Chapter 7

NUCLEAR POWER

A nuclear power station has been started at Tarapur in Maharashtra with two reactors (or piles) with an installed capacity of 420 MW. This station went into operation in October 1969. Power generated here is equally divided between Maharashtra and Gujarat. The second atomic power station is being set up at Rana Pratapagar in Rajasthan. Its initial capacity will be 200 MW which will be later augmented by as much. A third station with a capacity of 400 MW is being established at Kalpakan in Tamil Nadu. A few more are on cards, there being one for each Zone.

The Debate

When the discussion in respect of starting the programme of nuclear power in this country started in 1958, the first reaction was almost entirely hostile. Thanks to the tenacity of the first two Chairman of the Atomic Energy Commission which was established in August 1948 (Dr H.J. Bhabha and Dr V.A. Sarabhai) and particularly to the Prime Minister Pandit Nehru who was bent on leading India on the way to modernization, the country initiated the programme in the middle of the sixties. By the results of the first nuclear power station at Tarapur, some of the hostile opinion was reconciled to its establishment, though it has not
altogether ended. Some of the prejudices surfaced at the beginning of 1972 when, for some time, the supply was only partially made or stopped for refuelling and rectifying some defects in the Tarapur power station.

The initial reaction was expressed by press and also by some economists. A special correspondent of the Times of India wrote a long despatch criticising the proposal of Dr Bhabha and concluding in these words: "It would appear that from the economic point of view, which according to the Prime Minister must have the primary consideration, this country need not think of going in for nuclear power for at least another decade or so. If there are any non-economic reasons for undertaking the atomic power projects here and now, these have not been revealed to the public."

Within a few months the same paper wrote editorially: "The fact, however, remains unaltered that except from the point of view of having a showpiece the country has no need now to think of atomic power, and expenditure on it will only mean depriving the country of a more plentiful and cheap supply of electricity."

Among the influential economists, the two reputed foreign scholars were I.M.D. Little and P.N. Rosenstiein Rodan. They expressed their views in 1958 and 1959.

1. The Times of India, 19-12-1959.
2. The Times of India 11- 8-1959.
respectively. It is curious to note that these two economists had written a joint report in 1957 in which they had recommended nuclear power programme for Italy from 1960. Why not for India? It is necessary to consider the objections raised by these economists and to see how they could distinguish Italy's case from that of India.

Dr Little criticised the cost calculations which Dr Bhabha had presented at the Second Conference on Peaceful Uses of Atomic Energy at Geneva in 1968. Dr Bhabha in his schemata of nuclear power for India put the capital cost at Rs 1700 per kW (nuclear) as against Rs 1050 per kW (thermal), assumed the Plant Factor of 80%, the thermal efficiency of 28% for nuclear plant as against 25% of thermal plant and annual capital charge of 9%. Dr Little pointed out that the capital cost of thermal station was Rs 750 per kW, Plant Factor would be 65%, thermal efficiency of new thermal stations was 33% and annual charge for nuclear plant should be 15%. As against Dr Bhabha's calculation of the unit cost of nuclear power to be 3.9\text{\$} for 4.6\text{\$} (as against 3\text{\$} and 4\text{\$} for thermal power), Dr Little put it at 6.8\text{\$} or 7.5\text{\$} (as against 4.6\text{\$} in respect of coal-based power). His

conclusion, therefore, in the light of India's scarce capital resources was thus stated:

"The longer India waits, the more free benefits she will get from the immense investment which has been poured into nuclear physics and engineering in the USA and the UK. To put any of her own capital resources into buying the earlier products of the Western research would seem to be a great waste of the very limited savings of the Indian people. As Dr Bhabha says, electricity is in short supply in India. It is likely to go on being in short supply if one uses twice as much capital as is needed to get more."

Dr Rosenstein-Rodan reiterated some contentions of Dr Little. The reasons that he adduced against nuclear power production in underdeveloped countries were these: To be economical the power stations have to be large (i.e. 100 mW or more); Plant Factor has to be high (i.e. 75-80%); efficiency of 28% has to be established and capital charge has to be high (i.e. 15%). Of these conditions the first three are not likely to obtain or be satisfied in underdeveloped countries like India. Dr Bhabha visualised that in the second and third stages in his nuclear power strategy

India's abundant supply of thorium could be used, U-233 breeder would be developed and also that plutonium produced would be sold outside the country. There was, according to this critic, a great uncertainty about each of these. He therefore, made a sarcastic remark which is worth quoting, at least as one of the best quips in economic literature.

"The third generation atomic power station argument of Dr Bhabha does not justify the initiation at present of a nuclear power programme in India. When a man is hungry he may pay a high price for food but he should not proceed to buy a restaurant."^5

Having recommended a nuclear power programme for Italy, why should these economists be opposed to India's plans? We may make our surmise. These economists had emphasized in respect of Italy the following two points. (1) Italy has to import oil and coal. Italy's unused hydro resources were very limited. (ii) It was possible for Italy to benefit from European cooperation in developing nuclear technology and enriched uranium.

In India, though oil is imported, her low grade coal and hydro resources were ample. India will have to keep on importing nuclear technology and enriched

^5. Contribution of Atomic Energy to a power Programme in India, P.N. Rosenstein-Rodan (mimeographed) available at the library of the Gokhale Institute of Politics and Economics, Poona.
uranium. Apart from this there is a third point of contrast between these countries. Though Southern Italy is as poor and backward as India, the country as a whole was much advanced than India. Particularly her gross capital accumulation was much higher (20-25% of GNP) than India's (10-15%). Italy, therefore had a greater economic strength to develop nuclear power.

It may be noted that many of those who opposed the starting of nuclear power stations were afraid that there would not be such a large increase in load in the near future so as to sustain these stations which must be started on a large scale (say, not smaller than 200 mW) and must be operated at a high Plant Factor (say, 80%). The Times of India special correspondent referred to above, for example, had mentioned this objection. These fears were obviously based on myopic view of the accelerated demand for power in the future.

Case for Atomic Power

In making out a case for India adopting the nuclear technique for power manufacture, the following considerations should weigh with the decision-makers.

1. We cannot depend much on the use of diesel oil as fuel for power generation. We have to import fuel oils to a great extent. This import bill is large, it
having run into Rs 400 crores as against Rs 55.5 crores in 1960. In 1978-79 one-fifth of oil requirement is likely to be used for power generation.6

2. Nor can we depend much on coal. It is pointed out that our high quality coal deposits are limited. A large portion of coal is taken by power generation.7

Professor Harrison Brown of the California Institute of Technology raised a new point. To quote:

*Assuming a 10-year doubling time, India's rate of coal production in 1980 should be about 200 million tons annually. By that time the ratio of her ultimate recoverable reserves to her production would be about 200, a ratio about a factor of two lower than that in either the United Kingdom or Japan at the present time. Already we see that both the United Kingdom and Japan are suffering from energy difficulties and are looking toward nuclear electric plants as being at least a partial answer to their problem*.8

6. According to the Report of the Fuel Policy Committee (p.12), power generation would take 4.7 million tonnes out of the total requirement of 24.6 million tonnes for energy purposes.


Coal deposits being concentrated in a few areas (W.Bengal, Bihar, east of M.P. and Maharashtra, and north of Andhra) are far off from many load centres like Bombay. This presents the problem either of transportation of coal to these load centres or of transmission of electricity to the load centres, it being generated at the pit-heads. Both transport and transmission are expensive, making thermal power expensive.9

Coordination of supply of coal with requirements at different centres is another difficulty. Coal production is frequently interrupted by mechanical failures or labour strikes and also suffers from bad management. Similar difficulties are caused also in railway delivery system. Even at Baruni power house where electricity generation, collieries and railway transport are integrated the system came almost to a standstill in the first quarter of 1972. The haulage required to be done is also of such a magnitude that it imposes an extremely serious strain on the railway system. One calculation shows that a thermal station of 2000 mW would require 15 train loads every day.10 Between December and June there is heavy strain on railway and coal supplies in these months are delayed.

9. For these costs, vide Report of the ESIC, pp.132-136, and Norman L.Gold Loc cit, p.70
Fuel costs are heavy. In Gujarat coal is available at Rs 70 per ton as against Rs 30 in M.P. In Maharashtra the average price was Rs 44.73-74.39 at different stations of the MSEB in 1971-72. These were prices including transport costs. Here it may be noted that railway freight charges do not measure the cost properly. For one thing, the freight charges are alleged to be less than what they really cost. For another thing, the freight charges are telescopic. So, for long distances they measure cost even less.

3. Hydro resources have their own drawbacks. In the first instance, they are unevenly distributed. Fortunately they are in regions which are poor in coal deposits. Secondly, the water reservoirs fed on annual rains get depleted in the off-season. Thirdly, in the off-season there is competition between irrigation and power generation if the water reservoir serves both these purposes. If, in any year, water is inadequate this competition becomes so serious as to create tension between agriculturists in rural areas and industries and inhabitants in urban centres. Fourthly, irregularity of rainfall is a serious matter. Failure

11. Ibid.

of rains and failure to store water in the reservoirs makes power cuts inevitable. In Kerala, for example, from 1961-62 to 1965-66, power cuts due to this reason were effected for 724 days! Consequent average annual loss of production was Rs 7½ crores and the loss of GNP contribution (value added) was Rs 2½ crores.

In the year 1974-75 Tamil Nadu suffered the worst power famine due to failure of rains. In the same year Haryana too had been a sufferer for the same reason.

Fifthly, there are other problems like the silting of the Bhakra dam and tremors in Koyana area due to the water reservoir.

4. As compared to thermal and hydro stations nuclear power stations are foot-loose. The former have to be sited at coal pits and dams respectively. Places which neither have coal resources nor water resources can have nuclear power. The only geographical conditions required for siting nuclear power stations are (i) strong foundations to take the heavy weight of the large plant, (2) availability of plentiful cooling water as on the sea coast, (3) area not much populated so that there is no danger to human beings and animals from atomic hazards, (4) nearness to load centres and (5) clear routes for transmission lines.

The nuclear plants are foot-loose as they use the non-fossil fuel of uranium. Though uranium deposits are limited in this country a technique can be evolved to utilize thorium as fuel and there are abundant deposits (about 500,000 tons) of thorium in India. Thorium is found in the monazite sands of Kerala and on the Ranchi plateau. There are also uranium deposits in Bihar. Nuclear fuel can be transported to any remote place with very little transport cost. Regions which are remote from coal deposits and those where hydro resources are either not available or uneconomic to exploit, nuclear power may be economically produced. Atomic power station can work economically, among other things, at a high Plant Factor e.g. 90%. It is possible to maintain the high Plant Factor to feed the Grid. The core supply may be made by the atomic power station and the variations in load may be met by the conventional sources.

Construction of nuclear power plants may take less time than construction of hydro projects. In view of the immediate needs of power this time-saving factor should be an important consideration.

Lastly, it is pointed out that other aspects of nuclear energy are also of great use. Dr. Gold may be quoted in extenso:

"It is useful for the application of isotopes and radiation to agriculture and industry. India could gain much from radiation uses in agriculture both
to reduce losses in the production, storage and distribution of food, and also to increase the productivity of land, crops and livestock. In a country so dependent on cereals, cotton and vegetable oils, the use of isotopes and radiation to improve yields and reduce spoilage, especially since there is little refrigeration available, might offer greater immediate benefits than even the introduction of power reactors.\textsuperscript{14}

Thus the case for atomic energy in India is principally a regional one. There is no case either in the coal-abundant Eastern Region nor in the hydro-rich North Eastern Region. Only in the other three Regions atomic energy may be the alternative, particularly to thermal power. But the case also rests on a certain strategy of development of atomic power as will be shown in the following section.

**Strategy of Nuclear Power Development**

Dr Bhabha visualised a strategy of nuclear power generation, a strategy that using indigenous non-fossil fuels would generate power cheaply. In this strategy there are three stages or 'generations' marked by different kinds of reactors and fuels. In the first stage there would be a reactor using natural or enriched uranium as fuel. In the second generation plutonium

\textsuperscript{14} Op.Cit. p.127.
and in the third generation uranium 233 would be used as tertiary fuels. Plutonium and uranium 233 would themselves be produced in the reactors in addition to power; and also in the last stage more fuel would be produced than consumed.

In nuclear reactors natural uranium is the basic fuel for chain reaction. Only one particular form or isotope of uranium fission is used, emitting heat and neutrons. This isotope is of atomic weight 235 and is 0.7 per cent of natural uranium, the rest being the stable form U 238.

When a neutron enters an atom of U 238 it produces a plutonium atom, Pu 239 which is fissionable and can be used as an atomic fuel. When, similarly, a neutron enters an atom of thorium, Th 232, it produces an isotope of uranium, U 233, which also is fissionable.

Thus U 235, Pu 239 and U 233 are atomic fuels and U 233 and Th 232 are 'fertile' materials to be transmuted into fuels in reactors.

Every atom that fissions emits two or three neutrons. Only one of these is required to maintain the chain reaction. It is possible to design a reactor to save loss of neutrons and utilize them for fission. This reactor is called a 'breeder' as it produces more fissionable material or fuel than it consumes.
It may be noted that India's resources of uranium (uranium oxide or U 308) are very limited - are of the order of 2000 tonnes. On the other hand, resources of thorium are abundant. So India has to evolve a technology of using thorium rather than depend on uranium.

From fuels we may now turn to reactors. We may mention three main types. To use natural uranium the best reactor would be that type (Candu produced in Canada) which works on heavy water as moderator. This would be most economic in respect of fuel. This enables maximum generating capacity to be supported per tonne of uranium mined and maximum plutonium to be produced from each tonne of uranium mined. Heavy water (i.e. hydrogen in water being replaced by deuterium) least absorbs neutrons.

On the other hand, as light ordinary water absorbs neutrons, uranium has to be enriched (i.e. amount of U 235 in uranium being raised above its natural value of 0.7%). Reactor designed for light water as moderator is the second type. It is called Light Water Reactor (LWR). Actually there is only one method used for enrichment on a large scale, - the gas-diffusion method. Only eight gas-diffusion plants exist at present: three in the USA, two in the USSR and one each in Great Britain, France and China. These are nuclear-weapon countries and these plants were developed by them with military purposes.
The third type uses boiling water as moderator and enriched uranium (Boiling water Reactor, BWR). Steam produced is used directly. All these types are called thermal reactors.

In the strategy adopted in India it is the heavy water type (Candu) that is to be used out of these three. In the second and third generations, as distinguished from thermal reactors fast breeder reactors will be used. They use much greater proportion of the fertile $\text{U}^{238}$ in natural uranium and are thus economical. They transmute plutonium and thorium into $\text{U}^{233}$. It may be noted that it is the hope of using fast breeders as reactors and plutonium and thorium as fertile material that is crucial in the Bhabha strategy.

At Rana Pratap Sagar (Rajasthan Atomic Power Project) and at Kalpakkam (Madras Atomic Power Project), Candu type first generation reactors with heavy water and natural uranium are being used. At Kalpakkam a Fast Breeder Test Reactor is being fabricated. This is as per Bhabha strategy. However, at Tarapur (Tarapur Atomic Power Project) the first generation reactors are of boiling water and enriched uranium type (BWR).

Apart from this technical consideration of fuels and reactors the foreign exchange component in their costs have to be calculated. In the RAPP first reactor
it is 60%, in the RAPP second reactor 40% and in the MAPP first reactor 20%. In the TAPP it is 54%. In addition, in the TAPP enriched uranium has to be imported with a foreign exchange requirement of Rs 1.96 crore annually.15

Cost Estimates

Several estimates of comparative costs of producing power from the nuclear source and from the conventional sources were made. Among these we are mentioning below only the more important ones. We are giving below the kW and kWh cost from these estimates in a tabular form (Table 7.1). These estimates mainly pertain to nuclear and coal-fired stations. It is almost a foregone conclusion that the option of oil-fired station is most expensive and that of hydro station is cheapest. Thus the competition is limited to nuclear and coal-burning stations only.

<table>
<thead>
<tr>
<th>A Summary of Cost Estimates</th>
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<tbody>
<tr>
<td>A. Capital Cost per kW in Rs</td>
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<tr>
<td>Hydro</td>
</tr>
<tr>
<td>1. Bhabha (1968)</td>
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<tr>
<td>2. H.M.D.Little (1968)</td>
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15. This is calculated from the references that follow; viz., (1) annual fuel inventory inclusive of customs duty = Rs 3.5 crores, (2) proportion of fuel cost per unit of power = 1.630 + 0.410 and (3) foreign exchange component of fuel = 70%.
3. Bhabha-Dayal (1964) & 398 & 900 & 1291

4. Energy Survey (1965)

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<tr>
<th></th>
<th>Thermal</th>
<th>Nuclear</th>
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<tbody>
<tr>
<td>(a)</td>
<td>1559/1375</td>
<td>1343</td>
</tr>
<tr>
<td>(b)</td>
<td>1540/1354</td>
<td>1102</td>
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(a) for 1965-66 to 1970-71
(b) for 1970-71 to 1975-76


B. Total cost per kWh in P.

1. Bhabha (a) 4.05 (a) 3.90 (b) 4.51
(a) and (b) according to cost of nuclear fuel inventory

2. I.M.D. Little (a) 4.60 (a) 6.38 (b) 6.14
(b) 6.8 to 7.5

3. Bhabha-Dayal (a) 4.05 (a) 3.02 (b) 4.77 (b) 4.36
(a) and (b) according to interest rate 5% and 10% respectively

4. Energy Survey (a), (b) & (c) 2.6/2.9 (a) 2.6/3.2 (b) 4.7/5.8
(b) 4.0/4.6 (c) 5.7/6.3 respectively according to coal cost: nil, $24.54 & $53

5. Kirit Parikh (a) & (b) according to coal prices $40 & 60 respectively

(a) 5.32/6.14 (b) 4.97/6.00
Note: Costs at PF 75% and 60% are separated by a bar.


In a paper prepared in September 1967 by Dr Vikram Sarabhai, V.K.Meckoni and K.T.Thomas the competitive threshold of atomic power as compared with thermal power has been established. They show that at the cost conditions in 1967 a 500 mW Candu plant is competitive with a thermal plant of equivalent size at the pit head. Further they point out that if coal is as cheap as in some foreign countries, viz. Re 1 per million Btu the breakeven point is reached at a much larger plant size, viz. 800 to 1000 mW. They even aver that a smaller Candu plant of 200 mW is competitive beyond 800 mW from the coal pit-heads. Clearly Bombay lies outside this area. In fact, Tarapur, Rana Pratap Sagar and Kalpakam all lie outside the area covered by the radius. 16

Recently Kirit Parikh, S.S.Shiralkar and H.K. Agrawal have prepared a mathematical model to compare

costs of thermal and nuclear power.\textsuperscript{17} Using the model they reach conclusions which are in favour of nuclear power. Some of their conclusions are given below.

1. Over the next 20 years nuclear power saves nearly Rs 145 crores in discounted costs at 10 per cent per annum discounted to 1973-74.

2. Even when nuclear plant fixed costs increase by 10 per cent while thermal plant costs remain constant, nuclear power is economical. However, the benefit is reduced to about Rs 60 crores.

3. However, when nuclear plant fixed costs are increased by 30 per cent, nuclear power is no longer economically advantageous.

4. When the fast breeder reactor is delayed by three years and becomes available only during 1987-88, the costs are not significantly affected. We can afford to wait a little in developing the FBR technology.

5. LWRs are marginally advantageous compared to Candu reactors by about Rs 12 to 16 crores, when uranium available is 16,000 tonnes and by Rs 21-35 crores for uranium availability of 29,600 tonnes.

6. India’s choice of Candu over LWR is thus economically justifiable.

\textsuperscript{17} Role of Nuclear Energy in India's Power Programme, Indian Statistical Institute Planning Unit, New Delhi, March 1974, Unpublished.
Some of their assumptions should be noted. They may be summarised as these: (1) Capital cost of $325 \text{ MW}$ nuclear plant $= \text{Rs} \ 2700$ (LWR), Rs $3650$ (Candu) and Rs $3100$ (FBR); (2) capital cost of plant declines at $500 \text{ MW}$ by $10\%$ (thermal) and by $15\%$ (nuclear); (3) operating cost of thermal plant $= 3.5 \text{ paise} \text{ per kWh}$ if it is located at a distance of $800 \text{ km}$ and $2.5 \text{ paise} \text{ at a distance of} \ 200 \text{ km}$ from coal fields; (4) fuel cycle cost (excluding plutonium credit) per kWh $= 1.92$ (LWR), $1.23$ (Candu) and $1.0$ (FBR) paise; (5) price of natural uranium $= \text{Rs} \ 200/\text{kg}$; (6) fabrication cost of fuel $= \text{Rs} \ 200/\text{kg}$ (natural uranium), Rs $580/\text{kg}$ (enriched uranium); and (7) plant thermal efficiency $= 26.6$ (Candu), $28.5$ (LWR) and $40$ (FBR).

**A. Commentary on Estimates**

In interpreting the estimates and comparing them, the following points may be borne in mind.

(1) The estimates are made at different points of time and also for different times in the future. The costs at the time of making estimates may work as a bias and the estimates for the future only involve uncertainties and incalculables. Technological changes and changes in prices and energy demand are the principal amongst them. Whereas it is assumed that technological changes will fast reduce the cost of nuclear plants in real terms, it is believed that similar changes will not be so favourable for other types of plants.
(2) The size of plant and the factor of its utilisation have an important bearing on costs. It is said that with doubling of unit size there is reduction of capital cost of nuclear plant roughly by 15%.

Identical nuclear generating units also reduce cost. If two units cost 100 each a single unit would cost 118 and a four unit station would cost 372. Such considerations may more or less apply to other plant categories.

Plant Factor is important in cost determination. In hydel projects, thermal and nuclear plants, kWh cost declines with improvement in PF. However, in respect of hydro projects there is a countervailing rise in kW cost of increased water storage.

(3) What is the plant cost? Some estimates would include only the direct plant cost while others incidental fixed cost as well. The plant must be clearly comparable in each estimate.

(4) Fuel costs have prime importance. It is clear that between the thermal plant on the one hand and the hydro and nuclear plants on the other hand, the former is cheaper in kW cost. It is the saving in fuel cost in using the latter that decides the choice. Thus the...
fuel cost is the most crucial consideration. In respect of the thermal plant, the calorific value of the fuel, thermal efficiency, cost of fuel and transport cost have to be carefully calculated. Unless the project site is known the estimate can only be approximate. The transport cost may not accurately reflect the opportunity cost.

It should be clear from what is said above about technical aspects of nuclear power production that fuel used (e.g. enriched uranium or natural uranium, uranium or thorium) makes a great difference to the cost of atomic power. Not only fuel costs change but even capital costs change as models of designs of the plant are very much dependent upon the fuels used. The burn-ups of different fuels and in different plant designs are different. Similarly, transmission cost as an alternative to best transport cost has to be considered accurately.

(5) Special features of the site have also a part to play in determining cost. Foundation conditions, for example. Estimates of a general nature have, therefore, a limited value.

(6) O & M charges and insurance charges have to be higher for nuclear plant than for others. At what rates are they calculated?
(7) At what rate is depreciation calculated? It has to be according to the life of the plant. For different parts of the power station, there will have to be a different depreciation rate. The extent of expenditure on each must be accurately known along with its life. Atomic plants have a shorter life than others.

(8) Interest rate and profit rate also are not the same in all estimates. Profit rate ranges between 3% and 10%. Interest is about 6%. In calculating interest during the gestation period of the plant must be taken into account.

(9) Foreign exchange component in the fabrication of plant and in fuel is an important consideration. Not only changes in the rate of exchange will vitiate cost calculation but also the very extent of dependence on imports is a source of botheration to the importing country. Boiling Water Reactor at Tarapur may be cheaper in kw cost than heavy water reactor at Rana Pratap Nagar but enriched uranium required in the first has to be imported.

20. See the news "IAEA (International Atomic Energy Authority) ban move may affect India, The Times of India, 10-9-1974.

There are peculiar conditions surrounding each of these sources of electricity and they are not reflected in the comparative estimates. For example, it is uncertainty of monsoons and uncertainty of coal supply that cause interruptions in hydro and thermal power respectively. So the choice between the several sources cannot be governed by the cost estimates alone.

"Linkage" and "externality" effects and "social costs" will have to be considered in a wide perspective and on a distant time horizon. For example, there might be need to conserve coal though it is abundant. Again, there might be need to start atomic power as a part of a new essential complex.

The estimates assume that there are options, politically and economically. The establishment of atomic projects are politically prestigious. Even economically there may be no options. For example, imports of fuel oil may not be available. There might be urgency of augmenting power supply from all sources and immediate feasibility may become the permanent consideration.

**Tarapur Atomic Power Project**

The Tarapur power station was commercially commissioned in October 1969. Its generation capacity is about 20% of the power capacity of Maharashtra and Gujarat together.
Here there are two identical units each of 210 mW. They are of the BWR type using enriched uranium. They are moderated by light water. Tarapur being a coastal place, the plant can easily draw about 2300 million litres of water every day from the sea. The site has a strong rock foundation, favourable meteorological and environmental conditions and the place is very thinly populated. Tarapur is only 100 km north of Bombay, one of the biggest load centres. Thus at Tarapur the essentials of a proper site have been satisfied. The decision to locate the atomic power station here was taken after surveying twenty sites in Bombay-Baroda region.

The choice of the BWR for the Tarapur power station calls for an explanation. Why for this very first station did we depart from the Bhabha strategy? The explanation that is given is threefold. Firstly, from the global tenders two had to be finally compared. One was the French tender for natural uranium plant and the other was the (American) International General Electricity's for the BWR. The first was at Rs 89 crores and the second at Rs 60.69 crores. Foreign exchange requirements in these were Rs 59.30 crores and Rs 44.24 crores respectively. Thus in capital cost and in foreign exchange the BWR was much cheaper. This saving at 6% interest would offset the annual foreign exchange.  

exchange requirement for enriched uranium over the life of the station after credits for the sale of depleted uranium and also of plutonium to the USA are allowed. Secondly, the tenderer of the BWR was ready to put up the station without taking much time. Thirdly, this station should be regarded as an "isolated first step" not a departure from the general strategy. We had to train engineers and scientists and also to create a confidence that nuclear power can be produced competi­tively.

In the initial stage, fuel was almost entirely imported from the USA and later it is being fabricated (as fuel bundles) at Hyderabad from imported enriched uranium. Fuel cost and its foreign exchange component for the BWR at Tarapur will be higher than that of Candu. Fuel required is annually 20 tonnes. To produce electricity of the quantity that will be produced here, a thermal power station would have required one million tonnes of superior grade coal i.e. every day three train loads of coal. Saving on the transport system due to nuclear fuel may be imagined.

The transmission lines belong to the State Electric­city Boards of Maharashtra and Gujarat. Power cost that we will refer to is therefore at the bus bar. The

reported faults in the supply of power from Tarapur may also be due to the transmission system rather than due to the generation system.

**Tarapur Power Cost Estimate**

On completion of the TAPP its capital cost including interest during the period of construction, capital works (Rs 1.94 crores) and land (Rs 0.40 crores) was found to be Rs 73.83 crores. This works out at Rs 1757.8 per kw as against the cost of Rs 1700-1800 per kw of thermal plant. Depreciation rate and rate of insurance charges on the atomic plant is obviously much higher. A depreciation rate of 3.6% on the plant and 1.8% on the rest of capital may be calculated. Insurance may be 9%. Interest and profit may be calculated at 6% and 3% respectively. Annual fuel cost of Rs 3-3.5 crores may be estimated. Accordingly the estimated power cost is worked out in Table 7.2. It is 4.7 P. per kWh without return on capital and 5.6 P. with capital return.

<table>
<thead>
<tr>
<th>TAPP: Power Cost</th>
<th>Annual Charges Rs crores</th>
<th>Power Cost P/kWh at 75% PF</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Depreciation</td>
<td>2.54</td>
<td></td>
</tr>
<tr>
<td>2. Interest on capital (averaged over 25 years)</td>
<td>2.60</td>
<td></td>
</tr>
<tr>
<td>3. Total of depreciation and interest</td>
<td>5.14</td>
<td>2.055</td>
</tr>
<tr>
<td>4. Operation &amp; maintenance</td>
<td>0.70</td>
<td>0.280</td>
</tr>
</tbody>
</table>
Table 7.2 Source: Information from Department of Atomic Energy.

Performance of the TAPP

Let us see the performance of the TAPP in respect of the supply made by it and the cost of generation and supply.\textsuperscript{24}

From November 1969 to March 1971 (17 months), the Availability Factor of both the units, each of 210 MW

\textsuperscript{24}. We are basing this Section on the information that was available from Department of Atomic Energy.
was high at an average of 86.26%. In this period none of the two units was completely inoperative over a month or so, though in one month one was available for 7% and the other for 3.3%. In four months both units were available at 100%. The Plant Factor over this period of seventeen months averaged at 62.1%. In this period monthly production was 155.100 million kWh.

In the period April 1971 to June 1974, the performance was grossly dissatisfactory. Out of these 39 months, one or the other unit was not available for 24 months. Over this period of 39 months, the Availability Factor for the two units averaged at 54.12% only, and the Plant Factor was an average of 36.7% only. Monthly average generation of power was 113.767 million kWh. In atomic power plants the units have got to be shut down for refuelling at two years intervals, and the Availability Factor and Plant Factor will necessarily come down. However, whether refuelling was the only reason for the outages and whether the period of each close-down for refuelling was reasonable are moot questions. It seems that frequent trippings in the switchyard was also responsible for the low PF and the switchyard was under the control of the MSRB till recently.

As the Plant Factor was low, the supply of power made by the TAPP was inadequate. This in its turn,
affected the kWh cost of power generated. The costs are given here in Table 7.3.

Tarapur Atomic Power Station: Operational Expenditure (lakhs)

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
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<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Works</td>
<td>0.73</td>
<td>0.35</td>
<td>0.39</td>
<td>1.01</td>
<td>0.66</td>
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<tr>
<td>Maintenance</td>
<td>30.12</td>
<td>28.80</td>
<td>222.84</td>
<td>307.42</td>
<td>448.90</td>
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<tr>
<td>Transfer to</td>
<td>69.82</td>
<td>239.09</td>
<td>231.86</td>
<td>225.16</td>
<td>194.54</td>
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<tr>
<td>Depreciation Reserve Fund</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Transfer to</td>
<td>13.64</td>
<td>33.75</td>
<td>32.60</td>
<td>-</td>
<td>33.44</td>
</tr>
<tr>
<td>Contingency Reserve Fund</td>
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<tr>
<td>Establishment</td>
<td>5.76</td>
<td>21.40</td>
<td>25.33</td>
<td>31.97</td>
<td>38.28</td>
</tr>
<tr>
<td>charges</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Nuclear Insurance Reserve Fund</td>
<td>15.38</td>
<td>27.00</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Fuel Inventory</td>
<td>-</td>
<td>60.38</td>
<td>434.98</td>
<td>407.66</td>
<td>342.59</td>
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<tr>
<td>Interest on</td>
<td>-</td>
<td>54.21</td>
<td>122.22</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Deferred Payment Account with US AEC</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Interest on Capital at charge</td>
<td>-</td>
<td>522.27</td>
<td>280.54</td>
<td>308.23</td>
<td>318.16</td>
</tr>
<tr>
<td>Miscellaneous</td>
<td>4.93</td>
<td>21.26</td>
<td>22.52</td>
<td>35.75</td>
<td>66.38</td>
</tr>
<tr>
<td>Total</td>
<td>167.88</td>
<td>1013.11</td>
<td>1424.40</td>
<td>1326.19</td>
<td>1442.94</td>
</tr>
</tbody>
</table>

Table 7.3: Source: Information from Department of Atomic Energy
In the four years 1970-71, 1971-72, 1972-73 and 1973-74 the cost per unit generated works out at 2.67 Paise, 12.48 Paise, 11.70 Paise and 7.56 Paise respectively. As we are not sure that the cost in each year is necessarily shown above in the same year, we may take an average for the four years which comes to 6.55 Paise. These are under-statements in view of the fact that in the first of the four years inventory cost does not seem to be entirely included, insurance reserve fund is not shown in the next three years and interest payable to U.S. AAA is not shown in the last two years. Return on capital is not taken into account.

Actually the rate fixed for the NEER was 2.36 P. per kWh in the trial period upto 2nd October 1969 and 5.61 P. per kWh from 3rd October 1969 to 31st December 1970. From 1st January 1971 a two-part tariff was introduced. In this initially the fixed charge was Rs 38.35 lakhs per month and additional energy charge of 2.04 P. per unit. From 1st April 1973, the two-part tariff was revised for the following five years as Rs 35.45 lakhs (monthly fixed charge) and 2.70 P. per kWh (energy charge). The fixed charge assumes 50% PF. If the PF falls below this the charge rises. The fixed charge and the energy charge are arrived at by using discounted cash flow technique. This is a rigorous method of costing which allows for time-value of money.
and avoids notional expenditures like that on depreciation. All actual cash outflows on plant and equipment and running expenditure are equated to all inflows from the subsequent revenue at an interval rate of return of 8%. Taking the fixed cost as Rs 33.45 lakhs (ignoring variations in PP) the unit cost to the MSEB of the power it purchased from the TAPP in 1973-74 works out at 8.00 Paise.

Foreign exchange component is an important additional consideration. Foreign exchange used in the TAPP upto March 1973 was as in Table 7.4. A substantial saving in foreign exchange is caused by fabrication of fuel at Hyderabad from the year 1974. Uranium for fuel is imported and the fuel bundles are fabricated here whereas formerly the fuel bundles used to be imported.

<table>
<thead>
<tr>
<th>TAPP : Foreign Exchange Component</th>
<th>(Lakhs, Rs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capital cost</td>
<td>3365.43</td>
</tr>
<tr>
<td>Fuel</td>
<td>1340.63</td>
</tr>
</tbody>
</table>

Table 7.4 Source: Information obtained from the Department of Atomic Energy.

25. The MSEB expected this rate to be 8.78 P./kWh (m domestic charge 6.08 P. energy charge 2.70 P.) It complained that this charge was above the ceiling fixed earlier, viz. 6.09 P./kWh. MSEB Quarterly, January 1974.