Nuclear Power for Eastern India

No Basis for Choice

The nuclear establishment has clearly acknowledged that nuclear power is more expensive than thermal power within a 1,000-km radius of the pithead. So why is it looking for a site for a nuclear power plant in West Bengal and eastern India?

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The central government's move to locate a site for a 1,000 MW nuclear power station in West Bengal, a state endowed with rich coal base appears to be in sharp contrast to the stated policy in recent years. From the inception of the nuclear power programme it has been claimed that nuclear power was safer and cheaper than thermal power at all locations irrespective of their distance from the pithead in India. Towards the end of 1980s however, nuclear scientists conceded that the thermal power was cheaper than nuclear power at locations beyond 900 to 1,000 km away from coal fields.

Faulty Methodology

Leading nuclear physicists had been claiming for some time that the nuclear power was cheaper than thermal power even at the pithead. It is generally acknowledged [Raja Ramanna 1985; M R Srinivasan 1986] that the cost of nuclear fuel power per unit of energy generated would be much less than that for coal. Comparative advantage of nuclear energy can be established easily if it could be shown that the capital cost of nuclear energy was also less than that for thermal power. This is precisely what Srinivasan showed (see the tables reproduced below from a lecture delivered in 1986). The figures in the two tables differ slightly. This does not however affect the arguments developed here. The results of the exercise in Table 1 show that even though the capital cost for thermal power is marginally lower than that for nuclear plant, generation cost for thermal power always exceeds that for nuclear power at all locations irrespective of their distance from coal base.

What is unusual in the results is the closeness, or higher value, of the capital cost for thermal power plant to that for nuclear plant. For, in terms of hardware, the nuclear plant is more complex and costlier between the two. Nuclear reactor replaces the boiler in the thermal plant for generation of heat and steam. Beyond this, the turbine and generator and auxiliary equipment remain common for both the systems. The nuclear plant needs in addition a fuel processing unit to fabricate fuel rods from uranium ore and preparation of heavy water for the Indian reactor. One would therefore expect the capital cost of nuclear power plant would be substantially higher than that of thermal power. Explanation for the contrary result can be found in the figures in Table 2. It may be seen that a large proportion of investment cost for thermal power, around 44 per cent of the total, is accounted for by investment on exploration and mining of coal and transport facilities for coal. This method of loading on the cost of coal, an item of variable cost, the fixed cost for power generation defies the principles of economic accounting. Since the cost of fuel, like wages and other inputs, varies with the level of generation of power in a plant, they are treated under variable cost in the accounting procedure. This reflects the actual condition when a power station purchases coal from the market at the ruling price. It should be noted that the price of coal in the market is determined by the coal mine authority after calculating the fixed cost and the variable cost involved in the production of coal. Similarly for the railway authority, the freight rates are determined after accounting for the fixed cost and variable cost involved in the transport of coal. There is no point therefore in including the investment costs for mining and transport of coal in the accounting for cost of thermal power.

There can be a case for including investment costs for mining and transportation of coal, or uranium fuel, if the power generating authority actually owned the assets for themselves. Even in such cases the price of fuel would not exceed the price availing in the market for the same. It would be uneconomic to own the assets if it were otherwise. It is unfortunate that renowned nuclear scientists in India had been building their arguments that nuclear power was cheaper than thermal power even at the pithead on foundations of quick sand. The pity is that the fallacy had been pointed out as early as in 1979 [Bose 1980].

The cost of nuclear power was separately calculated in another study [Bose 1981] following the procedure adopted in a publication by the American Physical Society and the Institute of American Physics in 1978 which provided a methodology for "an independent evaluation of the technical issues in nuclear fuel cycles and waste management together with their principal economic, environmental, health and safety implication" [APS 1978]. The result of analysis were published in 1981.

In the absence of information required for calculation of fuel cycle cost from Indian source the exercise for the study was based on the APS example of heavy water reactor in the US. The data were adjusted for Indian condition by taking appropriate ratios of capital costs for a 200 MW heavy water reactor in the US and India respectively. The results showed that the cost of power generation by a coal-fired plant located at the pithead would vary from 14.91 paise to 18.84 paise at 1977-78 for capacity factor varying from 60 to 80 per cent. Comparable figures for the nuclear plant with recycling of spent fuel ranged between 17.52 paise and 22.08 paise. Nuclear power could then compete with thermal power if the differences were covered by transport cost of coal. At the prevailing freight rate the break-even point was at a distance of 750 km from the pit head. Nuclear scientists in India however remained unimpressed.

Nuclear Power at Load Centre

In a subsequent paper in 1989, Srinivasan showed greater realism in presenting the data for the pithead power stations as in Table 3.

The table shows the cost of thermal power to be cheaper at the pithead and the nuclear power cheaper at load centres distant from coal mines. There was no indication however of the capital costs for the two technologies respectively. In 1997 Y K Alagh, union minister of state for power, made a specific reference to eastern region in a statement about the cost of nuclear power.

> The coal deposits in India are concentrated in the eastern regions. The setting up of a coal fired power plant in western and in the north-west entails transporting coal over distance exceeding 1,000 km. As the distance involved in the transportation of coal from a mine mouth exceeds 1,000 km, the economics of nuclear power becomes favourable [Alagh 1997].

In a recent paper a comparison of the cost for the two technologies has been presented by A K Nema (1999), the convenor of a study committee set up by the Nuclear Power Corporation of India. The analysis concerned plants with 2 × 500 MW capacity for both nuclear and thermal power which could be operating in 2004-05. The capital costs at 1997-98 price level have been taken at Rs 5.23 crore and Rs 3.75 crore per megawatt for the nuclear and the thermal plants respectively. The distance of the thermal plant was taken to be 1,200 km away from pithead, presumably because thermal power plants any closer to a coal field generated cheaper electricity than did nuclear power. Nema followed alternative methods of calculation, levelised cost at constant price and return of equity method, for cost analysis. The levelised cost method is generally used at international levels for purpose of comparative analysis [Jones and Woite 1991].

Table 4 shows the results of analysis by levelised cost method. The cost for nuclear power in the table turns out to be cheaper than coal only at discount rates below 6.7 per cent which is seldom considered. The Central Electricity Authority uses 12 per cent discount rate in their calculations for planning and evaluation of projects. The nuclear power remains costlier than thermal power at 10 per cent and higher discount rates. Similar conclusions were reached in the study prepared by International Atomic Energy Agency in 1991.

This begs the question why, given this information, the department of atomic energy should direct the government of West Bengal to look for a suitable site for installation of 1,000 MW nuclear power plant in the state and why the state government should want the power plant for the same.

Open-ended Account

A perplexing feature in the comparative analysis of nuclear and thermal power is that the costs of the two technologies are not strictly comparable. While the accounting for thermal power closes with the disposal of fly ash within a definite period, that for the nuclear power remains open for an indefinite period. Fly ash generated by a thermal power plant during its life time is disposed of by use in the manufacture of bricks and cement, land fill and road building, and in filling up of abandoned open cast mines. To the extent these substitute for irreplaceable top soils their impact on environment is benign. In economic terms there are credits for such use of fly ash. At the end of a life time a thermal power plant is scrapped and sold in the market to earn further credits in the account. Emission of smoke and CO_2 contributing to the greenhouse gas, though not appearing in costing are, however, damaging to environment.

Waste generated by the nuclear power plant, however, stands out in sharp contrast. The fuel rods, large part of the plant, and some of the liquid effluents, all become highly radioactive and remain so for indefinite period. It has not been possible to devise any means of their disposal. About 50 types of elements in the waste remain highly radioactive for periods ranging from a few weeks to over 24,000 years. Radioactivity of plutonium, the most poisonous element entirely created by man, decays to half in 24,000 years. It takes four half-lives, 96,000 years, before it completely decays. All through these periods, the dangerous wastes have to be stored carefully in protective containers so that the environment is not affected by radioactivity. The span of history has witnessed the rise and fall of civilisations leaving only a few traces behind. Whether humankind or nature will continue to ensure the protective custody of the radioactive waste over the next 2,000 years or beyond as required by the demands of time is a moot point. This prompted eminent scientist Weinberg, an advocate of nuclear power, to exclaim in anguish "We nuclear people have made a Faustian bargain with society. On the one hand we offer – in the catalytic nuclear burner [the breeder] – an inexhaustible source of energy...But the price that we demand of society for this magical source is both a vigilance and longevity of our social institutions that we are quite unaccustomed to" [Weinberg 1972].

Just as physicists are required to consider the containment of radioactivity of the nuclear waste beyond centuries, economists are also required to account for the costs that would be incurred on maintaining the repository of the waste material over the centuries in the future. Economists are in no better position than the physicists to meet the challenge. The conventional practice in accounting is to reduce to present value all values of costs or returns accruing in future years by discounting them at appropriate rate of interest. The discount factor is given by $I/(1+r)^t$, where r is the rate of interest and t, the year to which the value refers. The factor reduces in value for a given rate of interest over the years. At 15 per cent rate of interest the factor reduces to 0.0009 in the 50th year. Because of this Rs 10,000

Table 1: Projected Costs of Nuclear and Thermal Power Plants to be Commissioned in 1992

	Nuclear 2 × 35 MW	Thermal 2 × 210 MW Located at Pithead	800 Kms from Pithead
Capital cost ($ KW)	1280		1229
Unit energy price (mills/Kwh)			
Return on investment method			
i) Generation: 5,500 Kwh/KW	82	84	99
ii) Generation: 6,570 Kwh/KW	70	76	91
Discounted cash flow method			
i) Generation: 5,500 Kwh/KW	69	71	86
ii) Generation: 6,750 Kwh/KW	59	65	80

Source: Srinivasan, 1986.

Table 2: Total Fuel Cycle Investment Cost

	Nuclear Per Cent$	Thermal Per Cent
Exploration	1	
Mining	4	20
Coal transport (800 km)	–	24
Fuel fabrication	2	–
Heavy water	21	–
Power Plant	73	56
Total	100	100
Total ($ KW)	1280	1320
Break-even cost ($ 6000 Kwh/KW)	1400	1400

Source: Srinivasan, 1986.

expected 50 years later would appear to an investor in the current year as Rs 9 only. Implicit in this method of accounting is that the present generation can ignore any cost that may be incurred by future generation inheriting the earth in 100 years time. The present generation enjoys the benefit of energy from nuclear plants and the future generation which does not share the benefits bears the cost of carrying the storage of waste under protective custody. Unlike thermal power radioactive wastes do not yield any credit to the account of nuclear power but only adds to its cost side for indefinite number of years.

Similar differences between thermal and nuclear power plants holds in respect of the equipment and structures at the end of the life of the plants. Here again the structure of the nuclear plant and its reactor are contaminated with a high level of radioactivity from operations over their life time. They have to be carefully dismantled and placed under protective custody along with other wastes. Decommissioning of nuclear power plants is a costly affair, accounting for about 4 to 13 per cent of the capital cost. This raises the capital cost of the nuclear plant further. Treatment of the wastes generated during operations and materials remaining to be scrapped after the life of the plants is diametrically opposite for the two technologies. One earns credit and the other adds to the cost in the accounting for generation of power. In one case the account can be closed, in the other it remains open-ended. That is why the nuclear power will remain costlier than thermal power in any comparison between the two technologies.

Coal and Environment

A point is made that the reserve of coal being limited there will be a time when we have to depend on alternative energy source. It has been suggested that coal may be exhausted in less than one hundred years' time in India. Some advocates of nuclear power have been urging the acceleration of the nuclear prograrmme on this ground. The fact however is that the proved reserves of coal in India stands presently at 82 billion metric tonnes according to the Geological Survey of India [GSI 2000]. The availability of coal per year in 1998-99 was around 292 million tonnes according to the ministry of coal. The Central Electricity Authority observed in one of their reports that the availability of indigenous coal in the country will have to be restricted at the level of 400 million tonnes per annum for practical purposes during the 11th Plan period, from 2007 to 2012 [CEA 1998].

Even if coal were used at the rate of 400 million tonnes per year, which is much higher than available presently, the stock of proved reserve would last for more than 200 years. Given some allowance for the fact that some of the proved reserves may not be accessible easily one can see that there is a safe margin of more than 150 years for the coal to exhaust in our country. This gives sufficient time to the scientists to find ways to resolve the outstanding problems of nuclear power instead of urging for acceleration of nuclear power programme on the specious argument of exhaustion of coal. But 150 years is not a very long period in the history of mankind. One has to find alternative sources of energy before the exhaustion of fossil fuels.

It has to be acknowledged that coal also has harmful impact on environment. Smoke from burning of coal in industries carry with it oxides of sulphur, nitrogen and carbon contributing to formation of greenhouse gas in atmosphere. Industries, particularly the electricity industry, have been adopting a number of measures to reduce emission of noxious gases in the smoke. While there has been significant progress in the treatment of oxides of sulphur and nitrogen in the smoke originating from combustion of coal in industrial boilers, treatment of CO_2 has proved less tractable. But CO_2 is a major constituent of greenhouse gas. As coal will continue to be used in industries for at least one hundred years all around the world CO_2 will continue to accumulate in the atmosphere,

However, it was only in 1980s that the statesmen took serious notice of the likely impact from the greenhouse gas, Kyoto Protocol calling for reduction of CO_2 emission was signed by various nations only in 1997. Nevertheless within the short span of years till now the scientists have come up with results that promise solutions to the problem. Carbon can be sequestered, i e, bound in repositories, by injecting in the ocean or geological reservoirs. Methane confined in deep coal bed can be displaced by injecting CO_2 allowing coal bed to serve both as a gas source for power generation and a highly stable repository. A zero emission electricity generating plant is at planning stage for a pilot scale unit in Alberta, Canada. Carbon sequestration in soils through tillage is another area under investigation now.

Afforestation has been a proven means for capturing CO_2 through photosynthesis. Land, forests and water bodies including oceans are now considered as useful repositories for CO_2. The United Nation's Framework for Convention on Climate Change (UNFCCC) has assigned to renowned scientists the responsibility for assessing earth's capacity to serve as sink for greenhouse gases and the possibility of its expansion. The developed countries have been participating in international programmes to extend the area under forests, specially in the tropical countries.

Feasible Alternatives

Advocates of nuclear power claim that given the present state of the art nuclear power remains the only feasible alternative to fossil fuels. It is generally thought that renewable energy like solar photovoltaic cell (SPV), wind energy, fuel cells, etc, are far removed from applications on wide scale. Actual facts will dispel such notions, It is not widely known that in

Table 4: Levelised Costs of Power Generation (1997-98 constant price)
(*Paise per unit*)

Discount Rate (Per Cent)	Nuclear	Thermal
5	177	186
10	249	225
13	306	254
Break-even discount rate 6.7	198	198

Source: Nema 2000.

Table 3: Energy Costs for Operating Stations
(*Paise/Kwh*)

Atomic Power Stations		Thermal Power Stations	
Tarapur	43.47	Korba pithead	40.52
Rana Pratap Sagar	44.48	Wanakbori	63.66
Madras	50.82	Singrauli pithead	40.46
		Kota	76.05
		Neyveli pithead	53.00
		Tuticorin	61.55

Source: Srinivasan 1989.

1997 India had an installed capacity of 902 MW of wind power, accounting for 1.05 per cent of total capacity. With 39 MW of SPV cell, 271 MW of small hydel plant and 132 MW of bio-mass based units, the percentage of renewable energy would be around 1.5 in 1997. As against this, installed capacity of the nuclear power in 1997 was 2,225 MW, being 2.59 per cent of the total power generation capacity of 85,795 MW. While nuclear power was developed over 50 years, the capacity for the renewable energy was built up with intense activity over the last two Plan periods.

It is not true that renewable energy can only be worthwhile at remote places where electricity cannot be reached over grid lines economically. In developed countries like Japan, Germany, Scandinavian countries, Switzerland, and the US, solar photovoltaic cells have moved over from remote sites to the stage of commercialisation in the urban centres. The Sacramento Municipal Utility District (SMUD) in California had to close down in 1993 a nuclear power plant under it as it had been suffering severe cash losses. SMUD installed 3 MW of SPVs and 350 rooftop SPV systems in Sacramento. Consumers agreed to pay higher tariff to stimulate the development programme. SMUD has been operating wind power in conjunction with hydro power to back up the peak demand on the grid. SMUD also installed two 200 kw fuel cells using natural gas as its source of hydrogen. Capital costs of fuel cells are now considered competitive with new thermal plants [Smeloff and Asmus 1997]. These are not mere straws in the wind. They are indications of the future.

There is a feeling among a section of population in the states in the coal regions of India that they are being denied access to an advanced technology because of the policy of siting nuclear power stations away from the coal fields. One can sympathise with this sentiment. However, there is a misconception that nuclear power is the only means to access nuclear technology. The heart of nuclear technology is the nuclear reactor which has more functions than substituting for a boiler to produce steam for power generation. Besides the nuclear reactor a power station shares in common the turbine and generator for both nuclear and thermal power technologies. It is the nuclear reactor that distinguishes nuclear power system from the thermal one.

From the very inception nuclear research has been centralised and an exclusive preserve of Bhabha Atomic Research Centre (BARC). Scientists in Indian academic institutions do not have the liberty to work on nuclear reactors to research on problems relating to nuclear fission, radio isotopes, etc, for themselves unless they belong to the exclusive community under BARC. In western countries major universities and engineering institutions have their own nuclear reactors for research. The institutions under the department of atomic energy (DAE) in India have become the sole repository of wisdom on the subject. This was a position disputed by no less a personality than Meghnad Saha who wanted scientists in academic institutions to involve in nuclear research independently. Saha secured for the Institute of Physics at Calcutta a cyclotron. The Institute, renamed Saha Institute of Nuclear Physics after his demise, could not retain its independent status for long. BARC took it under its fold in 1992. So long as the DAE keeps its monopoly hold over nuclear research in India the presence or absence of nuclear power stations in any state will not make any difference to the position. The nuclear power reactor is an operational equipment. It cannot be a substitute for a research reactor.

State control of nuclear plants is shrouded under secrecy. The Atomic Energy Act of 1962 prohibited any transmission of information by the agencies involved in nuclear research or power generation. A myth is created that nuclear technology is too dangerous to be disseminated freely. This is far from truth. In fact, manufacture and operation of nuclear power station have been undertaken by private enterprise in a number of countries besides the US. In the competitive market data were freely available. Economics of nuclear power could not be concealed. It was the hard realities of the market that failed nuclear power in the US and other countries.

When the government becomes the only agency for generation of power, data supplied by the nuclear establishment cannot be cross-checked. The methodology of estimation of costs are not explained that one may scrutinise the estimates independently. This devalues the credibility of the data provided. Such was the experience with the Central Electricity Generating Board (CEGB) under the government in the United Kingdom. CEGB had claimed in 1988 that the cost of nuclear power would be lower than thermal power. Subsequent costings for nuclear power was found to be much higher than those of fossil-fuel based power generation. The secretary of state reported to the House of Commons on November 9, 1989 that “the costs of nuclear power remained hidden throughout under nationalisation, and it was only preparations for privatisation that brought them to light.” The Conservative government then in power backed out from the move for privatisation of nuclear power as no private entrepreneur would invest on it in the UK.

Nuclear Power Unsafe

Contrary to the claims of the nuclear establishment, there have been serious accidents in the nuclear plants in India. The Official Secrets Act and Atomic Energy Act of 1962 have been protecting the power station authorities from the prying eyes of the media, Gopi Rethinaraj (1999) has compiled a list of such incidents. In March 1999 huge quantities of heavy water containing radioactive tritium leaked out from a special instrument used during inspection of a defaulted tube at Madras Atomic Power Station. No information could be obtained by the press from the power plant officials. It was only the workers’ union at the power station, who were already concerned with such incidents in the power plant, which provided some information to the media. Caught on the wrong foot the power plant officials were finally obliged to admit that six tonnes of heavy water had leaked out at the time. They claimed that this was ‘insignificant’ and was part of “planned escape of heavy water from the fuel machine vault”. Their assertion of the ‘insignificant’ incident was however negated by the plant authority declaring a plant emergency after it.

Rethinaraj reports on a series of accidents in the power stations at Narora, Kakrapar, Rajasthan, Kaiga and Tarapur between 1989 and 1999. The information reported were based on those that could break out of the curtain of secrecy. It leaves one to imagine what percentage of total number of accidents they represent. There are grounds for such surmise. The chairman of the Atomic Energy Regulatory Board, A Gopalakrishnan, submitted to the government of India a comprehensive report on safety issues and deficiencies at the installations under the Department of Atomic Energy in 1996. The report caused much resentment and hostility among the officials against Gopalakrishnan. An exasperated Gopalakrishnan resigned from the position and revealed that there were 130 cases which related to safety in the various nuclear installations which could not be elaborated because of the Atomic Energy Act of 1962. Efforts by NGOs in Mumbai to secure more information were blocked by the department with the plea that the documents asked for were classified, highly technical and sensitive in nature. The department maintained that transparency could not supersede the interests of national security. The argument sounds hollow in the face of the practices followed in the countries where private enterprise operating the nuclear power plants is open to public scrutiny and technical literature published provides relevant information. This however does not stand in the way of transferring spent fuel rods to the military for extraction of plutonium for preparation of bombs or nuclear weapons. So much for the peaceful use of nuclear energy. Nevertheless, whether the spent fuels from nuclear power plants will be used for weaponisation or for 'safe' storage remains a matter of policy at the national level. For instance, France and Japan which are largely dependent on nuclear power because of lack of other energy resources in their countries have not gone for weaponisation. On the other hand the US and erstwhile Soviet Union made the most of the nuclear power programme to collect plutonium for military use.

It may be noted that nuclear power generation has greater risks of accidents than thermal power generation because of technical reasons. The boiler in a thermal power station can withstand shocks from failures in power supply to it with less damage to itself than a nuclear reactor under similar condition. For, any failure in power supply to a reactor can lead to disastrous consequences. A power failure may immediately check the flow of coolant or liquid moderator in a reactor resulting in overheating and a threat of core meltdown. Rethinaraj cites three instances of fire causing failure in power supply at Narora, Rajasthan and Kakrapar Atomic Power Stations leading to near explosive situation. A serious incident the Narora Power Plant was prevented by some brave technicians who manually opened valves and poured borated heavy water down into the reactor to halt the nuclear chain reaction. The reactor was very close to meltdown that day, said Gopalkrishnan.

Much is made of the small number of casualties in the accidents in nuclear plants. This is not the complete truth. The nuclear plant is a highly automated system of production. All the operations in the nuclear reactor are remote-controlled for protection agaist radiation hazard. The number of persons engaged in operations of the power plant is therefore necessarily small. In the Chernobyl disaster, for instance, the number of persons directly affected including the fire fighters who received radiation in excess of 500 rads was only 50; 32 of them died within a short period. Lingering death awaits the others. The larger number of casualties were those that were indirectly affected by invisible radiation effects though living away from the plant sites. How many among the 1,35,000 persons shifted from within 30 km radius of the Chernobyl nuclear plant will die of cancer can only be estimated because many of them cannot be traced after dispersion to other areas. An American physician treating the victims of Chernobyl estimated that between 5,000 and 50,000 people would die of cancer in the Soviet Union and the rest of Europe [Flavin 1987]. Nobel Laureate Alvin Weinberg, a renowned advocate of nuclear power observed after Chernobyl that "supporters of nuclear power must accept the idea that nuclear hazard is somewhat different, that the notion of interdicting land with an unseen agent is viewed by the public as particularly threatening" [Weinberg 1986].

Regulated Board

The Atomic Energy Regulatory Board functions under the department of atomic energy. The Atomic Energy Commission which oversees and monitors the activities relating to nuclear energy, operations of power stations and research, is also under the department. The power station management, taking advantage of being under the same department, can afford to ignore the directives of the Regulatory Board with impunity. Such has been the experience of the Board ex-chief A Gopalakrishnan.

The Atomic Energy Regulatory Board is not an independent body. The DAE secretary is answerable to the Board on the safety issues for the nuclear plants under the department, the Board in its turn is to report to the chairman of the Atomic Energy Commision. A peculiar situation develops when the chairman of the Commission and the secretary of the department happen to be the same person. The countries' top nuclear scientists do not find any irrationality in the situation. EPW

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