REPORT OF
THE EXPERT COMMITTEE ON FUELS
FOR POWER GENERATION

EXECUTIVE SUMMARY

GOVERNMENT OF INDIA

CENTRAL ELECTRICITY AUTHORITY

PLANNING WING

NEW DELHI
FEBRUARY 2004

EXECUTIVE SUMMARY

Background:

The Expert Committee on Fuels for Power Generation was constituted by CEA under the Chairmanship of Member (Planning), CEA to carry out a comprehensive exercise to analyze and suggest the feasibility of using different fuels for power generation in the country. CEA constituted an "Expert Committee on Fuels for Power Generation" under the Chairmanship of Member (Planning), CEA. The Committee included members from NTPC, Ministry of Petroleum & Natural Gas, Ministry of Coal, Planning Commission, Oil Coordination Committee, Power Trading Corporation, Tata Energy Research Institute and specialized wings of CEA. Representatives from Department of Atomic Energy and Nuclear Power Corporation of India Limited, MNES and NLC also attended the meetings as Special Invitees. The committee met on 27th July 2001, 14th December 2001, 23rd January 2002, 9th October 2002 and 8th December 2003. The various fuel options for power generation along with their techno economics were deliberated upon in detail during the meetings of the Committee and certain factual information as available in CEA has also been considered. Detailed studies were also carried out to assess the relative economics of the various fuels

Power Scenario

2.0 At the end of the 9th Plan, the installed capacity in the country was 1,04,917 MW and peaking shortage of 12.6% and energy shortage of 7.5% were faced in the country. During the 10th Plan it is programmed to add 41,110 MW. By the end of the 11th Plan i.e. 2011-12, it is estimated that the installed capacity requirement to fully meet the demand projected by the 16th EPS would be 2,12,000 MW. Beyond 11th Plan the capacity addition is expected to match with demand growth and by the end of 12th Plan the installed capacity required would be about 2,83,000 MW

Fuels For Power Generation:

3.0 Various fuels for power generation considered in the report are:

- Solid fuels comprising of coal (domestic & imported) & lignite.
- Liquid fuels comprising of heavy oil, light oil, distillate No.2, naphtha, condensate, HSD, superior kerosene oil and refinery residue.
- Gaseous fuels comprising of Natural Gas including LNG.
- Nuclear, hydro and renewable sources of power.
- Emerging fuels like orimulsion, di-methyl ether, coal bed methane and gas hydrates.

Broad Assumptions:

4.0 The relative economics of the various fuels have been analyzed based upon the following assumptions. Total cost of generation for each fuel option has been worked

out for varying distances between location of fuel source/port & load center corresponding to varying PLFs of power plants. While carrying out an analysis of generation from different fuel types, certain basic standardization/assumptions have been made, to enable a meaningful comparison.

- The present study illustrates the comparative costs of electric energy delivered at the load centre bus bar from similar capacity 2000 MW power plants at load centre and at pit head/ port for various fuels assuming the same parameters for technical and financial aspects. The delivered cost of fuel has been worked out separately for each type of fuel. In case of diesel plants a capacity of about 20 MW for distributed mode of generation has been considered.

- The transmission of power from pit head/ port power plant to load centre has been envisaged through dedicated 400 kV transmission systems with 4% incremental line losses.

- Cost of transmission of energy has been calculated for transmitting 2000 MW power on two numbers 400 kV double circuit AC lines from pit-head/ port plant to load centre corresponding to distance of 200, 300, 500, 800,1000,1200,1500, 1800 and 2000 km separately.

- 34 % ash content coal has been used for distances of 1000 km and more as per MOE&F guidelines whereas run-of-mine coal has been used for distances lesser than 1000 km.

- The economics of coal-based power plants has been worked out considering cost of plant and associated transmission system along with cost of coal at the plant site. It is assumed that the concerned authorities prior to setting up of the project shall obtain all environmental clearances. Environmental stipulations shall be met in all cases.

Capital cost of power plants

- The normative capital costs of the various options for power generation have been assumed considering the capital cost of TEC cleared power projects by CEA in recent past and also considering the current trends in the capital cost. Details are as given in Appendix I.

Cost/ MW of Transmission System

- The cost per MW for transmitting 2000 MW over 400 kV AC system for various distances mentioned above, are given in Appendix I.

Cost/ tonne of Coal Transportation

- For Load Centre stations, coal movement has been considered by all rail-route and the freight charges taken are given in Appendix I.

Study Options with Various Fuels

5.0 The various options examined in the report re given below.

Domestic Coal

The two options considered for setting up domestic coal based plants are those located at the pit head with power being transmitted over 400 kV lines and load centre located plants with coal being transported from the mines through rail network.

The cost of coal at pithead along with other taxes and duties is given in Appendix I

The cost of beneficiation of coal has been considered as Rs.125 per Tonne, which would improve the calorific value of coal from 3750 kCal/ kg to 4150 kCal/ kg.

The delivered cost of coal at various locations at the specified distances has been worked out by adding freight charges as furnished in Appendix I to the cost of coal at pit head as above.

The cost of power transmission from pit head power station to load centre is worked out based on cost per MW for transmitting 2000 MW over 400 kV AC system for various distances as furnished in Appendix I.

Imported Coal

Like the domestic coal based power plants, two options in case of imported coal based power plants have been considered i.e one for setting up the plant at port and transmitting power over 400 kV AC System and the second option of load centre power plant considering the transportation of coal from port by rail like domestic coal. The cost and calorific value of imported coal at port considered for this report is as given below:

Cost of Imported Coal: 1925 Rs./Tonne
Calorific Value of Coal: 5400 kCal/kg.

Cost of power transmission and coal transportation, are as furnished in Appendix I

Lignite:

The lignite-based power plant cannot be set up away from the lignite sources. In view of this, it has been assumed that plants would be set up at the source of lignite and power would be transmitted over 400 kV AC Systems. The cost of lignite varies from place to place and typical cost and calorific value of lignite at power plant considered in this report is as follows:

Cost of Lignite: 800 Rs./Tonnes
Calorific Value: 2800 kCal/kg.

Cost of power transmission from pit head power station to load centre is worked out based on cost per MW for transmitting 2000 MW over 400 kV AC system for various distances as furnished in Appendix I.

Naphtha

The two options considered for setting up Naphtha based plants are those located at the port with power being transmitted over 400 kV lines and load centre located plants with naphtha being transported from the port.

The prevailing cost of Naphtha has been taken as Rs. 17,400/Tonne (including handling charges of Rs 100 per Tonne at port) with associated calorific value of 10,500 kCal/kg. The cost of inland transportation of Naphtha has been taken as double the cost of transportation of domestic coal, which is furnished in Appendix I. Power has been evacuated over 400 kV AC system from Naphtha based plants set up at the port and the cost of the same is furnished in Appendix I.

Gas

The option considered for gas based power stations is to set up such stations near the HBJ pipeline. Since the identified indigenous gas has already been allocated along the HBJ pipeline, setting up of gas-based power station at the source of domestic gas has not been considered. The cost of gas along the HBJ pipeline has been assumed as constant and has been taken as Rs 4000/1000* cum inclusive of Royalty, Sales tax and transportation charges of gas along gas pipeline, with associated calorific value of 10,000 kCal/cum. However the price of gas along the HBJ pipeline is location dependant due to varying sales tax in the different States. Variation in gas price on this account has not been considered in this study. The study only indicates the relative cost of gas-based projects.

LNG

The option considered for LNG based power stations is to set up these power stations at port with transmission of power over 400 kV AC lines to load centre locations. Setting up of load centre LNG based power plants has not been examined as it is considered more appropriate to set up mega LNG power plants at port. The price of LNG at port has been taken as Rs 6480/ Tonne* with associated calorific value of 9500 kCal/kg.

Diesel

Small diesel based plants may be set up at load centre away from the Grid supply to meet the requirement of electricity in distributed mode. The cost and calorific value of diesel considered in this report is as follows:

Cost of Diesel :	22000 Rs./ kL
Calorific Value:	10,860 kCal/kg.
Weight to Volume Ratio:	1.21

Reliance Gas

The finding of Reliance India Ltd. (RIL) of 7 TCF natural gas, out of which about 5 TCF is recoverable, is in the process of development. The price of this gas and also its marketing strategy is yet to be firmed up. In view of this, economics of power plants based upon this new gas find has not been examined.

Nuclear Power

The present total nuclear power capacity is 2770 Mwe. By the end of 10th Plan it would reach a level 4120 Mwe. It is projected to grow to about 10,000 Mwe by the end of 11th Plan, constituting about 5% of the total installed capacity in the country. The aim is to reach a level of about 20,000 Mwe by the year 2020 constituting about 7% of the total installed capacity. The targets of about 10,000 Mwe by the end of 11th Plan and 20,000 Mwe by the year 2020 through nuclear fuel resources should be pursued as a minimum. A combination of fuel options through indigenous natural uranium, plutonium reprocessed from indigenous uranium and imported uranium is considered prudent and appropriate. As mentioned previously, nuclear energy has the potential of providing long-term energy security to the country and all research and development efforts must be pursued to realize this objective. The cost of generation of nuclear projects have not been calculated.

Details of Source of Information for various fuel prices are given in Appendix II

Cost of Generation by Various Fuels at 80 % PLF

6.0 The cost of generation of the various fuel types at 80% PLF for base load peration is summarized below:

SUMMARY OF COST OF GENERATION BY VARIOUS FUELS AT 80 % PLF (Rs/kwh)

COST AT 80 % PLF	DISTANCE IN km								
	200	300	500	800	1000	1200	1500	1800	2000
Domestic Coal PH	1.56	1.59	1.62	1.69	1.73	1.77	1.83	1.88	1.92
Domestic Coal LC	1.58	1.63	1.73	1.88	1.97	2.06	2.20	2.31	2.36
Imported Coal At Port	2.15	2.18	2.22	2.29	2.32	2.36	2.42	2.48	2.52
Imported Coal LC	2.11	2.15	2.22	2.32	2.39	2.46	2.56	2.65	2.69
Lignite At PH	2.11	2.14	2.18	2.25	2.28	2.32	2.38	2.44	2.48
LNG At Port	2.16	2.19	2.23	2.29	2.33	2.36	2.42	2.47	2.51
Naphtha At Port	4.33	4.36	4.39	4.46	4.49	4.53	4.59	4.64	4.68
Naphtha At LC	4.19	4.22	4.27	4.36	4.41	4.47	4.55	4.62	4.66
Gas Along Pipeline	1.49	1.49	1.49	1.49	1.49	1.49	1.49	1.49	1.49
Diesel At LC	5.96	5.96	5.96	5.96	5.96	5.96	5.96	5.96	5.96

The above results have also been graphically depicted. Graph-1 illustrates variation in cost of generation of coal based power plants (domestic and imported) and lignite with distance between pithead/port and load centre as applicable.

Cost of Generation by Various Fuels at 30 % PLF

7.0 Comparison of cost of generation of peaking plants (30%PLF) by types of fuels is given below. As coal and lignite based plants are base load stations and cannot operate at low PLF as peaking plants, cost of generation of these types of plants is not considered in the analysis.

SUMMARY OF COST OF GENERATION BY VARIOUS FUELS AT 30% PLF (Rs/kwh)

COST AT 30% PLF	DISTANCE IN km								
	200	300	500	800	1000	1200	1500	1800	2000
Gas At LC	2.66	(Along HBJ Pipe Line)							
LNG At Port	3.45	3.52	3.61	3.78	3.88	3.98	4.13	4.27	4.37
Naphtha At Port	5.61	5.68	5.78	5.95	6.05	6.15	6.29	6.44	6.54
Naphtha At LC	5.36	5.39	5.44	5.53	5.58	5.64	5.72	5.79	5.83
Diesel At LC	7.48	7.48	7.48	7.48	7.48	7.48	7.48	7.48	7.48

The above results indicate that to meet peaking requirement, gas based plants along HBJ pipeline followed by LNG based plant at port are cheaper options as compared to Naphtha based plants at 30% PLF. Also Naphtha based plant at load centre with transportation of Naphtha is a cheaper option as compared to Naphtha based plant at port and transmission of power. Diesel is the most expensive option.

Graph 2 illustrates variation in cost of generation of liquid fuel based power plants with distance between port and load centre at 30% PLF.

Sample Application of the Study:

8.0 Utilizing the study results a case study has been carried out in Chapter-5 of the report for the State of Delhi considering various options for power generation. From the results it is observed that setting up a gas-based plant at load center (Delhi) is the cheapest option. This, however, is subject to the availability of gas in the long term without significant increase in price, which has been considered uniform along the gas pipeline. The next best option is to have domestic coal based power plant at pit head and transmit power to Delhi.

Broad Conclusions:

9.0 The broad conclusions based on cost of generation worked out in the Report for various fuel options are as follows:

- At 80 % PLF and 800 Km between the source and load centre, the ranking of the various options studied for base load operation is as follows:

Ranking	Fuel and location	Cost of delivered energy Rs/ kwh
1	Gas Along Pipeline	1.49
2	Domestic Coal at Pit Head.	1.69
3	Domestic Coal at Load	1.88
4	Lignite at Pit Head.	2. 25
5	Imported Coal at Port	2.29
6	LNG at Port	2.29
7	Imported Coal at Load Centre	2.32
8	Naphtha at Port	4.46
9	Naphtha at Load Centre	4.36
10	Diesel at LC	5.96

- At prevailing fuel prices considered in the report, gas-based power plants along HBJ pipeline is the cheapest option at all distances. At present the price of gas is administered whereas in future it is likely to be deregulated and linked to international price of crude oil. Therefore, since future trend of gas prices is not known, the relative economics of gas based plants vis-à-vis the other options could undergo a change in future.

- Next best option is domestic coal based power station at pithead followed by load centre located coal based station at all distances. However due to limitation of availability of pithead sites, a judicious mix of pit head and load centre stations has to be followed. This is also essential from system safety point of view as also danger to transmission network from terrorists. In all cases, the concerned authorities prior to setting up of the project shall obtain environmental clearances. Environmental stipulations shall be met in all cases. Coal based pit head power plants, in addition to being the cheaper option have following additional merits: -

    - Avoid air and water pollution in densely populated areas near the load centre.
    - Easy disposal of ash in exploited coalfield areas.
    - Avoid loss of coal in transportation
    - Reduce pressure on railway network and save the costs on transportation.

- Lignite based power plants is the next best alternative and is more economical than LNG, imported coal and Naphtha based power stations. Lignite based plants may be set up and efforts should be made to reduce the cost of production so as to make it more economical.

- LNG based plant at port and imported coal based plant at port are the next best alternatives. However higher price stability of coal in the International market may give preference to imported coal based power plants over LNG based power plants. Imported coal based plant at load centre is marginally higher than both Imported coal & LNG port based stations. It may be noted that at short distances lesser than about 500 km, imported coal based plant at load centre is a cheaper option compared to the other

two options. Other factors like feasibility of setting up plants, environmental stipulations etc. may be considered while firming up the location of imported coal based plant.

- Naphtha based power stations are more expensive vis-à-vis coal, Lignite and LNG based stations. Also Naphtha based plant at load centre with transportation of Naphtha is a cheaper option as compared to Naphtha based plant at port and transmission of power, for all distances.

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- At 30% PLF and 800 Km between the source and load centre, the ranking of the various options studied used for peaking purposes is as follows:

Ranking	Fuel and location	Cost of delivered energy Rs/ kwh
1	Gas Along Pipeline	2.66
2	LNG at Port	3.78
3	Naphtha at Load Centre	5.53
4	Naphtha at Port	5.95
5	Diesel at LC	7.48

  - For peaking purposes, gas based plants along HBJ pipeline followed by LNG based plant at port are cheaper options as compared to Naphtha based plants, for all distances. Also Naphtha based plant at load centre with transportation of Naphtha is a cheaper option as compared to Naphtha based plant at port and transmission of power, for all distances.

- Naphtha based power plants are the most expensive. In view of the difficult handling of Naphtha and wide fluctuation in its price in the past, it may not be advisable to go in for Naphtha based generation in future.

- For distributed generation at remote locations away from the grid, setting up of small diesel based power stations shall be considered, as diesel is available throughout the country.

- Keeping in view the limited availability of coal and energy security of the country, emphasis should be given for the development of the nuclear power plants. All steps to accelerate the research and development for realizing the energy potential of thorium must be undertaken.

- Hydropower development should be given priority not only to improve hydrothermal mix for optimizing the efficiency of our power system and usage of our resources for sustainability, but also to minimize dependence on thermal power so as not to add the various pollutants in the environment. The hydro potential and status of its development is given at Appendix III.

- The studies have used 400 kV AC systems for evacuation of 2000 MW of power. However, the need of higher AC voltage or HVDC would be considered on a

case-to-case basis wherever necessary depending upon the system requirements and quantum of power transfer, which may exceed 2000 MW.

- Emerging fuels such as coal bed methane may be considered at appropriate time when it becomes commercially available for power generation.

- Refinery residues can be considered in selective cases based upon its availability.

- The above ranking shows a general trend of the various options analyzed since the same are based on cost of generation figures which are indicative in nature. Future trends in cost figures are dependant on a number of factors, which are difficult to predict. Whenever techno-economics of a project are to be established, the study results would act as guidelines based on which specific studies need to be carried out on a case-to-case basis to arrive at exact results.

Appendix I

Capital cost of power plant

S.No.	Fuel Type	Capital Cost of Power Plant (Rs. Crore/MW)
1.	Domestic coal	4.0
2.	Imported Coal	4.0
3.	Lignite	4.2
4.	LNG	2.7
5.	Naphtha	2.7
6.	Gas	2.7
7.	Diesel	3.5

Cost/MW for transmitting 2000 MW over 400 kV AC systems for different distances

S. No.	Kms.	Cost/MW (Rs. Lakhs) (With IDC)
1.	200	16.50
2.	300	27.23
3.	500	42.54
4.	800	69.16
5.	1000	84.41
6.	1200	99.67
7.	1500	122.55
8.	1800	145.43
9.	2000	160.69

Domestic Coal Cost

Run Of Mine Coal		
Basic Cost	392	Rs/Tonne
Royalty	65	Rs/Tonne
Taxes & Duties	30	Rs/Tonne
Handling Charges	30	Rs/Tonne
TOTAL	517	Rs/Tonne
Gross Calorific Value	3750	kCal/kg

Appendix I (contd..)

Cost/ Tonne of Coal Transportation

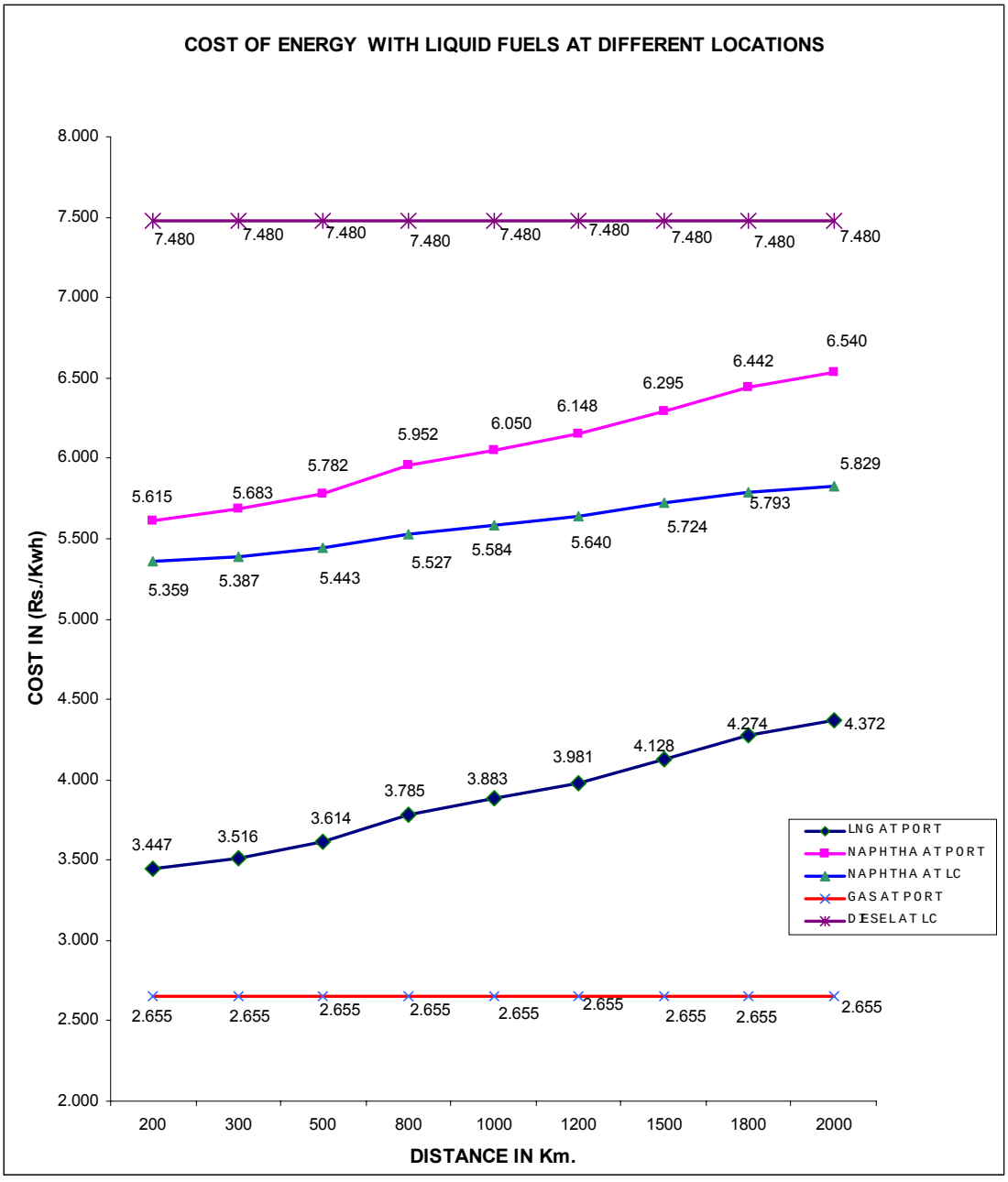
S. No.	Distance	Freight (Rs./Tonne)
1.	200	179.9
2.	300	251.4
3.	500	394.4
4.	800	608.9
5.	1000	751.9
6.	1200	894.9
7.	1500	1109.4
8	1800	1284.9
9.	2000	1375.9

Appendix II

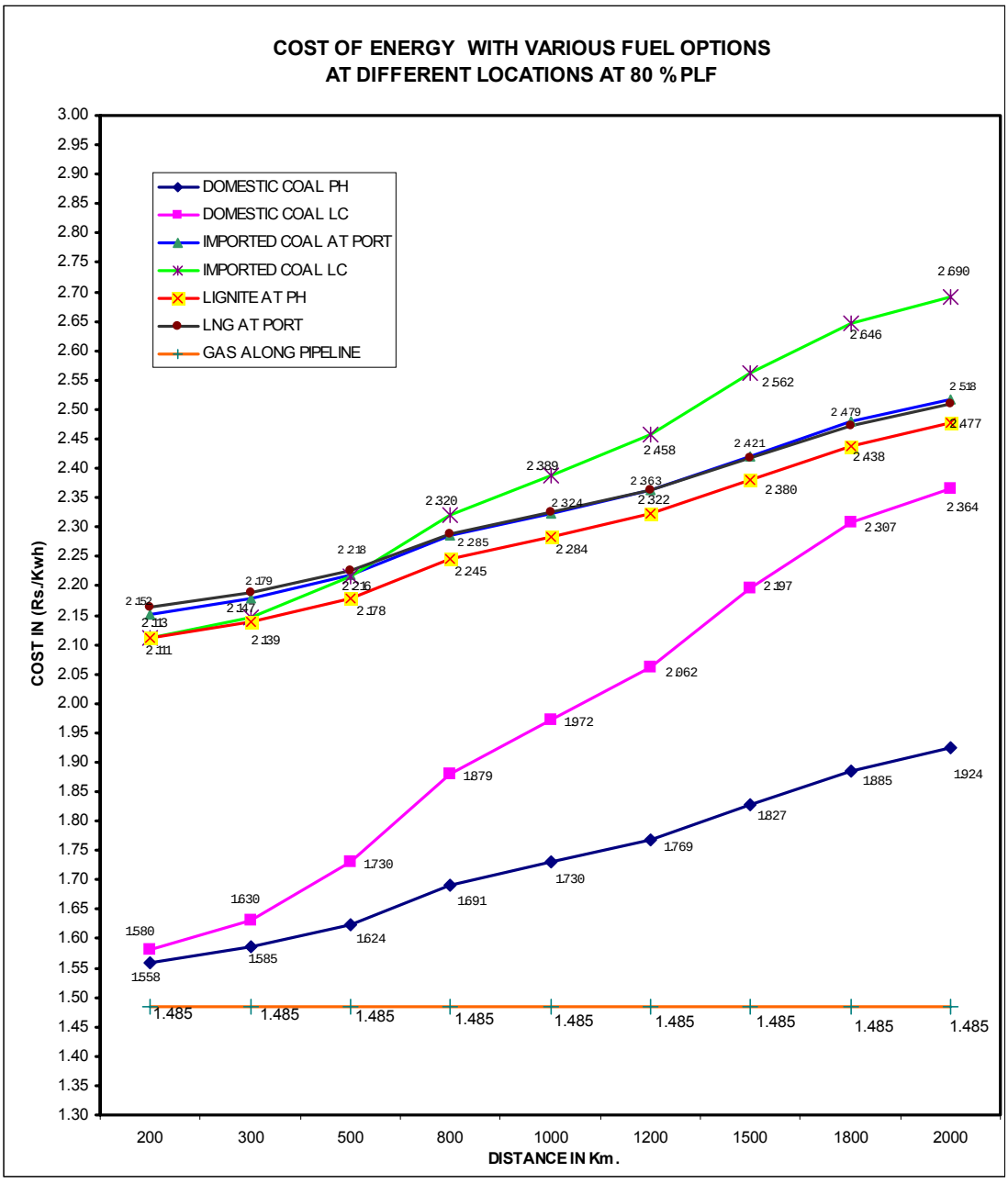
Details of Source of Information for various fuel availability and prices

Sl. No.	Price of	Pg.No./Table	Source of Information
1.	Transmission Cost/MW for varying distances (2000 MW over 400 kV AC)	Appendix I	Power System Wing, CEA
2.	Freight Charges for Coal Transportation	Appendix I	Gazette notification of Railways
3.	Coal reserves of India	Pg. 7/Table 3.1	*Ministry of Coal Statistics*
4.	Cost details & Calorific Value of domestic coal	Pg.27/Table 4.4	Coal India
5.	Cost details & calorific value of imported coal	Pg.28	Price of Imported Coal by BSES as informed to CEA
6.	Cost details & Calorific value of lignite	Pg.28	Thermal Wing , CEA
7.	Import potential of Gas	Pg. 14/Para 3.2.3.2	Energy Information Administration, USA
8.	Cost details calorific value of Naphtha	Pg.29	www.moneypore.com
9.	Cost details & calorific value of Gas	Pg.29	Basic Statistics on Indian Petroleum & Natural Gas 2002-03
10.	Cost details & calorific value of LNG	Pg.29	Discussions with NTPC
11.	Cost details & calorific value of Diesel	Pg 30	Ministry of Petroleum and Natural Gas
12.	Potential and Programme of development of Nuclear Energy	Pg 14-15/Para 3.2.I	Deptt. Of Atomic Energy

Graph - 1


COST OF ENERGY WITH LIQUID FUELS AT DIFFERENT LOCATIONS
COST IN (Rs./Kwh)
8.000
7.500
7.000
6.500
6.000
5.500
5.000
4.500
4.000
3.500
3.000
2.500
2.000
7.480
6.540
6.442
6.295
6.148
6.050
5.952
5.782
5.683
5.615
5.829
5.793
5.724
5.640
5.584
5.527
5.443
5.387
5.359
4.372
4.274
4.128
3.981
3.883
3.785
3.614
3.516
3.447
2.655
200
300
500
800
1000
1200
1500
1800
2000
DISTANCE IN Km.
LNG AT PORT
NAPHTHA AT PORT
NAPHTHA AT LC
GAS AT PORT
DIESEL AT LC

Graph - 2


COST OF ENERGY WITH VARIOUS FUEL OPTIONS
AT DIFFERENT LOCATIONS AT 80 % PLF
DOMESTIC COAL PH
DOMESTIC COAL LC
IMPORTED COAL AT PORT
IMPORTED COAL LC
LIGNITE AT PH
LNG AT PORT
GAS ALONG PIPELINE
COST IN (Rs./Kwh)
DISTANCE IN Km.
200
300
500
800
1000
1200
1500
1800
2000
1.485
1924
1885
1827
1769
1730
1691
1624
1585
1558
2364
2307
2197
2062
1972
1879
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2690
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2218
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Appendix III

Exhibit 3.1

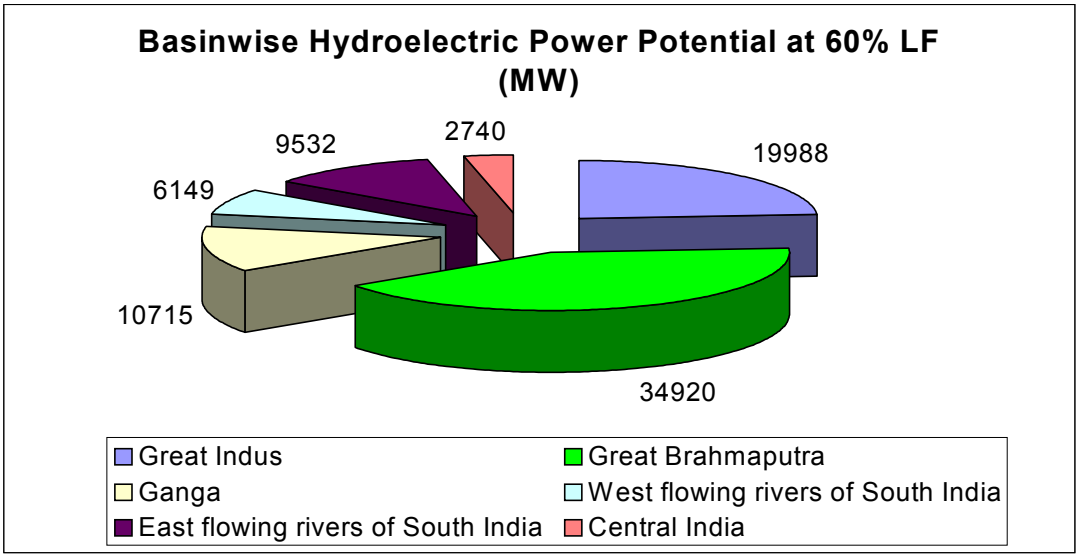

Exhibit 3.2