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Fuel for power*

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Of late, cases of black-outs and brown-outs are becoming increasingly frequent. In view of this, power calls for special attention. India needs to produce cost-effective and sustainable energy for its millions of farmers, workers and households.

INDIA is passing through a critical phase. Economic growth of the country is picking up. The Seventh Five-Year-Plan saw the economy grow at a rate of about 5.7%. During the Eighth Five-Year Plan, the performance was even better and the growth rate of the economy registered a high of 6.5%. During the Ninth Plan, the Planning Commission has set a target of 7%. However, in order to maintain growth at this impressive rate and to increase it further we need dependable and efficient infrastructural support. Power calls for special attention, particularly in view of the fact that of late the growth in power supply capacities has not been keeping pace with demand and cases of black-outs and brown-outs are becoming increasingly frequent. The growth rate of demand for power in developing countries is generally higher than that of GDP. The elasticity of demand tends to come down as the economy grows. In India, the ratio which was as high as 3.06 in the First Five-Year Plan, peaked at 5.11 during the Third Five-Year Plan and reduced to 1.65 from 1980–81 to 1992–93. For the coming decade, a ratio of 1.5 is projected. Considering the targeted GDP growth rate of over 7%, an average growth rate of nearly 10 to 11% would be required for the power sector. In terms of capacity, it would imply an incremental capacity addition rate of nearly 10,000 MW per annum.

Electricity is a secondary form of energy. For electricity generation, primary energy resources such as hydro-electric potential, different forms of fossil fuels, fissile materials, renewable and non-conventional energy resources, etc. are needed. Of different modes of power generation, fuel as primary source is required only in the cases of thermal and nuclear generation. In hydro-electric power generation, the source of primary energy is the high kinetic and potential energies of the water head while for power to be generated from the non-conventional sources such as wind energy, solar energy, geothermal tidal energy, etc. it is the energy potential of the respective source that is converted into electricity through appropriate conversion technology. For thermal power generation, different technologies are available to exploit the energy content of different forms of fossil fuels ranging from conventional boiler and steam turbine combination to technologically more advanced fluidized bed boilers. The gas turbine technology, to primary handle the liquid and gaseous fuels, also ranges from the simple gas turbines to more complicated integrated combined cycle gas turbine plants (ICCGTs). In the same way, depending on the available fissile material, suitable technologies are available for power generation. Fuel is essential for power.

India has almost all types of primary sources of energy, though available in varying quantities and at different locations. Therefore our generation mix comprises of power generation from almost all possible modes. Because of the inherent operation and long-term economic advantages, hydro-electric power generation assumes special importance. As a result, the planners in the country, till the mid sixties, accorded very high priority to this mode of power generation. This resulted in a generation mix, till the mid sixties, decisively in favour of hydel power. However, hydel power generation also has its shortcomings in terms of environmental and rehabilitation implications coupled with huge capital requirements, long gestation periods elongated further by the natural and geological surprises, etc. The relative ease with which thermal plants could be set up in much shorter time, with relatively low investments and the pressing need to add quick capacities to generate large quantities of power brought upon a paradigm shift in the power planning in the country with far-reaching implications. India was lucky to have a Fuel Policy Commit-

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tee Report in the early seventies, coinciding with the first energy crisis. The Committee lamented excessive reliance on petroleum as energy source and built up the case for pit head super thermal power plants based on coal. Today, the generation mix has got distorted to the extent that the hydel share in the total power generation in the country is reduced to only about 25% of the total generation in the country. This has not only resulted in extremely poor exploitation of the available hydro-electric potential in the country – about 20% of the available potential has either been developed or being developed – it has also resulted in sub-optimal utilization of available thermal power generation capacity. Increased dependence on thermal power generation, which requires some kind of primary energy for conversion into electricity, has also resulted in a phenomenal increase in the demand for fuel for power generation and the associated transportation infrastructure. India is endowed with a wide variety of energy resources (Table 1).

The hydel resources available in the country are capable of generating 600 TWh of electricity. This constitutes about 6% of the total hydro-electric potential available in the world. A substantial portion of the available hydel potential in the country is located in the ecologically-sensitive regions of Himalayas. There are many environmental concerns that are presently being voiced against the large hydro-electric projects being undertaken, specially in such areas. Coal and lignite reserves in the country also are substantial and they constitute about 6% of the total known coal reserves of the world. Indian coal is largely of low sulphur content but, with its high ash content, its calorific value is very low. Superior grades of coal are also available in the country but they are in limited quantities. Exploitation of the coal deposits available either in these seams or at large depths possess a technological challenge in the future years. Related to this is the possibility of extracting coal-bed methane in some regions. This is an unchartered area in the country. Also gas hydrates in the ocean bed to which we are now turning. The established oil and gas resources are largely available in the offshore areas of the country but at the present production levels these reserves may not last more than two to three decades. At present they constitute less than 1% of the total hydrocarbon reserves of the world. There are no immediate indications of discovering giant hydrocarbon fields that can significantly boost up the oil and gas production in the country.

Even though India has sizeable energy resources in terms of coal, lignite, hydro-electric and nuclear energy, the process of development of these resources is fraught with major technological and environmental problems. On the other hand, with its large and steadily-increasing population and the urgent need to step up the per-capita energy availability to reasonable levels, the energy requirements of the country are going to increase rapidly. Since the domestic energy resources, particularly hydrocarbons, are not that abundant as to be sufficient to sustain the rapidly-increasing level of demand for energy in the economy, the country may have to depend on energy imports in the long run. Vijay Kelkar has been arguing very convincingly that a suitable trade is an efficient instrument of overcoming this constraint. To an extent, the country may be in a position to minimize its dependence on imports and ensure energy security by enhancing the levels of efficiency of use of energy and the overall energy intensity of the economy.

It has been estimated by the Central Electricity Authority that to meet the projected demand for power in the country, the coal-based power generation would need to be about 435 billion units at the end of the IX Plan period. Accordingly the coal requirement works out to over 350 million tonnes. Similarly, for the X Plan, it is estimated that in the terminal year total coal-based power generation would be about 615 billion units requiring around 500 million tonnes of coal. Table 2 clarifies the position.

During the year 1996–97, the availability of coal for power generation was about 94% of the projected requirement. With an increase in coal demand during the IX and X Plan periods by 63% and 43% respectively, there would be greater need for rapid development of coal mines. In the past, after nationalization, the coal industry was able to augment coal supply to the power sector by about 50 million tonnes every five years. However, to meet the projected thermal power genera-

Table 1. Energy resources in India

Resource	Unit	Potential
Hydro-electric	MW	
Conventional		84,000 (at 60% load factor)
Pumped storage		93,920
Micro		5000
Coal	Bln. MT	186
Lignite	Bln. MT	26
Crude oil	MMT	728
Natural gas	BM^3	686
Uranium	MWe	10,000
Biomass	MWe	6000
Non-conventional	MWe	20,000

Table 2. Coal-based capacity, generation and requirement

Year	Coal-based capacity (MW)	Coal-based generation (BUs)	Coal requirement (Million tonnes)
1995–96	50,923	260	195
1996–97	53,323	280	215
2001–02	81,068	435	350
2006–07	111,068	615	500

tion targets, the incremental supply of coal to the power sector, every five years, is likely to be in the range of 150 million tonnes. With the projected increase in coal demand during the IX and X Plan periods, there would be greater need for rapid development of coal mines requiring the indigenous coal industry to plan for production of this order of coal and the creation of coal haulage capacity by the railways, and through coastal routes, keeping in view the massive additional volumes that would have to be transported across the length and breadth of the country.

Electricity is the most convenient of all forms of commercial energy. Against its many unique advantages, it however, suffers from at least two serious shortcomings. Firstly, it is one of the most expensive forms of commercial energy, both in terms of capital and operating costs and second, being a secondary source of energy, its generation has environmental, ecological, social and economic implications for the exploitation of primary energy sources such as coal, petroleum, water and fissile materials. The challenge thus facing us, is how best to go about developing this vitally important but expensive energy source in relation to primary sources so that the larger objective of higher generation compatible with the coal and environmental objectives is achieved. Central to this problem is the adoption of an energy strategy for future that can fuel economic growth and yet do so at relatively lower financial and environmental costs.

It is in this context that today's decision makers are faced with many critical decisions. The need for an optimal energy mix is only one of the decisions that has to be made, but nevertheless an extremely important one. The growing dependability on electricity as the source of energy has greatly increased the public awareness of our energy problems and has caused them to demand solutions that provide not only the cheap but also safe and secure supply of electricity. Opinions on which form of an energy source should be given precedence over others to produce electricity vary, but all tend to agree that a quantum jump in the installed capacity in short, medium as well as long run is urgently required to avoid an energy crisis. As we improve the running of our power plants, energy production will pick up. Energy production growth in June and July this year over the corresponding months last year has crossed 8% after 29 months and the Power Ministry is confident that its short-term measures will keep up the performance. Energy and peaking deficits have declined marginally in July, although the situation is still bad. But as generation growth keeps up, people will very correctly expect better performance in distribution and will turn to questions of costs, reliability and supply.

The cost of generation, at the national level, in hydel and thermal sector at the beginning of 8th Plan and in the year 1995–96 is given in Table 3.

Table 3. Generation costs in hydel and thermal sectors

	At the beginning of the 8th Plan	In the year 1995–96
Hydro power stations	Varied from 10 P/kWh to 69 P/kWh	Varied from 19 P/kWh to 115 P/kWh
Thermal power stations	Varied from 56 P/kWh to 190 P/kWh	Varied from 79 P/kWh to 288 P/kWh

Table 4. Nuclear power station supply rate

Nuclear power station	Existing rate (paise/kWh) effective from	Proposed rate (paise/kWh) effective from
Tarapur	57 (December 1992)	83 (July 1996)
Rajasthan	61 (1992–97)	206 (March 1997)
Kalpakkam	63 (April 1991)	130 (July 1996)
Narora	120 (January 1991)	159 (July 1996)
Kakarpara	207 (May 1993)	204 (July 1996)

Table 5. Factors responsible for increase in generation cost

Item	1992–93 (p/kWh)	1996–97 estimated (p/kWh)	% increase
Fuel	33	47	42
Power purchase	36	57	58
O&M	6	8	33
Establishment and administration	20	24	20
Miscellaneous	2	3	50
Depreciation	10	16	60
Interest	22	32	45
Total	129	187	45

Source: Planning Commission.

The rate of supply from different nuclear power stations to SEBs during the 8th Five-Year Plan is given in Table 4.

The main factors for the increases in the average cost of hydro and thermal generation are given in Table 5.

Fuel cost has been around 25% of the total cost of supply of electricity in the period 1992–93 to 1996–97. Fuel cost is dependent, apart from other things, on the specific consumption of coal and oil in thermal plants (Table 6).

Specific oil consumption in the coal-based thermal units declined from 7.8 ml/kWh in 1992–93 to 5.9 ml/kWh in 1995–96. It is expected to decline further to 5.8 ml/kWh in 1996–97. The situation is better compared to that in the late seventies and eighties. Average specific oil consumption in Assam, Bihar, DVB, Haryana and Gujarat is higher than the all-utilities average. On the other hand, Andhra Pradesh, Karnataka Power Corporation, Tamil Nadu, Maharashtra, Rajasthan and Punjab have lower consumption in the last 5 years. Cost

of coal per unit of supply of power has increased from 53.35 p/kWh in 1992–93 to 73.93 p/kWh in 1995–96. It is likely to increase further to 76.49 p/kWh in 1996–97. In DVB, Gujarat, Haryana, Karnataka, Punjab, Rajasthan and Tamil Nadu, the average cost of coal per unit of thermal generation is higher than the all-utilities average. The main reason lies in higher transport cost, as most of these states are located away from coalfields. These aggregate cost figures hide more than what they show. But they do show the hierachy of fuel costs in electricity – hydel, coal, nuclear. Improvement in PLF in the last five years would have affected specific fuel consumption rates. States away from the coal belt pay for higher costs of transportation.

Future policies cannot be determined by analysis of average costs of the past. The past hides the differences of changing energy mixes, plants of different technological vintages and managerial and financial efficiencies of different orders resulting in plant availabilities and PLFs. To examine various fuel options for power generation the Planning Commission, in 1995, carried out a study for comparison of the cost of generation with various alternative fuels like liquid hydrocarbon, natural gas, coal at different locations in the country considering the availability of fuel and the transportation distance of coal/natural gas and other liquid fuel from the supply point to the power station, etc. The Planning Commission study identified the following as the best fuel options:

i) In the Northern Region, the best fuel options are domestic coal, domestic and imported natural gas and domestic naphtha.
ii) In the Western Region also, the best fuel options are Indian coal and domestic gas. The next best option is imported gas, imported LNG and imported naphtha.
iii) In the Southern Region also, the best fuel options are domestic gas and coal. Imported gas and LNG and imported FO are the next best options.

Table 7 brings out these clearly.

Indigenous coal emerged as the best fuel option in almost all parts of the country. It is important to underline this as all the import agencies highlight only other options. However, it has to be recognized that considering the fact that indigenous coal reserves are available only in selected parts of the country and its availability all over the country for power generation gets restricted due to financial constraints in mine development and that of its transportation, the option of indigenous coal, at least in the present context, is not available at a scale desired. The next best options of domestic gas or naphtha also are practically of academic importance as the available domestic gas has already been over committed and there is no possibility of getting domestic naphtha for power generation, as projected by the Ministry of Petroleum and Natural Gas.

Table 6. Consumption and cost of fuel in coal-based thermal generation

	Fuel consumption per kWh		Fuel cost per kWh	
	Coal (kg)	Oil (ml)	Coal (Paise)	Oil (P)
1992–93	0.75	7.8	53.4	3.7
1993–94	0.76	6.2	62.5	3.7
1994–95	0.76	6.7	68.2	4.3
1995–96	0.75	5.9	73.9	3.6
1996–97	0.75	5.8	76.5	3.9

Table 7. Cost of generation with different fuels (in Rs/kWh)

Fuel type/location	Delhi	Gandhar	Vizag	Cuddalore	IB Valley
Domestic coal	1.99	2.09	1.77	2.13	1.58
Imported coal	2.48	2.16	2.15	2.16	2.26
Domestic gas	1.82	1.90	1.75	–	–
Imported gas	2.14	2.08	2.14	2.14	–
Imported LNG	2.47	2.21	2.21	2.21	–
Domestic naphtha	2.44	2.66	2.61	2.60	2.66
Imported naphtha	2.46	2.19	2.19	2.23	2.29
Domestic FO	2.47	2.48	2.41	2.49	2.55
Imported HSFO	2.45	2.17	2.17	2.21	2.27

Note. These figures were roughly w.r.t. 1994 fuel cost levels. With a naphtha price of Rs 7650/tonne, the levelized tariff of a recent project works out to Rs 2.6/kWh.

With the recent change in the duty structure for the imported coal in the country, which has brought the duty level to 10%, the cost of landed coal at the coastal locations of South India is quite comparable to the cost of landed coal from the mines located in Orissa. During the period 1992–93 to 1996–97, the coal import for power generation in the Southern states increased from 0.17 million tonnes to 3.80 million tonnes. Though the total import during the year 1996–97 is only about 1% of the coal production in the country, this throws open new possibilities at least for the states in the Southern region, which are located far away from the coal-bearing areas of the country and close to sea coast.

The country, today, has an installed capacity of over 85,000 MW with the utilities generating nearly 395 billion units of electricity. In addition, it is expected that over 10,000 MW power-generating capacity is captive to industries. The country is bestowed with vast power grade coal reserves and large hydro potential and therefore, most of the generating capacity in the country is logically based on either indigenous coal or hydel. By the same logic, even the incremental generating capacity should have been mainly based on the available indigenous energy resources in the country. However, there is a time factor also to be kept in mind. The country not only needs power, it needs to be assured that power would be available continuously, on demand for all the

economic and social activities and on this front there cannot be any slip-ups. Given the investments in the fuel sector in the country in the recent past, particularly the coal sector – inhibiting rapid expansion of coal-producing capacity to match the growing demand, the limited availability of natural gas and other liquid fuels in the country for power generation, it is quite unlikely that the fuel requirements of the sector would be met out of indigenous energy resources and considering the gestation periods of various types of power projects in the country and the preparedness in terms of advance action for new generating capacity and also the possibility of short supply of coal to the power sector, power-generating capacity based on liquid fuel appeared to be the only practical way to:

i) Avert a severe power crisis in view of the relatively long gestation period in case of hydel projects and projects based on coal or lignite.
ii) Supplement the coal-based power generation as coal supply to power industry is likely to fall appreciably short of the project demand.

This, however, as we all know, is a short-term arrangement primarily aimed at meeting the immediate energy demand. The country would need a long-term policy to fuel its power sector which should take into consideration the constraints in developing the locally available resources and the impact of any long term and large scale import of fuel. The analysis of the past few decades clearly shows that the use of coal and to some extent gas as the principal source of energy has been increasing more than proportionately. In 1996–97, for instance, some 75 per cent of our total power generation came from coal and gas. Coal is our most abundant fossil fuel resource. Naturally, the reliance on its use has been more. The increasing reliance on coal has predictably put considerable pressure on coal-mining activity and transport infrastructure. Thus a view is gaining ground that coal, though important in medium and a short term, alone will not solve our energy problem. Even if the coal industry can achieve its difficult goal of tripling production in another 10 years and railway infrastructure is able to undergo a revolutionary change, the task of capacity addition of over one lakh MW in the next ten years or so cannot be met by coal-based thermal units. Furthermore, as we look to the long term, perhaps in second quarter of the next century, when the world wide reserves of oil and natural gas approach depletion and coal is to be hauled from much deeper depths, seeking alternatives from now onwards are inescapable. A study I had got done in the BICP had shown that the long run marginal cost of coal was rising on account of increase in depth of underground mines and gassiness (partial real resource cost elasticities were as high as 0.6 with cost functions estimated from coal mines (Alagh, Y. K., *Indian Development Planning and Policy*, Wider Studies in Development Economics, Vikas, 1992, pp. 216–217). Alternative energy sources are available, but are at present either undeveloped technologically or underutilized. Some of these energy sources are renewable, such as solar radiation, hydro, wind, tidal energy, etc. Others are depletable, but relatively untapped, such as geothermal heat or synthetic fuels from coal or wastes.

On the supply side, the other possible alternative could be the fuel substitution for power generation, particularly in those regions of the country where economically-exploitable reserves of conventional fuel for power generation such as coal and petroleum products are not available. Hydel energy and nuclear energy, thus, seem to be the only realistic alternatives which hold the promise of substantially contributing to energy requirements. Most of the undeveloped hydel potential in India is concentrated in northern and north-eastern regions. CEA has in two recent reports brought out practical policies for prioritizing hydel investments. More resources need to be spent on geological and hydrological studies and project formulation. Poor project investigation has led to cost and time overruns. An agency for this purpose and adherence to the Project Appraisal norm approved by Lovraj Kumar that up to 1% of project cost can be spent on project formulation needs to be thought of. More than 6000 MW of small run-of-the river and canal schemes have been identified which have short gestation cycles and no serious environmental problems. These need to be implemented soon. The Ministry of Power has provided a financing package for this. If pricing and transmission problems are resolved, more private investment should also be possible. Nuclear energy clearly emerges as another viable option that can complement and supplement the coal-based capacity addition programme substantially. If we see the natural resources and the infrastructure available in the country, I see no reason why nuclear power should not be developed at the required pace. We have the worlds' largest reserves of thorium and some fairly large deposits of other fission materials. Over the years we have perfected the art of exploitation of nuclear energy. With the successful commissioning of Kamini Fast Breeder Reactor even though on an experimental plane, we are well on the way to mastering the nuclear fuel cycle. Our nuclear plants are now running well. Financing problems have to be resolved for more ambitious programmes.

On the demand side, the alternative has to come from load management measures and increased end use efficiency, ultimately leading to tapering of demand. Energy conservation methods can surely help to a certain extent to reduce the shortages and, therefore, we have accorded it very high priority. Higher productivity in generation and efficient energy conservation programme is extremely vital and its importance has been well recognized by the Government. Higher PLF and better demand management would translate into higher availability of power at a much cheaper cost. As a matter of fact, energy conservation has been identified as a very important component of the overall strategy adopted by the Government to im-

prove performance of the power sector. In fact, the Central Electricity Authority (CEA) has estimated that by the year 2006-07 (end of the 10th Five-Year Plan) about 15,000 MW could be saved by energy conservation measures alone. Another 15,000 MW could be saved if demand management measures are taken up in right earnest. Thus, there is scope to roughly save about 30,000 MW by 2006–07 by way of energy conservation measures. This is a significant quantity and we are committed to adopt measures to improve the productivity of our generation resources both conventional and non-conventional and at the same time save energy to plough back the benefits. We are equally concerned about the high transmission and distribution losses in our country, which are of the order of over 20%, and happen to be one of the highest in the world. We have initiated several steps to contain these to a reasonable level.

Yet another area which is extremely important is pricing of fuels for use in different sectors of the economy. In our country, fuel prices are generally fixed by the government under the Administrative Price Mechanism (APM). The APM, besides considering the commercial aspects of fuel price also takes into account the social considerations in fuel use and arrives at a price which may not always be commercially most efficient. As we all know, pricing is a strong mechanism through which efficiency in use and proper selection of a fuel for any particular purpose can be made. At the same time if the fuel price does not reflect the true cost of delivery and is not sensitive to the opportunity cost, it not only leads to injudicious use of the fuel, the distortion thus created gets reflected in utilization pattern of other fuels as well and in the extreme case the entire economy pays the price for it. The case in hand is selection of naphtha for power generation. It is widely known that naphtha is not the preferred fuel for power generation. It offers a much better economic value when used as feedstock in fertilizer and petrochemical industry. In addition, naphtha prices in the international market are more upwardly volatile compared to any other fuel in the same category. However, because of the disparity in price of other white oils in the same category under the APM – prohibiting their use as primary fuels for power generation – naphtha gets selected as fuel for power generation. The mechanism by which price of any particular fuel is determined also gets reflected on the way the fuel industry grows. Presently, for coal to be supplied from a mine developed by the Coal India Limited, a pooled price is charged even though the coal from the newly-developed mine costs substantially more than the pooled price charged. This greatly inhibits development of coal mine through private sector as the transfer price of coal, mined from a mine developed in the private sector, would have to be comparable with the coal price of a new mine developed by Coal India. Presently, there is no mechanism for determining the transfer price of coal to a power project and institutional arrangements to decide transfer price of coal from captive mines must be put in place.

In the ultimate analysis, it appears that probably there can be no general solution on a long-term basis to our fuel-related problems. We have to continuously strive for selection of the best combination of fuels, including their sourcing, the technology for their exploitation and use, etc. to arrive at a fuel mix that results in the lowest cost to the user. In order to arrive at the least cost option and an option that assures availability of fuel for power generation and other economic activities, we must also increase the end use efficiency through demand side management and energy conservation methods. It is heartening to note that the 'Approach Paper to the Ninth Plan' prepared by the Planning Commission, lays enough emphasis on a combination of fuel options and attempts to address the possible bottlenecks created by the non-availability of indigenous fuels. Among other things, the paper identifies promotion of hydro-electric resources as a major thrust area. Emphasis has been laid on better utilization of available capacity through increased productivity, reduction in losses, energy conservation and demand side management, etc. Option of importing fuels such as coal and other hydrocarbon products have been identified to bridge the demand gap. The approach papar also suggests steps to improve reservoir management to enhance oil recovery along with replacement of the administered pricing mechanism by a more rational pricing mechanism reflecting cost of supply. It is expected that these planned measures would pave the way for better management of our energy resources and would be able to meet the galloping demand for energy products in the country.

We have sketched the main options available to us. Domestic coal and imported gas as options have been discussed. There is unfortunately not as much discussion of the options available to us and the policies required to make the best use of them, in our interest, as is necessary. These are large and expensive project choices and a policy framework in the period in which energy price reform is underway in a phased manner is obviously important. Scale advantages lead to large cost advantages, whether it is power generation from coal, HDCV transmission or recondensation of imported gas and wrong or delayed decisions can be very costly. Inter country water and energy flows and joint projects now under consideration will need to be seriously evaluated as an option also. It is important that a strategic policy framework is established in which market policies and public initiatives can lead to India producing cost effective and sustainable energy for its millions of farmers, artisan, workers and households.

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