# Economics of Nuclear Power: Subsidies and Competitiveness

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In his response Ramana et al (2005), Sudhinder Thakur argues (December 3, 2005) that some of the inputs used in our paper are wrong and that if "correct input data" is used, the "crossover discount rate" between the Nuclear Power Corporation's Kaiga III and IV, and the Raichur Thermal Power Station (RTPS) 7, is "more than 6 per cent" and so nuclear power is clearly "very competitive". A similar criticism was levelled by Srinivasan et al (2005). As we shall argue below, this is debateable. Despite the importance of the subject, this reaction to the points raised was unfortunately delayed due to the ill-health and death of one of my co-authors (AKNR). I regret this delay.

The earliest public comparison of the unit costs of electricity from Indian heavy water nuclear power plants and coal plants was presented at the Indian Institute of Science, Bangalore during a debate about the Kaiga reactor in 1988 [Reddy 1988]. It was then formally published in 1990 [Reddy 1990]. A more detailed version of the nuclear versus coal comparison was published as part of the comparative costing of 15 technologies of centralised and decentralised generation of electricity and electricity saving [Reddy et al 1990]. It was clear that nuclear power was uneconomical compared to many alternatives. However, the atomic energy establishment did not react for almost 15 years. Hence, it is a very welcome step that Srinivasan et al and Thakur have published comments on Ramana et al (2005).

The basic criticism of Srinivasan et al is that we have chosen specific plants to draw general conclusions. This requires a clarification of the purpose of the costing exercise. If the purpose was an academic study of the costs of coal and nuclear plants, then the focus should be on *average* costs. Such a study would permit an understanding of historical cost trends or experience/learning curves for the technology. However, the purpose of Ramana et al (2005) was to look at the comparison of nuclear and coal technologies from the point of view of a decision-making agency (for example, the Planning Commission). Such an agency has to make an *investment decision today* in order to choose between these two technologies for the next project. For such an objective, what are important are the *short-run marginal costs*, i e, the cost of the next nuclear plant and the next coal plant. This means that the comparison has to be between the best nuclear plant and the best coal plant that have already been commissioned. In making this choice, the data on variables like the expenditure pattern, fuel consumption, have to be drawn from the latest plants, which in the case of nuclear and coal plants had to be Kaiga I and II and RTPS respectively. Thus, the average costs of nuclear and coal plants are irrelevant.

Plants that are under construction, but not yet commissioned (for example, Kaiga III and IV) should not be included as far the comparison is concerned. But, they must be immediately brought into the comparison as soon as they are commissioned and the actual (rather than expected) data becomes available. This is mainly because actual numbers invariably turn out to be different from expected numbers.

## Cost Overruns

This is amply borne out by the department of atomic energy's (DAE) record of cost overruns at all the reactors it has constructed. In our paper, we have already documented the cost overruns at all the reactors that had been commissioned before our paper was written [Ramana et al 2005: 1765]. Since then the Tarapur III and IV reactors have been commissioned. These reactors were initially estimated to cost Rs 2,427.51 crore, later revised to Rs 6,421 crore. Thus, as the Comptroller and Auditor General (CAG) pointed out, "excluding the interest during construction of Rs 1,580 crore, the estimated cost went up by 99 per cent" [CAG 1999]. The final cost was about Rs 6,200 crore [Subramanian 2006].

Futuristic developments in technologies pertain only to long-run marginal costing rather than to investment decisions today. Much about futuristic technologies is unpredictable, especially costs. As Niels Bohr is reported to have said, "Prediction is very difficult, especially about the future". Practically all of the predictions made by the DAE so far have come to nought. This means that a comparison between Kaiga I and II and RTPS VII is the right basis for an investment decision today. Even [Thakur 2005] does not, and indeed cannot, argue that electricity from Kaiga is cost competitive with RTPS VII.

However, to bend over backwards to favour the nuclear case, the comparison made by Ramana et al (2005) included the yet-to-be commissioned Kaiga III and IV plants even though the values for some (but not all) of the data for these plants have no empirical basis and involved guesses and estimates. In doing so, the projected values for construction time, performance, and input costs were used even though they are not based on actual experience and achievements. For the most part, it is this data that Thakur has called for changing based on "correct" inputs, though all that "correct" really means is currently assumed data. The suggestions made have been accepted, with the one exception of heavy water (HW) price that we will discuss later, and what is presented in this response is the outcome of reworking all the calculations as per the suggestions of Thakur (2005). In particular, the reworked figures have taken:

– The capital expenditure for Kaiga III and IV to be Rs 2,727 crore.

– The auxiliary consumption for all the Kaiga stations to be 9.5 per cent.

A crucial issue concerns the heavy water price to be used for the calculation. In our paper, we used a heavy water price of Rs 24,880/kg based on the CAG's estimate of the cost of HW at the Manuguru plant

[CAG 1994]. In contrast, Thakur and Srinivasan et al suggest that the price should be Rs 12,525/kg in 2003. But Rs 12,525 is a *government notified price*, and it is by no means clear whether this price reflects the actual cost of production, or whether it is an administrated price that is lower than the actual cost, implying an element of subsidy. In a paper submitted to this journal, I have elaborated on why there does seem to be a substantial subsidy being offered to the Nuclear Power Corporation (NPC) through lowered heavy water costs [Ramana forthcoming]. Based on the limited amount of data publicly available, I estimate that the production cost of heavy water should be over Rs 20,000/kg in 2003 rupees and could well be more. There is thus good reason to not take the Rs 12,525/kg figure at face value.

## Cost of Heavy Water

Given this uncertainty about what the cost of heavy water is, we redo the calculations with two values for the heavy water price – Rs 24,880/kg and Rs 12,525/kg. For the first price, the costs of the different options are given as a function of the real discount rates in Table 1. Above a crossover discount rate of 3.85 per cent, the levelised cost per kWh for nuclear electricity even with the projected costs of Kaiga III and IV is more expensive than that for coal. The crossover rate between Kaiga I and II and RTPS VII is only 2.7 per cent. By no means can these be considered competitive.

For a heavy water price of Rs 12,525/kg, the crossover discount rates are naturally higher; the rate at which the cost of electricity from Kaiga III and IV becomes higher than RTPS VII turns out to be 5.45 per cent (Table 2). However, when one compares the actually constructed Kaiga I and II reactors for which the prices are established and RTPS VII, the crossover rate is less than 3.6 per cent.

Leaving aside the issue of a fair cost for heavy water, the question is whether 5.45 per cent is high or low. There is a longstanding debate about what constitutes a reasonable choice of discount rate. Typical values chosen in costing electricity generation (or saving) technologies have ranged from 8 per cent to 10 per cent (real values) [see Shukla et al 2003 and Nouni et al 2006]. If one were to look to stock market returns as a measure of the cost of capital, nominal return rates have been 23 per cent on average between 1981 and 2005 [Varma and Barua 2006]. Since current inflation rates are less than 6 per cent, this means a real rate of return of over 17 per cent. All of these suggest that 5.45 per cent is a low figure.

However, rather than impose our views on what constitutes a fair rate of return, we redo the entire calculation at the nominal discount rate of 12 per cent which is used by various planning bodies in the country [Bose 2000; Public Accounts Committee (1991-92), 1992].[1] This also allows for easier comparison with other studies of the relative economics of different sources of electricity which use a nominal discount rate. We have listed the levelised costs at this nominal discount rate for various input values in Table 3. Even with the most optimistic choice of input parameters and assumptions, nuclear power is not cheaper than electricity from RTPS VII.

When we wrote our paper, we were aware that some of our assumptions may be wrong. In part, this was because the NPC was not forthcoming with data [see endnote 2 in Ramana et al 2005]. Some of these assumptions are the ones that Thakur and Srinivasan et al have questioned. However, in order to make amends for any assumptions unfavourable to nuclear power, we did make a number of assumptions favourable to nuclear power. Just as variations in the assumption about the price of heavy water results in changes in the cost of electricity, many of these make a difference to the relative economics of nuclear power. For example, we assumed that contrary to actual practice RTPS VII would have to spend Rs 174 to dispose of each tonne of fly ash. In actual fact, the fly ash is used to make saleable products like mosaic tiles and bricks, and hence the power plant does not pay anything for its disposal [Ghanashyam 2006; Staff Correspondent 2006]. Removing this charge lowers the levelised cost of production at RTPS VII significantly (Table 3).

Another significant expense that we did not include in the cost of nuclear power is that of reprocessing the highly radioactive spent fuel that comes out of the Kaiga reactors. At the time when we wrote the paper, there were no public estimates of this cost. Since then, based on an analysis of the government budget figures for the Kalpakkam Reprocessing Plant (KARP), we have estimated that the levelised cost of reprocessing each kilogram of spent fuel is about Rs 26,000 [Ramana and Suchitra forthcoming]. Currently, the DAE bears this entire cost [Thakur and Chaurasia 2005]. This is yet another subsidy offered by the DAE, and effectively the taxpayer, to the NPC. If even a reasonable fraction of this, say Rs 10,000/kg, is assigned to and internalised within the cost of producing electricity at heavy water reactors, then it would become far more expensive than thermal power from coal (Table 3).

All of this should not be surprising. Studies in many countries have found similar results. In the country with the most nuclear reactors, the US, a detailed study conducted at the Massachusetts Institute of Technology compared the constant or "levelised" price of electricity over the life of a power plant that would be necessary to cover all operating expenses and taxes and provide an acceptable return to investors for a number of base load electricity sources [Deutch et al 2003]. The study found that unless there are dramatic improvements in nuclear cost factors (and none in the other technologies), nuclear power is simply not competitive with the other technologies. As things stand, the MIT study's model estimated a real levelised cost of 6.7 cents/kWh for nuclear power, 4.2 cents/kWh for pulverised coal, and 3.8-5.6 cents/kWh for gas. It is no wonder

**Table 1: Levelised Cost of Electricity with Heavy Water Price of Rs 24,880/kg**

| Discount Rate (Per Cent) | Kaiga I and II | Kaiga III and IV | RTPS VII |
|---|---|---|---|
| 2 | 1.28 | 1.19 | 1.36 |
| 3 | 1.43 | 1.31 | 1.39 |
| 4 | 1.61 | 1.43 | 1.42 |
| 5 | 1.81 | 1.57 | 1.45 |
| 6 | 2.04 | 1.72 | 1.49 |

**Table 2: Levelised Cost of Electricity with Heavy Water Price of Rs 12,525/kg**

| Discount Rate (Per Cent) | Kaiga I and II | Kaiga III and IV | RTPS VII |
|---|---|---|---|
| 2 | 1.18 | 1.10 | 1.36 |
| 3 | 1.31 | 1.19 | 1.39 |
| 4 | 1.47 | 1.29 | 1.42 |
| 5 | 1.65 | 1.41 | 1.45 |
| 6 | 1.86 | 1.55 | 1.49 |

**Table 3: Levelised Cost of Electricity at a Nominal Discount Rate of 12 Per Cent**

| Heavy Water Price | Kaiga I and II | Kaiga III and IV | RTPS VII |
|---|---|---|---|
| Rs 12,525/kg | 1.97 | 1.63 | 1.56 |
| Rs 24,880/kg | 2.11 | 1.77 | 1.56 |
| Rs 12,525/kg, no ash disposal cost | 1.97 | 1.63 | 1.43 |
| Rs 12,525/kg, waste management cost of Rs 10,000/kg | 2.20 | 1.86 | 1.56 |

*Note:* All prices are in 2003 rupees.

that there have been no new nuclear reactor orders in the US for nearly three decades.

To conclude, the NPC's claim that nuclear power is cost competitive can only make sense if one ignores the significant subsidies offered to it through the DAE. Even when those are included, nuclear power is not really economically viable in a competitive environment. EPW

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## Note

1 The relation between real and nominal discount rates is in principle simple. But if the inflation rate varies, then it is no longer so straightforward. The real ($d_r$) and nominal ($d_n$) discount rates in any given year are related by: $(1+d_n) = (1+d_r)*(1+i(Y))$, where i(Y) is the inflation rate for that year. In projects such as the ones we are considering here, expenditures are made over several years with different inflation rates. Thus it is not possible to simultaneously talk about a uniform nominal and a uniform real discount rate.

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