SOME QUESTIONS ABOUT THE ECONOMICS OF NUCLEAR ENERGY

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This paper was presented recently at an SLAAS seminar on Sri Lanka's Nuclear Options after the Chernobyl Disaster. Diandas maintains it is commonly claimed that nuclear energy is cheap; but this depends on the size of the plant. At 300 MW or above it appears competitive with oil. But calculation of cost is a matter of perception. Different appraisers can find different costs.

1. Introduction

1.1 The aspects that I will deal with in this paper are:-

.1 the uncertainty of cost, which is a a matter of perception

.2 a comparison of cost/kwh by coal and nuclear

.3 The SMPR (small or medium power reactor)

.4 the habit of discounting costs and benefits.

1.2 In a previous Section E Panel Dis cussion in Aug 80 I addressed a different list of commercial questions for Sri Lanka energy planners:-

.1 Very long lead time: for a project to be switched on 11-13 years after commitment, how does one assess the capital cost? the actual switch-on date? the cost of uranium from that date on? the cost of operating expenses from that time on? and the cost of other alternatives at that time?

.2 Risk of premature close-down: what is the likelihood of a mishap compelling close-down? how long would a close-down last? and how much would diagnosis, inquiry and repair cost?, all assuming no catastrophe or third party damage.

.3 Dependence on expatriate personnel: how many expatriate personnel will be needed at the stages of planning and preparation, construction, start up and teething, normal running, mishap (if any) and de-commissioning? how much will they cost? and what will be the availability of expatriate specialists in any given international political scenario?

.4 Cost of waste disposal: how much will it cost to store waste? or to dispose it abroad? will anybody accept it?

.5 Cost of de-commissioning: what estimate should be made for de-commissioning cost? to what extent should installers of nuclear power stations concern themselves with costs likely to arise after they have left the decision-making arena, by which time the ingenuity of man may have found low-cost solutions....(or may not have)?

.6 Future cost of uranium: what are the world's total uranium resources? what will world demand for uranium be in the period 1990-2025? how much will uranium cost in that, time span? will re-cycling be generally adopted? will fast-breeders elsewhere take the pressure off world demand for uranium?

.7 Potential obsolescence: what would be the commercial risk, and how much would it cost, if a reactor's supplier went out of business, or a reactor or a component in it was embargoed?

1.3 These are still live questions.

2. The uncertainty of cost

2.1 In any economic analysis one seeks to ascertain the cost of one option as against another. If electricity is needed, is it better to grow trees, import coal, impound rivers, or set up a nuclear reactor? Which is better may depend on many factors. One of the most important is comparative cost. To assess comparative cost, one must know what the cost per kwh will be in each option.

2.2 However, because of difficulties in projecting the future, and in allocating the capital investment over life-cycle production, cost itself is no more than a perception. I have adverted to this on several occasions when addressing hydro-electricity as well as nuclear energy, but for now I will quote from a publication of the NEA (Nuclear Energy Agency, a wing of OECD) entitled:-

"The costs of generating electricity in nuclear & coal-fired power stations" 1983.

2.3 This publication confirmed my view in many aspects. I quote just a few:-

"Any manufacturing or production cost can be calculated in a number of different ways which yield different numerical results.....The method chosen depends in part on the purpose for which the calculation is made......... Depreciation repayment period may be the expected economic life or any shorter period, chosen arbitrarily or by convention....A station's performance may vary from year to year (hence) the capital annual charge may be spread over a greater or smaller number of kwh, thus giving apparently lower or higher kwh cost......There are several ways in which a calculation can be performed and there is a range of factors that may or may not be taken into account, depending on the perspective of the group conducting the calculation".

2.4 Following from these quotations, I warn that if anybody is making a decision, or forming an opinion about competitive cheapness of nuclear or any other form of energy, based on costs statements presented to him, he should have those costs independently evaluated without taking anything for granted. And if anybody is preparing such cost statements, let him consult with a dozen others before issuing them.

2.5 Regrettably I have not done this for this paper. In the next section I present a tentative table of comparative costs which I hope will be challenged in at least some particulars so that it can be refined or even significantly amended.

3. Comparative Cost

3.1 The following is an oversimple computation of comparative cost per kwh:

		Nuclear (Candu type)			Steam		Combustion	
	Hydro	1GW	300MW	60MW	coal	oil	gas	diesel
Capital Cost								
Cost RsM		30000	12000	3000				
Cost RsM/MW	60	30	40	50	20	15	12	12
De-com RsM		3000	3000	3000				
De-com RsM/MW		3	10	50				
Life years	100	20	20	20	30	25	20	20
Hours yearly	6000	6000	6000	5000	4000	5000	2000	2000
Life gwh/MW	600	120	120	100	120	125	40	40
Rs/kwh	.10	.25	.33	.50	17	.12	.30	.30
Fuel Cost								
CPC Rs/litre						4.72	7.83	4.00
raw cost $		55/kg	55/kg	55/kg	60/T	12/bl	12/bl	12/bl
delivereed $		330/kg	330/kg	330/kg	72/T	14/bl	16/bl	14/b1
delivered Rs		9/gr	9/gr	9/gr	2/kg	2½ lt	3/lt	2½lt
kwh/input		32/gr	30/gr	28/gr	2/kg	2.8/lt	2.5/1	4.2/1
Rs/kwh		.28	.30	.32	1.00	.89	1.20	.60
Cost Rs/kwh								
capital	.10	.25	.33	.50	.17	.12	.30	.30
de-commission		.03	.08	.50				
fuel		.28	.30	.32	1.00	.89	1.20	.60
run	.10	.10	.18	.74	10	.10	.10	.10
desilt	.03							
safety	.01	.03	.11	.67	.01	.01	.01	.01
total:	.24	.69	1.00	2.73	1.28	1.12	1.61	1.01

3.2 I have not been able to verify the basic inputs to this table. If any participant would like to correct any of the figures, such as prices, we can adjust the table here and now. For example Prinath claimed last week 10,000 mwd (th) per Ton Uranium, which means, say, 72 kwh (e) per gram. If this was substituted in the above table the cost of nuclear energy would come down by 10 cents per kwh. But my price for delivered nuclear fuel does not include fuel waste disposal cost at the rate of $ 800 per kg fuel cited in IAEA Spring 85 Bulletin, or enrichment cost, which does not arise for Candu reactors.

3.3 I have taken Nuclear reactor life at 20 years and 120 million kwh per MW, which is close to the 20 years and 126.8 gwh used in the NEA calculations.

3.4 I have taken nuclear de-commissioning to cost $ 100 per KW (say Rs 3,000) for a 1000 MW plant vide IAE Bulletin, Winter 1985, page 14, giving an absolute cost of $M 100, which according to the bulletin "for smaller plants may not be significantly different". Hence Rs M 3,000 for de-commissioning in all 3 nuclear columns in the table. Note the difference in cost per KW and per kwh on this basis.

3.5 The same Bulletin mentions that the Canadian 250 MW Gentilly 1 cost $25M for partial de-commissioning so far, full dismantlement to take place 50 years hence with appropriate (costly) security measures in the meantime. The Bulletin also mentions a Uranium processing plant (no energy generated) at Weldon Spring USA which will cost $ 357 million to decontaminate in a decommissioning project running from 1987-1996, and gives $ 98.3M as estimated cost for dismantling the 72MW Shippingport plant in USA which delivered 7,200 gwh during its 25 year life. This works as follows:-

	kwh	$	Rs(at 28/$)
kwh/KW	100,000		
kwh/KW/year	4,000		
decommission		$M 98.3	RsM2752
decom/MW		$M 1.36	R$M38
decom/kwh		$ 0.014	Rs 0.38

3.6 If there is a lot of foreign expenditure involved, then the exchange rate at time of de-commissioning is critical, even if inflation perse is ignored. Will the rate still be Rs 28/- when Sri Lanka's possible first nuclear plant is due for de-commissioning in say 2020?

3.7 To complete the section on costs, the following are a few examples from France, Canada and Japan cited in IAEA Bulletin fror Spring 1985, which could be mentally adjusted by reducing oil fuel cost to 50% of the figure given to reflect recent petroleum prices changes:-

France Projection for 1992: converted at Rs4/Fr

Rs/kwh	nuclear (large)	thermal	
		coal	oil
capital	.48	.33	.28
fuel	.25	.84	2.52
other	.17	.14	.12
total	91	1.3	2.92

Canada 1979: converted at Rs 25/c$

Rs/kwh	nuclear	coal
capital	.27	.09
fuel	.07	.55
other	.09	.03
total	.43	.67

Japan given in US$: converted at Rs 28/$

Rs/kwh	hydro	nuclear large	thermal		
			coal	oil	LNG
capital RsM/MW(given)	67	30	22	15	19
life cycle gwh/MW (?)	67	120	80	120	100
cost Rs/kwh	1.00	.25	.28	.12	.19
interest (?)	1.00	.25	.28	.12	.19
total capital	2.00	.50	.56	.24	.38
fuel (given)	-	.34	.84	1.79	1.49
other costs (?)	.24	.50	.28	.21	.26
total (given)	2.24	1.34	1.68	2.24	2.13

3.8 The Japanese figures do not make. sense with my interpolations between the given figures (or with any interpolations) against the question marks. But they illustrate the effect of differing cost perceptions and of including interest. In effect the capital cost of hydro is recovered from just 33½ gwh or 6,700 kwh/KW over 5 years, leaving the scheme to deliver zero-cost energy thereafter. This shows that Japanese hydro sales are overpriced just as are Lanka's if yesterday's newspaper report is to be believed to the effect that Victoria has already, in 1½ years, reaped one seventh of its cost, implying that Victoria's electricity after 10½ years will have zero capital cost.

4. SMPR (Small and Medium Power Reactors)

4.1 IEAE has been promoting small reactors as a means of making power plants acceptable in small grids. Sri Lanka's 1,000 MW system, perhaps 2,000 MW in ten years time, can only accept a maximum 200 MW capacity plant then in order to fit the rule that no single plant should occupy more than 10-15% of the grid.

4.2 Manufacturers have had a bad field for the last several years. If they are to stay in business and retain their highly skilled multidisciplinary teams of experts, they must get some orders, and better small than never. They would be under business presure to offer small reactors at less than cost, or on interest-free supplier's credit.

4.3 In respect of financing of nuclear plants, the IAEA Winter 85 Bulletin says at page 47:-

"industrial nations have been willing to provide assistance, many times under exceptionally generous terms, to assist their manufactures in establishing a position in the nuclear power export market".

4.4 Perhaps this accounts for the claim that small reactors can be as cheap per KW as large ones, despite the normal economies of scale. In-house prefabrication is said to be in vogue as a means of reducing installed cost. But the cost of location studies, preparation and planning can hardly be scaled down.

4.5 Yet even if the capital cost per KW could miraculously come down to the same level as for 1,000 MW plants, and thus remove the disadvantage of smallness from the capital cost per kwh, the running and safety costs can hardly be scaled down. I estimate Rs 200 M per year as the minumum staff cost per annum however small the plant, and this would have to be shared by fewer kwh.This explains, in the table above, why cost/kwh rises so sharply as nuclear plants become smaller. The impact of de-commissioning cost has already been discussed.

4.6 A intriguing IAEA argument says that introducing a 100 MW plant once a year is better than introducing a 1,000 MW plant every 10 years, because there is less gap between supply capacity and demand before and after the new introduction. However this does not create an advantage, it merely removes one disadvantage of nuclear as against coal, which can easily be incremented at 100 MW/year because, in the case of coal, the economies of scale are not so marked.

4.7 In respect of SMPRs, Prinath Dias said last week that 60MW plants were contemplated, but the Winter 1985 IAEA Bulletin quotes EPRI's Braun as saying only "a strong interest exists in evaluating plants with output less than 600 MW; apart from India, which has its own interest in building up to a total of 18 plants between 210 and 235 MW, only the following are mentioned in the SMPR range (i.e. less than 600MW):-

4.8 Even IAEA's Director General Blix only noted that the nuclear industry is showing greater interest in smaller nuclear reactors, typically those below 600MW; that suppliers are now ready to offer smaller reactors for export; that potential buyers in developing countries are expressing renewed interest as well; and that the likely next steps are economic feasibility studies for particular solutions.

5. Discounting

5.1 The only other thing I wish to address in this presentation is the vexed question of discounts. For the Channel Tunnel the British-French Bankers adopted a 3% discount rate as representing the real rate of commercial long-term interest shorn of inflation. It is common in feasibility studies undertaken for the purpose of obtaining loan financing, or even government funds, to discount all future costs and benefits at a rate of discount approximating real interest rates if cash flows are to be projected in constant money terms, or at a rate enhanced by projected inflation rates where cash flows are to be forecast at inflated monetary values. In a sense, the inflation component and the discount enhancement cancel out, leaving the real rate of interest in the calculation.

5.2 However, discounting itself is originally a banking practice for approving commercial loans, when the bank is concerned to retrieve its money plus interest within its lending period rather than within the lifetime of the project. It suits the banker to ignore the value of benefits coming in over the long-term future and to ignore future costs too. This discounting habit has been justified in a whole library of literature, but also critisiced by authors like Clifford Sharp of Leicester University.

country	name	plants	on-line date	each MW
Argentina	Atucha 1	1	1974	367
China	Quinshan	1	due 1989	300
India		12	1995-2000	500

5.3 The effect of discounting in the present instance is to change the perception of cost and benefit, and in particular:-

:make the future energy flows of hydro schemes look insignificant.
:make the de-commissioning and after costs of nuclear schemes look small.

6. Conclusions

6.1 Although large-scale nuclear looks to be the cheapest non-hydro source of electricity according to the figures in para 3.1, small-scale nuclear electricity, even if made available, will not be cheap.

6.2 Although large scale nuclear looks cheap, it too could turn out dear in a number of circumstances leading to lower productivity. One such circumstance could be a non-catastrophic accident like that at 3-Mile Island, where two plants have been non-productive for the last seven years.

6.3 The figures in para 3.1 are very sensitive to the assumptions on which they are based. The following table shows how they vary cumulatively if:-

.1 Interest on capital is included in the cost
.2 Prices rise to Uranium. $ 82½, Coal $ 90, oil $ 18,
.3 The US dollar goes up to Rs 35
.4 Hydro scheme life is reduced to 33 years
.5 All capital costs increase further by a factor of 2

Rs/Kwh	para 3.1	cumulatively adjusted[1] .1	.2	.3	.4	.5
HYDRO	.24	.34	.34	.39	.79	1.39
NUCLEAR						
1 GW	.69	.94	1.08	1.34	1.34	2.00
300 MW	1.00	1.33	1.48	1.81	1.81	2.73
50 MW	2.73	3.23	3.39	2.03	2.03	3.90
STEAM						
Coal	1.28	1.49	1.95	2.41	2.41	2.83
Oil	1.08	1.20	1.64	2.03	2.03	2.18
COMBUST						
gas	1.61	1.91	2.51	3.11	3.11	3.86
diesel	1.01	1.31	1.61	1.98	1.98	2.73

6.4 If on top of these adjustments, or any of them, discounting were applied, those sources with higher capital costs, viz hydro and nuclear would look progressively worse as the rate increased, but nuclear's decommissioning cost would appear to decline.

6.5 Sensitivity of output has not been tested. Yet the nuclear capital cost allocations are based on 6000 hours/year which is 68½% load factor. However the world's average only reached 69% in 1984. It is likely that Lanka would be lower than average, perhaps 60% or if plagued with teething and later problems as Pakistan has experienced, less than 50%. Such low outputs would again increase cost/kwh.

6.6 There remain the many unanswered (some unanswerable) questions in para 2.2, a number of them of the "what if?" nature. How much would we have to pay other countries to take away the spent fuel? What happens if the supply of some critical operating material (eg heavy water) or of nuclear fuel itself, dries up for political reasons? All these are commercial questions.

6.7 Out of 374 working reactors in the world there has been only one Chernobyl and one 3-Mile Island, but there have been a couple of dozen lower level incidents that have caused premature closure. Insurance would have to be taken for the risk involved covering rectification costs and loss of output.

6.8 And finally what size of plant could Lanka's grid accomodate? When total demand reaches 2,000 MW, base load might be 800 MW or less. Would it be wise to place more than 200 MW in a single nuclear station at that time?