

CONTRIBUTION OF ATOMIC ENERGY TO A POWER PROGRAM

IN INDIA

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I. Atomic Energy in Developed Countries.

Nuclear power prospects for the next decade were considered in 1956 to be of major importance in only two areas of the world, namely, Europe and Japan. Those were the areas in which nuclear power could reach a competitive threshold with conventional power for three reasons:

1. The hydroelectric potential was limited and nearing exhaustion
2. Coal had to be imported at very high prices, around \$20 per ton.

At such prices, incidentally, residual fuel oil for thermal stations appeared cheaper than coal.

3. Europe and Japan were highly industrialized areas with electric grids in which installation of large units (150 Mw or more) for base load electricity at very high plant factors (75% to 80%) was possible.

Accordingly, ambitious programs for installation of new power stations were established both in England and in Europe foreseeing installation of 6 million Kw in each within ten years. On the basis of the estimates then available, it appeared that the cost per Kwh of nuclear power would be around 10% higher than that of conventional thermal power. It was thought, however, that such a margin of 10% might be well worth the end of becoming less dependent on one source of power (notably oil) and also that in a short time cost reducing technical progress would be greater in the new field of nuclear power stations than in that of conventional thermal stations.

Experiences of the last three years -- which is admittedly a short period -- do not seem to confirm these expectations.

1. Coal prices fell in Europe by at least 25% so that a ton of coal today costs under \$14 instead of the previous \$20. It is now fully competitive with oil.
2. Residual fuel oil supply has also become more abundant at slightly lower prices.
3. Interest rates in Europe (with the exception of Italy where they were calculated at 7%) rose from 4% to 5-6% raising thereby the relative cost of nuclear power.
4. Cost reducing technical progress did not materialize in nuclear power but it has been achieved in thermal power.

The first two changes may be short-run phenomena although it has to be remembered that the price of coal imported from the U.S. has fallen by 25%, mainly because of the collapse of freight rates and experts doubt that the freight rates will recover to the '55-'56 level.

Accordingly, many authorities doubt that one should project \$20 per ton of coal for the near future. While opinions may differ about the long-run price prospects of coal and oil, the fact remains that, on the whole, pessimistically high price expectations have given place meanwhile to optimistically lower ones.

More important, however, are the results of technical development during the last three years. Contrary to expectations cost reducing technical progress did not materialize in the nuclear field but it did materialize in the field of thermal electricity. The introduction of large turbo-generators of 200,000 Kw and more has reduced fixed investment costs for large thermal electric power stations by about 20% from, say \$150 to \$160 per Kw installed to \$120 and \$130 per Kw. This also benefits large nuclear power stations, but the cost reduction there amounts to under 10%: half that (or less) of large thermal stations. At the same time, the cost of

nuclear energy for stations of 150 Mw could not be reduced; this can be clearly seen from offers submitted at the international tender under the auspices of the International Bank in 1958 for the Italian E.N.S.I. project. Accordingly, several voices in Europe recently have been advocating a slowing down of the EURATOM and U.K. atomic power program, since it appears that the cost of nuclear energy will be higher than that of a conventional one not by a mere 10% but by at least 20%,<sup>1</sup> or, as some people say, by even 40% to 50%.<sup>2</sup>

## II. Atomic Energy in Underdeveloped Countries

While prospects of atomic energy appear, for the time being, to be well below the optimistic expectations even for developed countries like Europe and Japan, all the arguments which made the introduction of nuclear power in underdeveloped countries much less promising remain fully valid. There are, as is well known, at least four reasons against the introduction of nuclear power in underdeveloped countries. They are:

1. Only large power stations (100 Mw or more) are suitable for atomic power. In most underdeveloped areas these units may be too large since such large units can normally be well used only if their output can be fed into an electric grid.<sup>3</sup> Most underdeveloped countries, however, are not covered by electrical grids or have them only in very exceptional cases in the neighborhood of a few large cities.
2. Atomic power stations can only be used for base load electricity on a very high load factor of 75% to 80%. This is due to the fact that capital charges are very high in nuclear power (2/3 or more of total

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<sup>1</sup>See The Economist, London, May 9, 1959.

<sup>2</sup>See Ferdinand Dierkens, "L'atome En Belgique," L'Opinion Economique et Financiere, March 19, 1959.

<sup>3</sup>This is an even greater obstacle to obtaining high load factors (see next point II. 2.).

power costs) while in thermal stations capital charges are lower (about 1/3 of the cost of power). The condition of a high load factor is much more difficult to meet in an underdeveloped country and it seems unlikely that the load factor of 80% or even 75% could be obtained in India. Even in Europe, incidentally, the early calculation based on an 80% load factor had to be revised to a 75% load factor since it seemed unlikely that the higher target could be met.

3. Since capital costs form a so much higher proportion of total costs of nuclear power, the rate of interest has a major influence on cost determination. In the EURATOM and U.K. calculations, the rate of interest was raised from the original 4% to about 6%. In Italy where the scarcity of capital is certainly less than in India it is calculated at 7%. In underdeveloped countries where there is a much greater scarcity of capital, the underlying rate of interest should undoubtedly be higher. There is no doubt that in India, for instance, an assumed "shadow" rate of interest should be put at around 10% and certainly nowhere near 4 1/2%. Together with the depreciation, the charges on interest and depreciation should be at least 15%.
4. A relatively high overall efficiency, say 28%, is to be assumed for a nuclear power station. That might also be somewhat lower (say 25%) for an underdeveloped country since the choice between various power stations of different age structure and efficiency to provide for peak loads is much more restricted.<sup>1</sup>

### III. The Need for Atomic Energy in India

1. Dr. H.J. Bhabha proposes a nuclear power program of 1 million Kw in India for the next decade.<sup>2</sup> He recognizes, albeit platonically,

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<sup>1</sup>This point is left out of account in the following text. A 28% efficiency is in fact assumed.

<sup>2</sup>See H.J. Bhabha, The Need for Atomic Energy in the Under-developed Countries, lecture delivered at the Second International Conference on the Peaceful Uses of Atomic Energy held in Geneva in September, 1958, and H.J. Bhabha and N.B. Prasad, A Study of the Contribution of Atomic Energy to a Power Program in India (Department of Atomic Energy, dittoed document, 1958).

the first two (a minimum large size plant and a very high load factor) of the four reasons against the introduction of nuclear power in underdeveloped countries. He argues, however, that in some places like Bombay and Ahmedabad a very high load factor is obtained already (63% to 69%) and seems to infer from it that an 80% load factor in the future might not be too unrealistic an assumption. He presents the following cost calculations: (Table IX, H.J. Bhabha and N.B. Prasad, op. cit.)

Comparison of capital and power costs

Load factor = 80%; efficiency of nuclear power station = 28%;  
 efficiency of thermal power station = 25%; fuel burn-up = 3,000 MWD/tonne

	Coal-fired power station	Oil-fired power station	Atomic power station First generation
Unit capital cost	Rs.1,050/kw*	Rs.800/kw*	Rs.1,700/kw
Unit fuel inventory cost at Rs. 300,000 per tonne at Rs. 400,000 per tonne			Rs.500/kw Rs.667/kw
COST OF GENERATION in Rs./kwh			
1. Capital charges			
a) Depreciation @ 5%	.0075	.00571	.01214
b) Interest @ 4.5%	.00675	.00514	.01092
c) Interest @ 9%	(.01350)	(.01028)	(.02184)
2. Interest on inventory @ 4.5%			
Fuel at 300,000/tonne			.00321
Fuel at 400,000/tonne			.00429
3. Operating Costs	.00125	.00125	.00125
	(Table cont. on p. 5a)		

\*This excludes filling and improvements to site.

<sup>1</sup>Not included in Dr. Bhabha's Table.

	Coal-fired power station	Oil-fired power station	Atomic power station First generation	
4. Fuel costs:				
Coal at Rs.45/ton	.025			
Oil at Rs.96/ton		.027		
Fabricated uranium at Rs.300,000/tonne			.01488	
Rs.400,000/tonne				<u>.01984</u>
	<u>.04050</u>	<u>.03910</u>	.04240	.04844
5. Less credit for plutonium at Rs.56,000/kg.			<u>.00333</u>	<u>.00333</u>
			<u>.03907</u>	<u>.04511</u>
		Net cost of nuclear power		

Assuming 9% interest the costs per Kwh of a coal fired power station amount to 8.7 mills, those of atomic power (allowing for the credit for plutonium and assuming the cost of uranium of rupees 400,000 per ton = \$83,330) to 9.6 mills.

We might readily agree that in some Indian towns a relatively big size thermal station (150 Mw or more) may usefully be installed but it seems quite unrealistic to assume an 80% load factor. Any realistic comparison should contrast a thermal and a nuclear power station of 150 Mw or more but on the assumption of a 65% load factor. If we add to it that the rate of interest in India should be calculated at 10% rather than at 4½%, then the comparative costs per Kwh can be assumed to be 9.58 mills for a thermal coal fire station against

14.16 up to 15.6 mills for a nuclear power station. These are the only relevant cost comparisons: See I.M.D. Little, "Atomic Bombay?, A Comment on 'The Need for Atomic Energy in the Under-Developed Countries,'" The Economic Weekly, November 29, 1958, in which the following costs are calculated on the above mentioned assumptions:

	Coal		Nuclear	
	Rupees	\$ mills	Rupees	\$ mills
Capital Cost	.01975	4.114	.0518 to .0542	10.808 to 11.310
Operating Cost	.00125	.260	.0012	.260
Fuel Cost	.02500	5.208	.0148 to .0198	3.100 to 4.133
Total	.04600	9.583	.068 to .075	14.166 to 15.625

In this calculation a cost of \$156 per thermal Kw installed has been assumed. A larger power station of over 200 Mw may nowadays be installed at a lower cost of \$130 per Kw. It is thus quite clear that nuclear power costs 50 to 60% more per Kwh than thermal power. It would be sheer waste to spend twice as much capital on atomic energy to produce electric power at 50% to 60% higher costs than that which can be obtained from equivalent thermal power. This is a decisive

argument against the introduction of nuclear power in India, even disregarding the fact that the foreign exchange component of nuclear power investment is more than twice as high as the foreign exchange costs of thermal power. If a "shadow" rate of foreign exchange higher than the existing rate were to be applied in the programming of the Third Five Year Plan -- which would be quite appropriate in view of the foreign exchange gap -- then the argument against nuclear power would be still stronger.

2. Dr. Bhabha, however, produces two additional arguments which might change, if not redress, the balance in favor of a nuclear power program in India:

- i) (To be considered in this paragraph) is the fact that the present coal prices in high coal price areas (for instance, Bombay) of 45 rupees per ton may not reflect the present and certainly will not cover the future real costs of coal.
- ii) The second argument (to be considered in the next paragraph - 3.) submits that while the comparative costs of nuclear power may not be attractive for the first and second generations of nuclear power stations, they will become very much more attractive for the third generation power stations.

It may be readily admitted that the presently very high coal price of 45 rupees per ton in Bombay (among the highest in India) may not fully cover all the indirect costs, notably, of transport and transport equipment. This may be especially the case if we consider that the cost of capital necessary for the maintenance of rail trucks and railway equipment may be based on an interest rate which is too low, say  $4\frac{1}{2}\%$



instead of the more probably correct "shadow" rate of interest of 10%. Dr. Bhabha gives estimates of additional investment costs for the railways and mines -- but this is insufficient to determine what the proper coal price is. Dr. I.M.D. Little correctly argues, however, that the coal price would have to reach 87 to 103 rupees per ton in Bombay in order to equalize costs of nuclear power stations. "It is hard to believe that the long-run real cost of mining and getting coal to Bombay is as much as this, or will ever be as much as this over the course of 20 years -- anyway, long short of these figures, oil is cheaper."

In the long run the balance of cost charges, at present decidedly against nuclear power costs, may gradually swing more in favor of atomic energy for two reasons. First, because contrary to the results of the short run of the last three years, cost reducing technical progress may be greater in nuclear than in thermal power. Secondly, because in the long run the real cost of mining coal may rise increasingly. "But that it might be good to have atomic energy in 20 years, or even in 10 years, is little reason to buy uneconomical plants from the U.K. or U.S.A. now . . . To put any of her own capital resources into buying the early products of this 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."<sup>1</sup>

3. Dr. Bhabha's main argument in favor of a nuclear power program in India is his calculation of the third generation atomic power costs. These costs are assumed to be a mere 50-60% of those of the first and second generation atomic power stations. The first and second generation atomic power stations should be considered, according to him, as mere stepping-

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<sup>1</sup> I. M. D. Little, op. cit.

stones or instruments of producing locally uranium U<sup>233</sup> for the "third generation power stations." Using local monazite,"with the vast reserves of thorium available in India, an additional investment in nuclear power in the first ten years would repay itself within the following ten years and, what is more important, hold out the possibility thereafter of an expansion of the power program at the maximum rate considered reasonable, namely, doubling every five years for an indefinite period...If India is to benefit from the advantages of nuclear power ten to fifteen years hence, and be in a position to utilize further the technical developments which may be expected by then, an investment in a million kilowatts of nuclear power has to be made within the next seven years."<sup>1</sup>

Unfortunately the argument and its operational conclusions are wrong for three reasons:

A. Uncertain cost estimates

The technology and the cost of the various processes involved in the second and third generation stations is not yet firmly established even in the laboratory stage, not to mention on a commercially or practically feasible stage. Dr. Bhabha recognizes this difficulty -- albeit insufficiently -- when saying: "Since the technology of this reactor (LMFR) is still in its early stages, and no prototype power reactor of this design has yet been built, our discussion at this stage must necessarily be subject to considerable uncertainties"<sup>2</sup> and: "Our estimates for latter parts of the program are necessarily invested with much greater uncertainties, and we regard them as indicating only the correct order of magnitude on the basis of present technology."<sup>3</sup> The uncertainties are so

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<sup>1</sup>H.J. Bhabha and N.B. Prasad, op. cit., pp. 34-35, paragraph 47.

<sup>2</sup>Ibid., p. 18, paragraph 27.

<sup>3</sup>Ibid., p. 21, paragraph 31.

great, however, that even a correct order of magnitudes cannot be estimated at the present stage. Even if the purely technological problems were clearly solved it would be excessively risky to initiate a nuclear power program in India before industrially and commercially checked cost estimates can be obtained. In addition, however, a number of purely technological items in Dr. Bhabha's argument appear highly doubtful.

B. Technological doubts<sup>1</sup>

- i) It appears doubtful whether the doubling time of five years for  $U^{233}$  fueled plants is not too optimistic. The benefits of the third generation plants may take 15 or 20 years instead of the 10-15 years assumed.
- ii) The feasibility of any type of  $U^{233}$  breeder is not yet practically proved. The internally cooled liquid metal fuel reactor (IMFR) on which the calculations are based<sup>2</sup> disappointed expectations: it will not breed.
- iii) Recycling thorium<sup>3</sup> is unattractive economically because costs of handling irradiated thorium, which will have been made radioactive with  $Th^{228}$ , would be much higher than costs of fresh thorium.
- iv) Recent calculations seem to show that costs of power produced in a  $U^{233}$  breeder will be substantially higher than in a reactor fueled with natural or slightly enriched uranium.
- v) It is quite uncertain whether plutonium will fulfill the expectations as to its productive use in the future. Far from basing costly investment decisions on this hope, it appears even highly doubtful whether deducting credit for plutonium produced by the nuclear

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<sup>1</sup>The author had the benefit of advice from Professor M. Benedict (M.I.T.) on these matters, who is not responsible, however, either for his interpretation (or misinterpretation) or his conclusions.

<sup>2</sup>H.J. Bhabha and N.B. Prasad, op. cit., p. 18.

<sup>3</sup>Ibid., p. 20.

power station is justified for more than the next few years. It is quite uncertain whether the U.S. and the U.K. Atomic Energy Commissions will go on paying the present prices for plutonium. Without this credit the costs per nuclear Kwh would increase by a further 0.7 mills.

C. Unwarranted conclusions.

Points A and B show that the economic and the technological arguments used are at best doubtful. If they were to reveal themselves as correct after a few years further experience the impression is given that a failure to initiate a nuclear power program in India now would lose valuable time, since it takes 10 years or more before third generation atomic power stations can be built. This is, however, a completely unjustified conclusion. It appears unnecessarily wasteful to build three generations of reactors. India could then start off with third generation plants and may import U<sup>235</sup> to start them from the U.S. The U.S. costs of U<sup>235</sup> are very low, being based inter alia on low hydroelectric costs of 3-4 mills per Kwh. As long as U<sup>235</sup> was available only for a short run, the dependence on one source of supply -- even if very much cheaper than own-produced costs -- may have been felt to be politically unpalatable. Since purely commercial long-run contracts for delivery of U<sup>235</sup> are available, however, this argument does not apply.

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