition to this, even the performance of existing coal plants is affected due to shortage of supply and high ash content. In the Maharashtra state, Maharashtra State electricity Board's (MSEB) coal plants are reported to have de-rated by 11% (by 670 MW) on account of poor quality of coal (MSEB 2000 pp. 193).

But problems relating to coal are not new. The 'National Power Plan Generation Expansion' prepared by the Central Electricity Authority (CEA) nearly two decades ago

---

[2] *The coal reserves as on 1-9-1997 are estimated at 204 Billion Ton. Of these, cocking coal reserves are about 15% and non-coking coal are 85%. The category wise break-up is; 35% proved, 44% indicated, and 21% are categorized as implied reserves. Depth wise, 67% of the reserves are distributed in the range of 0-300m deep, 26% are in the range of 300-600 m, and the remaining are in the range of 600-1200 meters (GOI1997 pp.). The estimated coal production is about 346 million-ton for 2000-2001(GOI 1997). It is estimated that Indian coal reserves can satisfy the demand for over two centuries.*

points out problems relating to coal, such as poor and decreasing quality of coal, production shortfalls, and transportation bottlenecks[3] (CEA. 1981 pp. 115,121-123). This plan suggested urgent steps such as speedy completion of existing mining projects, taking up additional mining projects, developing a long-term plan for coal mining, coal benefaction processes to improve quality of coal, and consideration of alternate transportation modes (i.e., coastal shipping, slurry pipelines, among others). Unfortunately, sufficient actions have not been taken to overcome these problems and these problems have only intensified. The 9th Five-Year Plan, prepared by the Planning Commission again discusses these issues and moreover suggests very similar remedial measures (GOI 1997 pp. 31-42). In short, lack of sufficient action on this front is the main barrier for better utilization of the vast coal reserves in the country.

Economics of LNG-based Power Generation

In 1988, Bureau of Industrial Costs and Prices (BICP), Ministry of Industry (MOI) published a study titled "Towards a New Energy Policy" (BICP, MOI 1988). It was one of the first studies challenging the role of coal as the primary fuel for power generation in the country. It argued that imported oil would be a cheaper option under certain conditions. This study worked out distance of the load center from coal mines and from the sea shore for which power generation based on imported oil would be more economical than use of Indian coal. This study concluded that, for the load centers located near the shore and at a distance of more than 400 to 1,000 km from coal mines, imported oil would be a cheaper option. The paper did not analyze the option of importing coal. This study did not analyze the option of importing coal. It generated substantial debate and led to serious thinking about using imported hydro carbon fuels for power generation, which earlier was a non-option owing to the restrictions on foreign exchange and the policy of self-reliance. However, the conclusions of the BICP study are no longer valid because the prices and dollar-to-rupee exchange rates have both changed drastically from the values used in the study (oil price was assumed to be in the range $16 to 20 / Barrel, and exchange rate at $1 = Rs 13).

During mid 1990s, the Government of India (GOI) sanctioned oil import for over 10,000 MW of short gestation power plants, in an attempt to achieve rapid capacity addition. But these projects are now seen as prohibitively costly and only few of these projects have come on line. As mentioned earlier, now the focus has shifted from import of oil (i.e. naphtha) to import of LNG.

But little reliable information is available in public domain about the key aspect, the cost of LNG and the resulting cost of electricity that would justify use of LNG for power generation. For example, though Dabhol plant is expected to run on LNG from 2001, information about salient aspects of the LNG contract (such as the LNG price, its linkage with oil price, and take-or-pay clause) is not available in public domain. As LNG price is linked to oil price, there is an element of large uncertainty introduced. The fuel

---

[3] *The study reported that the average calorific value of coal supplied to the power plants declined from 5900 Kcal/Kg in 1960-61 to 4,300 in 1981(CEA 1981pp. 123). Presently the average calorific value is in the range of 3,400-3,800Kcal/Kg.*

policy document by a high-level committee of Prime Minister's Office, assumes the price of imported LNG at $3 to 4 /MMBTu, while arguing that LNG-based capacity addition of 23,000 to 30,000 MW by 2007 would be economical (PMO 1999). On the other hand, Mr. R.V. Shahi, Chairman and Managing Director of the largest private utility in India (Bombay Suburban Electric Supply), claims that LNG price was expected to be $ 4/MMBTu when crude oil price was $18/Barrel but now the "(with) crude oil price (of) almost $ 28 to 30 per barrel, might mean … the fuel cost itself (excluding the customs duty) would be more than Rs. 2 / kWh". (Power Line 2000 pp.41). This indicates burner tip price of imported gas of around $6 /MMBTu. This price is substantially higher than what has been assumed in the earlier study.

The emphasis on the use of LNG for power generation is growing while the knowledgeable individuals and institutions have been expressing caution about it. While rejecting the request to support Enron's Dabhol power plant, the World Bank pointed out that the LNG is not the least cost option for capacity addition for a country like India (World Bank, 1992). It needs to be noted that the oil price was very low when this warning was given. In the above-mentioned interview, Mr. Shahi also argues against increased reliance on LNG-based power plants. In addition to such adverse comments on economics of LNG, the foreign exchange implications of LNG import are also large. In the 4th National Power Plan document the CEA says "The present action of restricting the liquid petroleum import due to the perceived foreign exchange constraint and yet planning to import LNG without having a clear idea of overall capability to bear foreign exchange outgo, thus needs some thinking" (CEA 1997 pp. 11). Thus there is no unanimity over the economic advantage in use of LNG.

Considering the enormous implications of increased reliance on LNG for the foreign exchange balance, and national security issues, in addition to those for the power tariff, it is extremely important to have in-depth analysis and public debate before committing to such a shift. On this background, this paper compares the economics of LNG-based power with the following two competing options: (a) pit-head power plants based on Indian coal and (b) on-shore power plants based on imported coal. Section two discusses the methodology used for this comparison. Section Three provides the information about the capital cost and fuel cost of different options. The fourth section presents the results of the 'base-case' scenario comparing the economics of two competing options to LNG. In Section Five a sensitivity analysis evaluating impact of change in I) capital cost and ii) fuel costs on the economics of different options is carried out. The last section presents the conclusions.

2. Methodology

The LNG import terminals are planned on the west and east cost of peninsular India, where the power plants are expected to be located. Most of the load centers are close to these terminals. The paper compares the options of pit-head power plants based on Indian coal and on-shore power plants based on imported coal with the power plants based on imported LNG for base-load generation. It is assumed that high-voltage transmission lines will evacuate the power from pit-head plants (based on Indian coal) that are located away from the load center at a distance of 2000 km. This assumption would cover most situations in the country and hence is justified for calculating the associated transmission costs. The LNG plants and the plants based on imported coal are assumed to be on the seashore close to the load center (Typically within 200 km from load center).

The cost of power from any plant has three major components: (a) capacity cost of plant, (b) the cost of transmission, including the losses in transmission, and (c) the fuel cost. The total of these costs largely determines the resultant cost of electricity that is used to compare the above-mentioned options for power generation.

The capacity cost is the sum of annualized capital cost and the operation and maintenance (O&M) cost. The annualized capital cost is in turn a function of capital cost, life of the plant (assumed), and the discount rate. The annualized capital cost is divided by the total net output (in kWh) of the plant in one year to arrive at capacity cost per unit of electricity. The higher availability and lower auxiliary consumption of the LNG power plants, compared to the coal plants has been taken into account. Considering the capital-shortage situation in India, a discount rate of 15% has been used for the calculations.

For arriving at transmission cost per kWh from the capital cost of the associated transmission infrastructure, a similar methodology is adopted. The cost associated with technical losses during transmission of power is added to this.

Fuel cost per unit of electricity is worked out considering the cost of fuel and the efficiency of the generating plant. In the case of imported fuels, a foreign exchange premium of 15% has been added.[4]

Section three discusses the basis for the values used for above parameters. It also presents the historical trends in fuel costs and the variation in capital cost of plants. Considering the likely best case favoring LNG (i.e. low cost of LNG) a 'base scenario' has been worked out.

Though cost of all three fuels (LNG, imported coal and Indian coal) are subject to a wide variation, considering the past trends, a likely range of their costs has been taken for carrying out a sensitivity analysis. The capital cost data of plants commissioned and being planned in India also shows a wide variation. Hence, a sensitivity analysis has been carried out to judge the robustness of results arrived in the base case.

3. Cost Components and Related Factors

As mentioned in Section 2, the costs of supply of three generation options depend upon their various components such as capacity cost, transmission cost, the fuel costs, as well

[4] The customs duty on imported coal has recently been hiked to 32% while that for LNG is 5% .The reason for high import duty on coal is given as protection of the domestic coal industry. For comparison on level playing field, this analysis takes foreign exchange premium of 15% for both the imported fuels.

as the operating parameters of the power plant. This section discusses the available information on these components of costs.

3.1 Power Plant Parameters

The power plant life, availability, auxiliary consumption, heat rate (or efficiency), and O&M costs are the key plant parameters required for our analysis. Assuming that the plant runs as a base load plant, as is planned for most projects, the net plant output (kWh/kW/year) depends on plant availability and auxiliary consumption. The values considered for the above parameters are tabulated below.

Table 1: Assumptions of Main Power Plant Parameters for LNG (Combined Cycle Gas Turbine (CCGT)) and Coal-based Power Plants

No.		LNG, CCGT	Coal Plant
1	Plant Availability (%)	90	80
2	Auxiliary consumption (%)	3	8.5
3	Life (years)	30	30
4	Gross Efficiency (%)	46	37
5	O&M Costs (% capital cost /yr)	2	2

Notes:
1. Plant availability and auxiliary consumption as given in Ministry of Power, Government of India (MOP GOI) tariff notifications (MOP GOI 1992). It allows an auxiliary consumption of 3% for CCGT (oil /gas-based) power plants and 9% for coal-based plants. The auxiliary consumption of coal plants is taken as 8.5% based on the achieved performance of several plants.
2. Efficiency of the power plants: This is a crucial issue, but several sources indicate a wide range of values. The gross efficiency, i.e. at generator bus of CCGT and coal plants are indicated in the range of 43 to 47 and 35 to 38 respectively (MOP tariff guideline(MOP 1992), EPRI 1989). This difference in efficiency for plants using the same fuel can be explained by the variation in plant size, technology, site conditions, and fuel quality.
3. O&M costs are taken at 2% of capital cost, the norm allowed by MOP for tariff notification (MOP 1992).

3.2 Capital Cost

Capital cost depends on issues such as site conditions, associated infrastructure development needs (such as roads and ports), financing costs, and construction period. The capital cost of power projects in India is considered to be higher than the international norms.[5] It is one of the most debated issues in the Indian power sector.

[5] Initial IPPs were negotiated on cost plus basis without incentive for cost reduction. Recently, some contracts have been negotiated through competitive bidding for tariff. But their capital cost are not known. Such projects are few and the non-competitively bid projects are expected to dominate in the near future.

For the purpose of this paper, three different sources of capital cost of power projects in India are considered. Table 2 summarizes the comparison of these capital costs.

Table 2: Capital Cost of Ongoing / Approved Power Plants in India (Rs Crores/MW)

	Source 1	Source 2	Source 3
Avg. cost of CCGT plant	3.36	4.28	3.45
Avg. cost of coal-based plant	4.47	5.1	4.5
Cost of coal plant as % of CCGT	133%	119%	130%

Notes:
Source 1: Ministry of Power, list of Private projects with techno-economic clearance. Data for 9,781 MW of gas-based;16,679 MW of coal-based projects respectively (MOP 1999a).
Source 2:- Project Finance Ware 2000. Data for 11,537MW of CCGT and 23,087 MW of Coal-based power projects proposed in India (Project Finance Ware 2000).
Source 3:- Fuel Map for India, CEA, 1998. (CEA1998 pp. 7).

As seen in the above table, capital cost of coal projects is 20% to 33% higher than that of CCGT project. This analysis considers the capital cost of CCGT and Coal plants in India as Rs. 3.5 Cr/MW and Rs. 4.5 Cr/MW respectively (i.e. Coal plant to cost 30% higher than CCGT plant).

3.3 Transmission Cost

As mentioned in Section 2, transmission cost consists of transmission infrastructure cost and the cost associated with technical losses. Both of these costs depend upon the transmission distance as well as the transmission technology (DC or AC and the voltage level). Infrastructure cost consists of costs of transmission lines and towers (which is directly proportional to the distance) and the substation cost (which is not directly linked to transmission distance). A transmission distance of 2,000 km for domestic coal plants and 200 km for plants based on imported coal and CCGT has been considered.

Transmission losses are taken as 4% and 1% for transmission distance of 2000 km and 200 km respectively. For transmission over large distances such as 2000 km the suitable technologies are 765 kV AC or 500 kV DC. For short distances (such as 200km), a 400-kVAC technology is considered appropriate. The total transmission cost including the technical losses is reported to be in the range of Rs. 0.4 to 0.55/kWh for 2,000 km and Rs. 0.08 to 0.12/kWh for 200 km (WCD 1999 pp. A 13, TERI 97 pp. 82, CEA 1998 pp. 5). Here, the transmission costs are considered as Rs. 0.55/kWh for 2000 km and Rs

---

The capital cost of Enron's Dabhol project is US $ 920 /kW (excluding the LNG facility) where as another CCGT project in Bangladesh is expected to costs only US $ 500 /kW. (Report of Enron Power Purchase Agreement Re-negotiation Committee1995, World Bank press release (World Bank 2000))

0.1/kWh for 200 km. A recent study by Power Grid Corporation of India indicates similar costs for HVDC transmission of bulk power for large distances (L .S. Jha 1999).

3.4 Fuel Costs

This section describes fuel prices and their trends in the past decade. For imported coal, there exists a spot market and price trends can be found. For Indian coal the price has been de-controlled only recently. The past prices and expected future price is discussed. The LNG prices are the most difficult to obtain, as most LNG contracts are not available in public domain. Estimate of LNG prices based on the information available in public domain is used here.

3.4.1 LNG Cost

The natural gas price at the power station consists of several components. The cost of LNG, LNG shipping costs, taxes and duties, and regasification cost. LNG contracts are usually long-term contracts, LNG price being either fixed or linked to oil price indices. In case of linkage with the oil price, some-times the possible fluctuations are limited by adding ceiling and/or floor prices Most contracts also include "take or pay" clauses. Shipping and re-gasification costs are usually fixed. The estimation of LNG price is based on following information available in the public domain.

a) Some news reports indicate that the companies marketing natural gas (regasified LNG) are quoting a price that is 10-15% lower than price of oil like Naphtha / Distillate. This, at today's cost, amount to $ 5.8 /MMBTu.
b) A study by Tata Energy Research Institute (TERI) argues that the LNG cost generally has a 10 to 15% premium compared to price of Brent crude oil (in $/MMBTu). With the oil price range of $ 16 to 18/barrel, the estimated price of LNG is $ 3.1 to 3.6 /MMBTu in India[6] (TERI 1997 pp. 21,22).
c) As per the earlier quoted interview of Mr. R. V. Shahi, LNG price was $ 4 /MMBTu when oil price was $ 18/barrel and with present oil price of $ 30/ barrel the gas price (including cost of regasification) is expected to be around $6/MMBTu (Powerline 2000).
d) The USA federal docket shows a LNG sales price of $ 3.47/MMBTu while the crude price was $ 18/barrel (Federal Register 2000).

The above references suggest that burner tip LNG price would be over $ 3.5/MMBTu when the oil price is about $ 18/Barrel and it would be in the range of $ 5.5 to 6 /MMBTu when the oil price is about $ 30/Barrel. The price would also depend upon the nature of the contract as mentioned above.

For this analysis, it has been assumed that LNG price at the burner-tip (without taxes) will move in the range of $ 4 to $ 6 /MMBTu. In terms of $ per Million Kilo Calories (Mkcal), this works out to be $15.8 to 23.8. For the base case scenario burner-

[6] The study also says that in 1997 the cost of regasified LNG in Japan was just over $ 3.5 /MMBTu.

tip LNG price is taken as \$4.5/MMBTu, with forex premium of 15% it works out to be \$ 20.5/Mkcal.

3.4.2. Imported Coal Cost

Some state power utilities in India (like Tamilnadu, Panjab, Gujrat, and Maharashtra) have imported coal in the past. But this is not a regular phenomenon. The price of imported coal at the power station is sum of Free On Board cost (FOB cost, at the producers end), shipping cost, port handling charges, taxes and duties, and land transportation cost (if any).

Over the last decade, the international price of coal has been steadily declining. The US coal price in real \$ has declined steadily in the last decade (about 20% in last 10 years) and is estimated to decline further. This trend can be seen in the case of Australian coal also. The FOB cost of Australian coal in 1997 was \$34/Ton and the present price is around \$24/Ton (a 30% decline in nominal \$). A study by Gas Research Institute expects the coal prices to marginally increase in nominal terms (in US \$), but decline in real terms (constant \$) till 2015 (GRI 2000). Major options for coal import include, import from South Africa, China, and Indonesia. In August 2000, the FOB price of Australian coal was around \$ 24/ ton[7] (Coalportal 2000, Personal communication).

The cost of shipping coal for 5080 knots, using medium sized vessel, is reported to be around \$6.9/ton (Coalportal 2000). For importing coal in India, the freight is expected to of the same order (distance between Newcastle, Australia to Madras, India is 5561Knots). The freight rate from Australia to India will be in the range of \$ 7 to 8.5/Ton depending upon the coast. The port handling costs at Indian ports are in the range of \$ 5/ ton (TERI 1997 pp. 33). All these costs need to be added to arrive at the effective cost of coal. Considering these aspects, landed cost of imported coal would not be more than US \$ 40/ton (i.e. Rs. 1800 / ton).

For this study, the present cost of imported coal (with a calorific value of more than 6,500 Kcal. /Kg) has been considered at Rs. 1,800/ton. A foreign exchange premium of 15% has been added to this cost, implying an effective cost of 2,070 Rs/Ton. Power plant close to port has been considered and hence no cost for land transportation has been considered. With calorific value of 6,500 Kcal/Kg the landed cost is equivalent to or \$ 6.15/MKcal. Though the international coal costs are expected to decline in real term. For the sensitivity analysis, we have taken a price range of 10% on both sides of the present price.

3.2.3 Domestic Coal Cost

Indian coal is classified in grades A to F according to decreasing calorific value. Typically, coal of D, E, and F grade is used for power generation. Table 3 shows range of the pit head cost and calorific value of Indian coal.

Table 3: Average pit head price of power-grade coal in India (Rs/ton in June 1999)

[7] The Australian coal typically has low Sulfur (of 0.6% by weight), high calorific value (6,500 Kcal/Kg), and fairly low ash content. (Coalportal 2000) A price of \$ 24/ton for Australian coal is also quoted on Coal India LTd (CIL) web site. (CIL 2000)

Grade of Coal	Price Range (Rs/Ton)	Average Calorific value (Kcal/Kg)	Price (Rs/Mkcal)
D	621-599	4583	134
E	465-450	4045	114
F	375-361	3437	106

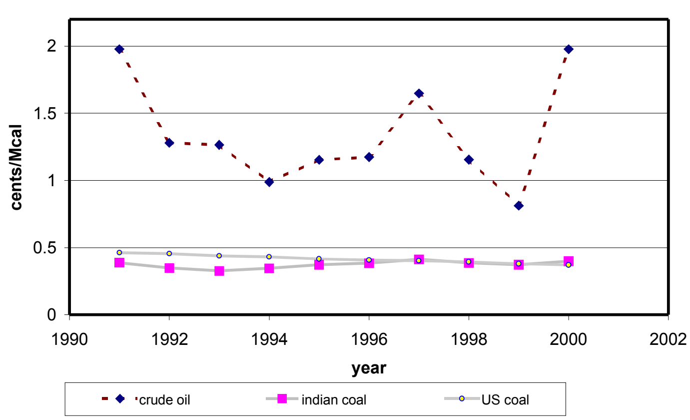
Source: www.indiapoweronline.com obtained from Coal India LTD, Fuel Map of India (CEA 1998 pp. 6).
Note: The prices exclude royalty and taxes, which are around Rs. 100 /Ton

Until the end of 1999, the government administered coal prices. The present prices are not much higher. But the study assumes that the prices will increase and stabilize at around the long run marginal cost. Estimates of long run cost of Power-grade coal production from various coal fields, carried out in the study Energy Modeling for India, indicates a price of around Rs. 800/Ton (in 2000 prices)[8] (GOI 1993 study as quoted in TERI (1997)). In the base-case scenario, we have taken coal price to be Rs 800 /Ton, with calorific value of 3,800 Kcal/kg implying a coal cost of Rs. 198/MKcal ($ 4.4 /Mkcal).

3.2.4 Fuel Cost Fluctuation

The following section shows fluctuations in fuel price over the last decade. The price trend (in US Cents/Mcal) is shown in Figure 1 for (a) international crude oil (Brent oil), (b) power-grade coal in USA, and (c) Indian coal. The LNG price is said to have a premium over the crude price and hence will be higher than crude oil price.

Figure 1: Fuel prices fluctuations



a) All prices in nominal cents
b) Source:

Domestic coal prices: Ministry of Coal (MOC)(1999)
US Coal Prices: Energy Information Administration (EIA)(2000) a
Crude oil prices: Energy Information Administration (EIA)(2000) b

The oil price (and hence price of LNG) would have undergone a major change over years. The cost of coal in the USA is coming down. As mentioned earlier the fall in Australian coal prices is even more drastic. The price of Indian coal has more or

[8] The study estimates the long run prices in 1996 prices. This has been converted to the present prices.

less remained constant in US $ terms. The wide fluctuations of oil/ gas prices can be seen in contrast to the relative stability of Indian as well as international prices of coal.

4. Base-Case Comparison of LNG, Imported Coal and Domestic Coal Options

This section presents a base-case economic comparison of power generation for three competing options. This comparison is carried out using the following methodology and assumptions. Exchange rate of $1=Rs. 45 has been assumed for all the calculations

The assumptions made earlier are reflected in the calculations for the base case comparison. The table below illustrates the calculation methodology.

Table 4: Base Case Comparison of LNG, Imported coal and Domestic coal based base load power generation.

			Formula	Domestic coal	Imported coal	Imported LNG
I	CAPACITY COST					
	A	Capital cost (Rs Crores/MW)		4.5	4.5	3.5
	B	Economic life (Years)		30	30	30
	C	Discount Rate		15%	15%	15%
	D	Capital Recovery Factor	C/(1-(1+C)^(-B))	0.1523	0.1523	0.1523
	E	Annualized capital cost (Rs/kW/year)	D*A*10^4	6854	6854	5331
	F	O&M cost (Rs/kW/year)		900	900	700
	G1	Plant Availability (%)		80%	80%	90%
	G2	Auxiliary Consumption		8.5%	8.5%	3.0%
	H	Capacity cost Rs/kWh	(E+F)/(G1*8760)/ (1-G2)	**1.21**	**1.21**	**0.79**
II	TRANSMISSION COST					
	I	Distance From the Load center km		2000	200	200
	J	Transmission cost Rs/kWh		**0.55**	**0.1**	**0.1**
III	FUEL COST					
	K	Calorific value (kcal/Kg)		3800	6500	NA
	L	Generation efficiency (at generator bus)		37%	37%	47%
				Rs/Ton	Rs/Ton	$/MMBTu
	M	Fuel cost		800	1800	4.5
	N	Heat Rate Net of Aux. (Kcal/kWh)	860/ (L *(1-G2))	2540	2540	1886
	O	Fuel Cost (Rs/ kWh)	(M*10^-3/K)*N	0.53	0.70	1.52
	P	Forex Premium (%)		0%	15%	15%
	Q	Fuel Cost with premium (Rs/kWh)	O*(1+P)	**0.53**	**0.81**	**1.74**
IV	COST OF SUPPLY AT THE LOAD CENTER					
	R	Total Cost (Rs/Unit)	H+J+Q	**2.29**	**2.12**	**2.63**

It can be seen from the above table that, even in the base case which considers the price of LNG at $ 4.5 /MMBTu (which is low case for LNG price) domestic coal and imported coal-based generation is cheaper than imported LNG-based generation. For load centers that are closer than 2000 km from coal mines (which would cover major part of the country) the domestic coal would have further advantage. This conclusion is striking and cast a serious doubt about the economic advantage of LNG power plants as base load generation stations.

5. Sensitivity Analysis

As explained earlier, the LNG cost, coal cost, and the capital cost of projects are the variables selected for carrying out the sensitive analysis. The difference in the cost of electricity delivered at the load center (in Rs/kWh) for LNG-based generation and coal-based generation (from imported as well as domestic coal) is taken as the result parameter for the sensitivity analysis. This result parameter clearly indicates the economic advantage of the competing options. The difference in the cost of supply is calculated for a range of prices of the parameters chosen for the sensitivity analysis. These parameters and their levels of prices considered for the sensitivity analysis are shown in the table 4.

Table 4: Parameters and their values taken for the sensitivity analysis

Parameters	Range taken for sensitivity analysis
Capital cost of coal-based plant as % of capital cost of LNG-based plant [9]	1) 128% (4.5 Crores/MW) (prevailing) 2) 143% (5 Crores/MW) 3) 158% (5.5 Crores/MW)
LNG cost ($/MMBTu)	4, 5, 6
Imported Coal cost (Rs/ Ton)	1620, 1800, 1960
Domestic Coal cost (Rs/ Ton)	800, 880, 960

Note: The basis for range values of the above parameters has been discussed in section 3.

Such analysis gives 27 values of difference in the cost of supply for each of the comparison; namely (a) LNG-based generation with domestic coal-based generation and (b) LNG-based generation with imported coal-based generation. These values are represented in graphical from Figure 2 and 3.

To indicate the significance of this difference in the cost of supply, it is also represented in terms of Crores Rs. lost or gained per year per 2,000 MW of power plant. It is calculated by multiplying the difference in the cost of supply per unit with the number of units generated by a 2,000 MW LNG plant in a year. The calculation methodology and other assumptions made are same as that used in the base case comparison.

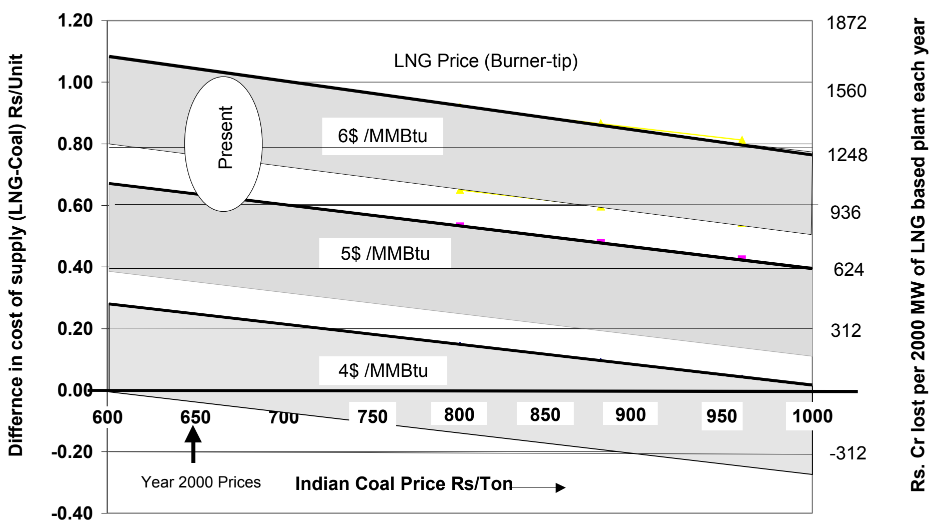
[9] Capital cost of LNG-based plant is taken as 3.5 Crores/MW

Figure 2 shows the sensitivity analysis of the comparison of LNG-based generation with domestic coal-based generation for the variables mentioned above. Y-axis of Figure 2 shows the difference in the cost of electricity supply, i.e. cost of supply from LNG power plant less the cost of supply from domestic coal-based power plant. As discussed above, the secondary Y-axis indicates the corresponding economic loss (or gain) because of opting for a 2000 MW LNG power plant over the domestic coal-based plant. Various levels of domestic coal prices are plotted on the X-axis.

Three slanted lines in the Figure show difference in the cost of supply for three LNG prices, namely $ 4, 5, and 6 per MMBTu. These lines are drawn for the prevailing capital cost of coal-based plants (i.e. 28% higher than LNG-based plant). The bands below these lines indicate the result for increasing levels of capital cost of coal-based plant. The lower bound of the band represents the results, for the assumption that capital cost of coal plants is 58% more than that of LNG-based plants.

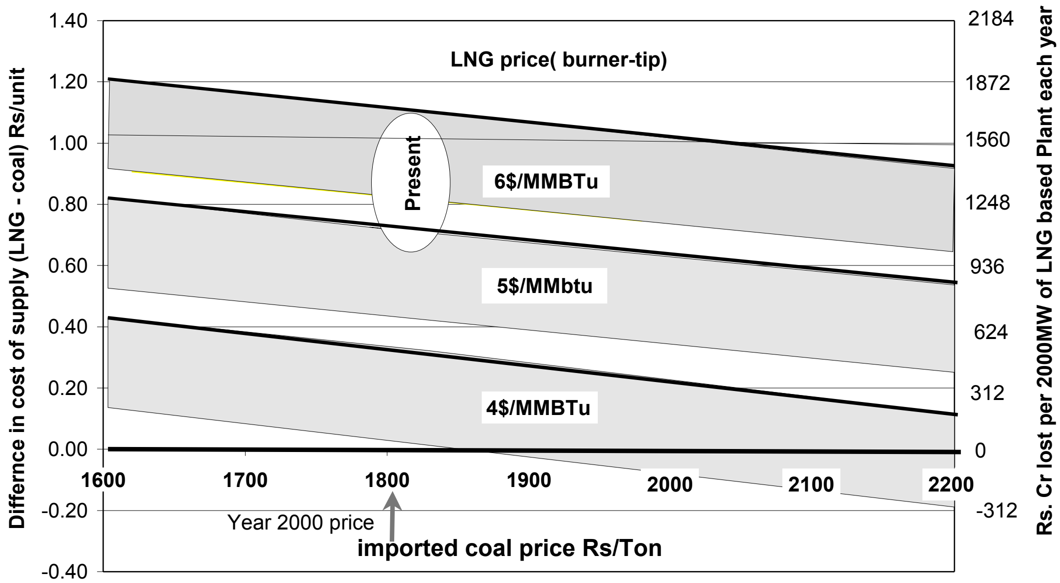
Similarly Figure 3 shows the comparison between LNG-based power generation and the imported coal-based power generation. The Y axis of figure 3 shows the difference in the cost of supply between LNG-based power generation and imported coal-based power generation and the X axis shows various prices of imported coal. The rest of the figure is similar to figure 2.

Figure 2: Sensitivity analysis of comparative economics of LNG-based power generation with domestic coal-based power generation.



a) The figure shows the difference in the cost of supply, i.e. cost of supply from LNG-based plan less cost of supply from coal base plant, and the corresponding loss or gain per 2000 MW of LNG-based plant per year.
b) All the points above the zero line indicate that coal is a cheaper options while those are below zero line indicate that LNG is a cheaper option.
c) The Coal and LNG prices represented in the graph are exclusive of the taxes, duties and foreign-exchange premium.
d) The ellipse on the graph shows the present range of LNG and coal prices

Figure 3: Sensitivity analysis of comparative economics of LNG-based power generation with imported coal-based power generation.



a) The figure shows the difference in the cost of supply, i.e. cost of supply from LNG-based plan less cost of supply from coal base plant, and the corresponding loss or gain per 2000 MW of LNG-based plant per year.
b) All the points above the zero line indicate that coal is a cheaper options while those are below zero line indicate that LNG is a cheaper option.
c) The Coal and LNG prices represented in the graph are exclusive of the taxes, duties and foreign-exchange premium.
d) The ellipse on the graph shows present range of prices of LNG and imported coal.

The following conclusions could be drawn from the above two figures:

1) Even at the lowest level of LNG price of $ 4 /MMBTu and at the prevailing capital costs, both imported coal as well as domestic coal-based generation is cheaper than the LNG-based generation for a wide range of coal prices. At the present coal prices of imported and domestic coal, the loss per year because of choosing a 2,000 MW LNG-based plant over an imported coal-based plant or a domestic coal-based plant is about Rs. 500 Crores to 300 Crores respectively

2) At the prevailing price of LNG (which is in the range of $ 5 to 6 /MMBTu), the loss per year because of choosing a LNG-based power plant instead of a similar coal-based power plant is colossal. When compared with domestic coal-based power plant it is in the range of Rs. 1,000 to1, 500 Crores per year; while for imported coal, it is in the range of Rs. 1,200 to 1,700 Crores each year.

3) The above figure also considers the possibility that the capital cost of coal-based projects is substantially higher than LNG-based projects. At the prevailing fuel prices, even if we assume that the capital cost of coal-based plant is much higher than the prevailing trend (i.e. the capital cost of coal-based plant is about 60% more than capital

cost of LNG-based plant, instead of prevailing value of 30%) the Coal projects are far more economical. The loss because of choosing a 2000MW of LNG-based power plant instead of coal ranges from Rs. 400 to 900 Crores each year, when compared with a domestic coal base plant.

4) LNG-based generation is economical only in a very unlikely situation when, LNG cost are very low, capital cost of coal-based plants are much higher than the prevailing costs, and coal prices are much higher than the prevailing prices. In all other situations, the LNG is uneconomical for power generation.

5) As the analysis assumes a transmission distance of 2,000 km for domestic coal-based power plants, for transmission distances less than 2000 km (which could be the case for substantial part of the country) domestic coal-based generation will be more economical than indicated here.

6) Imported coal prices are showing a steady decline for the last decade, this trend is expected to continue, and in that case imported coal-based generation will be more economical than LNG-based generation for almost all-possible prices of LNG.

6. Non-economic Issues

The above analysis clearly points out serious economic dis-advantages of using imported LNG for base-load power plants. There exist other considerations, which are also important in the plant / fuel choice. This section considers such issues in brief.

6.1 Power Plant Characteristics

The gas-based power stations are capable of running as intermediate load stations and this can be useful in the light of limited peaking capacity in most states. But unfortunately, the nature of commitments in the take-or-pay contracts for in case of many projects in India indicates that the planned LNG generation is seen as a base load stations and not as intermediate load stations. The DPC plant for example is expected to run at 82% PLF. As the planning documents consider up to 30,000 MW of LNG-based capacity addition; it is clearly not for the intermediate load operation. If the LNG plants are to be considered for intermediate load options, than their capacity will be much lower than what is being discussed.

The economics of even the intermediate load operation does not derive much advantage to LNG. In the base case scenario (that considers low LNG price), the option of LNG would be economical over coal only below a PLF of 50%. Hence, at the prevailing capital costs, even at the low LNG price, it is not economical to opt for LNG over coal. Further while considering intermediate load plants , other options such as Pump-storage in combination with coal based plants need to be considered.

6.2 Price Stability and Foreign Exchange Risk

As seen in Figure 1, the coal prices are far more stable than the oil (and hence LNG) prices. Coal market is decently competitive; where-as the LNG has no market. LNG contracts are long-term bilateral contracts (between two parties) and are known to be highly secretive. Hence, price volatility is a much bigger risk in case of LNG. Moreover, with large coal reserves, India can mitigate the risk of unlikely event of coal price volatility by increasing its coal production. This is not possible in the case of oil or gas.

The foreign exchange outgo for the fuel purchase is another issue that needs serious considerations. A LNG contract for 3.3 MTPA (representing 2,000 MW base load capacity) at a LNG price of US $ 4.5 / MMBtu is equivalent to US $ 700 Million per year, which is nearly 9% of the present oil import bill. The Indian coal-based plants are ideal for this consideration. But even the option of imported coal is much better than imported LNG. The cost of fuel per unit of electricity is less than half in case of imported coal compared to the fuel cost of LNG. Further the imported coal can be replaced by Indian coal, with proper care taken at the time of plant design.[10] In addition, coal import has a distinct advantage over LNG in terms of national security, due to wider spread of coal reserves in the world.

6.3 Environmental Considerations

LNG is a cleaner fuel than coal. This is put forth as one of the considerations opting for LNG-based generation. First, this advantage needs to be viewed on the backdrop of economic and other disadvantages of LNG-based power generation.

Second, the issue of environmental considerations needs to be integrated in the overall policy debate. Unfortunately, in India the environmental considerations are yet to get integrated in the planning. However, until this is done, the environmental considerations cannot be brought in a piecemeal and ad-hock manner, otherwise they can distort decisions.

When these considerations are integrated in planning, all options for reducing environmental damage would need to be listed and priorities based on least cost considerations. Plant siting, efficiency improvement, and a host of other options would also be competing options in that case. This aspect is not the focus of the paper and would need separate study.

In any case, if some decisions are taken for environmental considerations, their costs need to be clearly spelt out. The reduction in carbon emissions is one of the important benefits of LNG. But the cost sharing of carbon reduction, between industrialized and industrializing countries is a topic of broader debate. But it is clear that power consumers in country like India should not pay for the cost of carbon reduction at this stage.

Higher sulfur content of some imported coals is another concern. But the cost of imported coal considered in this analysis represents low sulfur coal (that has same level of sulfur on calorific basis).

[10] As Indian coal has high ash content, the boiler design needs to be appropriately different for imported coal with low ash content.

7. Conclusions

The preliminary analysis in the paper clearly indicates that domestic coal and imported coal based power generation are more economic options than LNG based power generation in most parts of the country, under a wide range of assumptions regarding the capital and fuel costs. The loss due to a single LNG power plant (of 2,000 MW) is in the range of Rs 300 crores per year, in case of low oil price of $ 16-18 /barrel to 1,400 Crores per year, in the present case of high oil prices.

The non-economic aspects of foreign exchange balance, price stability, and national security further increase the advantage of coal-based plants. The environmental advantage of using a cleaner fuel (i.e. LNG) needs to be seen on this back-drop, and its cost should be clearly spelt out.

It is argued that import of fuel is essential due to limitations of coal mining capacity. This argument holds little water, while we are planning for long term capacity addition. This is especially true, when, for decades, the conventional wisdom is repeatedly pointing out the urgent need to expand coal-mining capacity, remove coal transportation bottlenecks and improve utilization of enormous national wealth.

Import of LNG is a bad option even if one decides to import fuel as a short-term measure on account of availability and quality problems related to Indian coal. The option of imported coal turns out to be more economical than import of LNG. It would result in lower cost of generation even if the LNG cost (at burner tip) is as low as $ 4 / MMBTU, and capital cost of coal projects in at high as Rs. 5.8 Crores Rs. /MW. The relative stability of imported coal is another reason for favoring this option. The on shore coal plants can be supplied with Indian coal, through coastal shipping when Indian coal mining bottlenecks are removed, this offers much higher flexibility of fuel choice.

This raises a fundamental question about policy making in the country. In the case of IPP policy, in case of Naphtha-based (liquid fuel) projects, and on several other situations, the decisions have turned out to be highly incorrect. The country is paying a heavy price for this. Hence, there is an urgent need to make the decision-makers accountable through a public debate.

Acknowledgments

My collages/guides in Prayas Shantanu Dixit, Girish Sant and Subodh Wagle helped me during every stage of this paper, right from evolving the scope of the paper to final finishing touches and I am very thankful to all of them. I am also grateful to external reviewers Dr. Ashok Gadgil, Suhas Paranjape and KJ Joy for their detailed, valuable and prompt suggestions.

References:

1. Barley and Jonker (2000) “Coal Spot Prices.” Barley and Jonker Web-site. www.coalportal.com

2. Bureau Of Industrial Costs and Prices (BICP) (1988) “Towards a New Energy Policy”. BICP, Ministry of Industry (MOI): New Delhi, India.

3. Central Electricity Authority (CEA) (1997) "Fourth National Power Plan 1997-2012." CEA, Government Of India (GOI): New Delhi, India.

4. _________ (1981) "A Report on National Power Plan (India) Generation Expansion Program (1981-82 To1994-95) Volume I". CEA, Ministry of Energy (MOE), GOI: New Delhi, India

5. _________ (1998) "Fuel Map of India ." CEA, MOE, GOI: New Delhi, India.

6. Coal India Limited (CIL) (2000) "Pricing, Comparative Coal Prices." CIL Web-Site http://www.coalindia.nic.in/vscoalindia/pricing.htm.

7. Embassy of India, Doha-Qutar (1999) "Monthly Newsletter Vol. II No. 8 August 15th, 1999." Embassy of India, Doha-Qutar Web-Site www.

8. Federal Electricity Regulatory Commission (FERC), "Federal Register: May 2, 2000 (Volume 65, Number 85)] [Notices]" (Pages 25475-25477) Online via GPO Access [wais.access.gpo.gov] [DOCID: fr02my00-40]

9. Gas Research Institute (GRI) (2000) "GRI Study Abstract.", GRI Web-Site http://www.gri.org/cgi-bin/re?url=http%3A//www.gri.org/pub/pressreleases/prstaticpages/pr826.html

10. Government of India (GOI) 1997 'Ninth National Five Year Plan 1997." GOI: New Delhi, India.

11. Jha, S. (1999) "Transmission of Power Vs Transportation of Coal," A Study Carried out for Power Grid Corporation. Power Line Web –Site www.indiapoweronline.com

12. Maharashtra State Electricity Board (MSEB) (2000) "Tariff Revision Proposal submitted to Maharashtra Electricity Regulatory Commission (MERC)". MSEB: Mumbai, India

13. Ministry of Coal (MOC). (2000) "Coal Production Distribution and Marketing (Chapter VII). MOC (GOI) Web-Site http://www.coal.nic.in/vscoal/chap7.htm

14. Ministry of Power (MOP) (1992) "Tariff Notification for Generating Companies." MOP Web-site http://powermin.nic.in/nrg47.htm , New Delhi, India

15. MOP (1999a) "Private Projects having Techno-economic Cclearance." MOP Web-site www.powermin.nic.in/nrg.72

MOP (1999b) "Private Projects under Construction." MOP Web- site www.powermin.nic.in/nrg75.htm, New Delhi, India

16. Power Line (2000) "Coal Vs LNG The Best Bet for India", Volume 4, No7 (April 2000). Power Line New Delhi, India

17. Power line (2000) "Fuel Prices Indian Non-Cocking Coal", Power Line Web-Site http://www.indiapoweronline.com/Scripts/GNT006C1.ASP?ArtID=491&CatID=1&SecID=8,

18. Prime Minister's Office (PMO) (1999) "PM's Initiatives. Chapter III Supply of Gas, Recommendations and Summary of Sub-Groups." PMO web-site www.pmindia.nic.in/pminitiatives/hydro_rv2d.htm

19. Project FinanceWare (2000) Database search and analysis conducted by the World Resources Institute using Project Finance Ware (a database product of Capital Data Limited), United Kingdom, 2000.

20. Tata Energy Research Institute (TERI) (1997) "Inter-Fuel Substitution-Final Report." TERI: New Delhi, India.

21. US Energy Information Administration (EIA) (1999 a) Table 92. "Average Price of Coal Delivered to Electric Utilities by Census Division and State 1994-1998." EIA web-site http://www.eia.doe.gov/cneaf/coal/cia/t92p01.txt

22. _____ (1999) b Crude Oil Prices, EIA web-site http://www.eia.doe.gov/emeu/international/crude1.html

23. Utility Planning Methods Center (1989) "Electric Supply-1989 (Revision 6), Technical Assistance guide (TAG)," A Study made for Electric Power Research Institute (EPRI), EPRI P-6587-L". EPRI: California, US.

24. World Bank (2000) " World Bank Group catalyzes Private-Sector Investment in Bangladesh Haripur Power Project." World Bank News Release No: 2000/387/SAS

25. World Bank (1992) "Letter from Senior Financial Analyst to Secretary (Energy) Government of Maharashtra" 8th July 1992.

26. World Bank (1993) "Letter from the Country Director to Secretary, Ministry of Economic Affairs, Government of India". 13th April 1993.

27. World Commission on Dams (WCD) (1999) "Electric Supply and Demand Side Management Options", Thematic Reviews–Option Issue Series IV.1. WCD: Cape Town, South Africa.