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REVIEW OF ECONOMIC ANALYSIS OF ALTERNATIVES FOR CHARLESTOWN NUCLEAR POWER PLANT AS SET FORTH IN DRAFT ENVIRONMENTAL STATEMENT OF NUCLEAR REGULATORY COMMISSION MAY 1979 (NUREG 0529)

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MY ASSIGNMENT

I have been asked to review the sections of the DES on the comparative economics of the proposed Charlestown nuclear plant with generation by coal and other alternatives. My sections are: 9.1, 10.2, 10.4, 10.5 and Appendix D.

My review is structured as follows:

1. A brief background statement of the scope of the project and the appropriate response for an economic analysis of costs.

11. An itemization of the essential factors that must be specified in an NRC economic analysis, and a parallel evaluation of how far each of these items has been covered, or not covered by NRC staff. This is done on a scale of 10 for the optimum response and showing for each item what part of 10 has been covered by NRC, in my estimation. These quantifications are necessarily approximate, but relatively valid.

III. An item by item review of the sections assigned to me on the alternatives to nuclear power other than coal.

IV. Nuclear and coal generation

V. Conclusion

I. BACKGROUND

The DES is for a 2 unit nuclear power plant of 2300 MW costing $2.8 billion. Since this assumes a 5% escalation to 1988, and inflation rates have been higher, we may take a rounded cost of $3 billion. Also, since provision is made on the site for another 2 units, the cost in 1988 dollars could go to $6 billion.

The investment, at either the 3 or 6 billion levels, more than justifies a thorough, comprehensive and adequate study of the comparative (competitive) economics of the proposed plants versus coal and other alternatives.

Under certain circumstances, the economic study can be crucial to the question of whether to build a nuclear power plant. If the economics for nuclear were no better at best, or worse, than coal, say, then the cost-benefit question arises of why build the nuclear plant and subject RI and neighboring states to the costs and risks of possible meltdowns, low level radiation during routine operation, and the presently unsolved waste storage for thousands of years. This economic possibility happens to be well within the range of the best economic studies I have seen, even including that of the NRC in its DES.

Contrariwise, if nuclear were clearly and substantially cheaper than coal or other alternatives, there would then be the massive, often subjective, task of measuring against this benefit the costs noted in the above paragraph. This possibility appears to be much more remote than the opposite possibility.

I will now address myself to the question of the adequacy of the NRC Staff's "independent" economic analysis.

II. REQUISITES OF AN ADEQUATE ECONOMIC ANALYSIS

Factors which are essential to a comprehensive statistical and qualitative analysis are listed in Table 1. The explanatory adequacy of the NRC staff's analysis as contained in the DES is rated for each factor on a scale of 10. The number 10 represents optimal adequacy. The rating can only be approximate, but is an indicator of the area of adequacy. A 2, for example, says that the staff's treatment of the factor is not far from "0", but has some small amount of explanatory and analytical value.

My matrix shows 10 factors for nuclear and coal. Half have been given virtually no qualitative analysis in depth. Except for O & M, the othersare close to zero. The average for nuclear is 1.3, for coal 0.7. Just what these low ratings mean is now explained, item by item.

1. Capacity factor definition etc. How this is defined can make a 3 to 5 percentage point difference. For Millstone 2 nuclear power plant at Waterford, Connecticut, eg, the monthly "Gray Book" report shows the following capacities:

Nameplate rating	910	MW
Design electrical rating, net	830	
Maximum Dependable Capacity, (gross)	842	
Maximum Dependable Capacity, (net)	810	

Unit capacity factors are shown for MDC net and DER net, but not for nameplate. In this case, the MDC capacity factor is 11% less than that based on nameplate rating.

The curious fact is that the Federal Power Commission from the beginning has expressed capacity factors only in terms of net generation and nameplate rating. The problem for individual plants and other capacity factor definitions has arisen pretty much only since the nuclear power plants have come in.

The only objective capacity is the nameplate rating fixed to the generator by the manufacturer. It is true that companies may unintentionally misreport nameplate ratings, but on the whole errors will be symmetric for other definitions, so that nameplate remains the best single basis for capacity factor.

The NRC staff estimates do not specify which basis is used for capacity factor, but I believe that MDC net is used, because this is the definition which NRC appears to favor in, eg, the Gray Book when calculating actual versus potential energy production monthly.

I would recommend that nameplate ratings be used by NRC.

TABLE 1: EXPLANATORY ADEQUACY OF NRC STAFF ANALYSIS

ITEM	10 = optimal adequate	
	NUCLEAR	COAL
1. Capacity factor: a conceptual, definitional, functional and methodological examination	1	1
2. Senescence: of plant & capacity factors	2	0
3. Economic life of plant	2	?
4. Lifetime capacity factor (1+2+3)	2	1
5. YoYo effect, with histograms. More important, perhaps, than capacity factor	0	0
6. Operation and maintenance costs: historical vs design	5	5
7. Scale (size) effects: for primary and secondary nuclear circuits	0	0
8. Technological constraints - cost & safety welding art for containment vessels and piping and tubing, valving, pumps, metering etc	0	0
9. Human factor constraints, costs, safety: a. management & labor at power plants b. Similarly at equipment manufacturer c. Similarly on construction site	0	0
10. Low sulfur Eastern coal, as alternate for Western coal in New England	N.A.	0
Simple arithmetic average	1.3	0.7

2. <u>Senescence</u>

This is the decline in capacity factor with age of the plant. It has been given virtually no attention in American literature.

New England Power (NEP) assumes a rise in CF to the 6th year and a leveling off thereafter at 76.2%:

Year 1	59.2%
Year 2	60.9%
3	66.8%
4 & 5	71.0%
6 +	76.2%
30 yr. average	74.5-
40	74.9
28	74.34
20	73.6

NRC staff assumes a 60% CF with a range of 50% and 70% but does not specify any senescence factor.

ERDA (Energy Research and Development Administration) in a 1975 publication assumed the following senescence:

Year 1 & 2	65%
3 to 15	75% high 70% low
16 to 30	minus 2% per year to a minimum of 40%

Source: ERDA, "Total Energy, Electric Energy, and Nuclear Power Projections, United States" (Feb. 1975) p6.

In my discussions with RWE, the largest German electric utility they felt that senescence was a correct principle, but would start the decline in CF at the 18th year.

It is obvious that senescence is a crucial factor in the lifetime economics of a nuclear power plant, or coal plant and that the absence of any consideration in the DES is a serious flaw.

3. <u>ECONOMIC LIFE OF PLANT</u>

With the high capital intensity in a nuclear plant, and a high but somewhat lesser intensity for coal plants, the life assumed for the plant is vital in any economic analysis. The standard assumption of government and utilities is 30 years for both plant types, and this is the assumption of the NRC staff. The assumption, however, is not pure. At pages 7-1, 10-12 and 10-15 the staff also uses 40 years. Some utilities, including NEP, have begun to use a 40 year life, apparently in order to make nuclear costs seem lower, but this is unsystematic. NEP's assumed life in the DES is not specified, and is perhaps 30 years.

A most significant deviation from the 30 year assumption for nuclear is embodied in the study done for NEP by Arthur D. Little Company in 1975, which is understood to be the basis on which the NEP directors decided to build the RI nuclear plants. This report does not state the assumed lives of coal and nuclear, but at my request NEP found out from ADL that a 30 year life was assumed for the coal plant, but 28 years for nuclear.

This drop to 28 years for nuclear is important not so much for that particular number, but as an indicator that ADL felt that nuclear would have technological problems which would shorten its life. The 28 is simply a proxy for this principle, and not significant as that particular number by itself.

The French use a 20 to 21 year economic life for nuclear, the UK 20 years at a derated CF, the Germans 20 years. RWE, the German utility, uses a technical life of 30 to 32 years, but an economic life, based on internal calculations, of 20 years, both for nuclear and for coal. Dr. Schoch, who is manager of the generating station at Mannheim in Germany and head of the national TUV as well as the

Baden TUV, has told me that he thinks the nuclear plant life is under 20 years, and would have to cost more to bring it up to 20 years.

I have tried to give some idea of the importance of the assumed life of a nuclear versus a coal plant in the comparative cost analysis. The omission of any analysis on this point in the DES is serious.

4. Lifetime capacity factor

This is dependent on points 1,2,3, above and nothing more need be added here.

5. YoYo effect

If one looks at the annual chart of daily CF's for nuclear power plants, which are known as histograms, he will see that these CF's rise and fall like a yoyo with considerable frequency. This fluctuation factor can be more important than the CF itself. Thus, two plants with 55% CFs could be entirely different if in one the availability can be controlled to be had at the peak, but if in the other this usability was only poorly predictable. An example is the cold spell in March 1978, when there was an auxiliary peak, but both Millstone nuclear plants were shut down.

Dr. Schoch, who must sell his power wholesale competitively, told me he could not operate with the nuclear histogram patterns. He must have 90% availability at the peak in winter, with 3 hour overload capability. The somewhat stochastic quality of the nuclear histogram is one of the main reasons, he told me, for his not buying a nuclear plant.

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There is no attention to the yoyo, or reliability, effect, as distinguished from CF, in the DES and virtually none elsewhere in the literature. It must be an essential of any valid economic analysis of nuclear power.

6. Operation and maintenance costs

O & M costs are available for nuclear and fossil fuel plants in the necessary detail mainly in the FPC/FERC Form-1 reports of utilities. Since so much of the low capacity factor below the 80% design for nuclear plants is due to technological problems, they should be reflected in erratic patterns of O & M from year to year as CF fluctuates. As CF drops, O & M, if fully reflected in utility accounts, should rise. Conversely, for fossil plants, assuming in general that lower CFs are due to load following (ie. drops in demand), O & M should drop.

Staff uses a comparison of 2 x 1150 MW nuclear units with 3 x 767 coal units with flue gas desulfurization (w/FGD). O & M is given as follows:

	Mills per Kwh		Coal with
CF	NUCLEAR	COAL	NUCLEAR = 100
50	7.4	11.2	151
60	6.2	10.1	163
70	5.4	9.4	174

To see what comparisons of actual plants look like, I prepared the following table for the Millstone nuclear power plant #1, 662 MW, commercial in 1970, with the Canal fossil fuel plant in Massachusetts, 542 MW, commercial in 1968, and burning fuel oil.

	Mills/kwh		Nuclear	CF	
Year	Nuclear	Canal	= 100	Nuclear	Canal
1976	3.73	1.45	39	65	73
5	3.09	1.00	32	67	81
4	2.72	1.38	51	62	71
3	4.07	.74	18	32	81
2	2.42	.72	30	55	78
1	.91 (*)	.78	86	62	78

(*) First year of operation, which is usually low in O & M.

I've also compared 3 Midwestern plants burning coal with the Kewaunee nuclear plant. The coal units range from 460 to 668 MW, the nuclear is 535 MW. Kewaunee O & M was 3.17 mills/kwh in 1976, compared with .66, .69 and .84 mills for the 3 coal plants. With Kewaunee at 100, the coals were 21,22 and 26. CFs for coal were 60%, 52% and 49%, and for Kewaunee 72%. Point Beach nuclear plant, one of the better managed apparently, operated at .92 mills, with the coals then being 72, 75 and 91 percent respectively of Point Beach.

What this means is that the actual numbers, selected at random, are opposite to the O & M relationships of nuclear and fossil fuel plants assumed by the NRC staff. This illustrates my point that some qualitative analysis of O&M is essential in an economic analysis of nuclear versus coal, and that this is entirely missing from the DES.

7. Scale

Scaling up of size of nuclear power plants has engendered two problems, large jumps in size without first exploring on prototypes the effects of moving well up the line on size; and the aggravation of this risk in nuclear plants as opposed to those using fossil fuel. I asked Siemens, which has made all nuclear power plants in Germany, why the non-nuclear part of the plant seemed to have more casualties than the primary nuclear circuit -- something I had observed in reviewing the individual plant data from the International Atomic Energy Agency. The answer is that since pressures and temperatures of steam in nuclear plants are a fraction of those in fossil fuel plants, the size of the equipment such as boilers and turbogenerators must be much larger, and has breached the experienced limits of scale. I give examples I have selected at random in Table 2.

This factor must be considered in a comprehensive analysis of future plant economics, but has been overlooked in the DES.

TABLE 2: Pressures and Temperatures of Coal and Nuclear Power Plants

	COAL				NUCLEAR				
UNIT	Manatee	Wansley	Mansfield	Bull Run	Browns Ferry	Trojan	Beaver V	St. Lucie	Indian Point 3
Company	Fl PL	GaPC	PaPL	TVA	TVA	Ptlnd	PA	FlPL	PASNY
MW	863	952	914	950	1152	1216	923	850	1125
Year Built	'76	'76	'76	'67	'74	'76	'76	'76	'76
Type					BWR	PWR	PWR	PWR	PWR
Turbine:									
a. PSI	2400	3500	3500	-	950	873	735	750	715
b. °F	1000	1000	1000	-	575	533	517	513	507
c. RPM	3600	3600	3600	-	1800	1800	1800	1800	1800
Boilers:									
a. Number	1	1	1		2				
b. PSI	2500	3625	3785	3650	1005	895	781	750	
c. °F	1000	1000	1000	1003	575	533	517	513	507

Source: FPC/FERC, Statistics of Steam Electric Plants, 1976 and earlier years.

8. Technological constraints

There are serious questions of corrosion in nuclear power plants, including leakages from the primary into the secondary circuits. The best state of the art of welding is in question for the containment vessels. The metallurgy and welding and wall thicknesses of piping and tubing is also in question. The quality and adequacy of valving, pumps, metering etc. are also uncertain. The Germans and British, particularly, have been uneasy on these points and have commissioned extensive studies of the factors involved. The DES gives no mention of these risk factors in prediction of operation of a nuclear plant, but such mention is essential.

9. Human Factor constraints

A certain high level of quality control is essential at all levels of nuclear power manufacture, construction and operation and this depends on labor, management and design personnel, as much as on pure technology. There are serious questions of the level of human excellence in these areas in terms of quantity available, adequacy for the requirements of the sensitive nuclear technology, and willingness to work in the nuclear power industry. Three Mile Island only brought these factors to the public attention, but only more in degree than the Browns Ferry Fire. These questions go to the heart of the real world feasibility and costs of nuclear power. However, no recognition has been given to it in the DES.

10. Low sulfur Eastern coal, as alternate for Western Coal in New England

The DES is couched entirely in terms of either high sulfur Eastern coal with FGD, or low sulfur Western coal without FGD. There is another real possibility low sulfur Eastern coal. There are billions of tons of this coal. At minimum the DES should mention and evaluate this possibility.

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III. SPECIFIC COMMENTS ON DES

I now comment on specific items referring to the page in the DES. Six general comments can be made by way of the DES frame of reference.

-- It uses a strict time horizon of 1986-90. Any alternative which will not produce 2300 MW by that time is eliminated as a possible substitute for nuclear power plants. For several of the alternatives, however, their additive effect exceeds the output of at least one, possibly the two nuclear units, but this has not been considered by the DES. Also, there is substantial evidence that there is conventional non-nuclear fossil fuel supply(oil, coal hydro) which, with a reasonable degree of conservation, will carry us through a 50 year time horizon. Therefore, it is not necessary to posit nuclear plants for 1990 if other costs, such as risks and radioactivity are considered primary. I am not advocating that position here, but making the point that it should have been given some recognition in the time frame of the DES.

-- The DES bases its economic analysis on a 60% ± 10% capacity factor. Operation and maintenance costs are then keyed to this as the normal expectation in planning the nuclear capacity. There is a possible error of assumption here. If the company ordering the nuclear plant assumes a higher CF, and bases its power supply planning on that assumption, then any serious shortfall requires it to purchase power to replace the deficit. The cost of purchased power is very high because it generally is from older and less efficient fossil fuel plants. This is the case at hand. NEP assumes a 74% CF. The shortfall when 60% is achieved, or 50 to 55%, engenders two expenses not included in the DES staff analysis: purchased power, and high costs of repairing the casualties or other defects which cause the shortfall. On this ground, the DES analysis is seriously defective. If corrections are made for purchased power and maintenance, the excess of 15% for coal generating costs over nuclear costs estimated by the staff at 60% CF (at p. 9-27) more than disappears, and on these two points alone coal becomes cheaper.

-- The DES assumes that coal and nuclear will be paired at the same CFs. This is an error. Nuclear power must be treated as close to run-of-stream hydro, therefore used whenever available (with few exceptions). Coal is load-following and will be shut down in regions such as upstate NY (where the Niagara and St. Lawrence hydroelectric projects, run-of-stream, supply half the energy) whenever demand is less than run-of-stream supply. This will occur 11 pm to 6 am, and weekends and holidays. When considering new plants, a baseload coal plant can consistently average 75 to 85 percent, as shown by actual data of large units. The 50 to 60 percent limitation on nuclear is entirely due to technological shortfalls below the 80% design. If these shortfalls can be corrected, the costs would rise substantially for nuclear power. The DES has completely ignored the considerations in this paragraph.

- The DES overlooks the purely fuel savings value of substituting cheap power on a non-base load arrangement in certain situations. This is due to the reversed ratio of fuel to total generating cost between 1968 and 1979. In '68 this ratio was about 40%, today it is about 60%. Therefore, substitution of Canadian power when it is available, if the rates are low enough, or wind, solar and solid waste alternatives may be economic. There should be a good degree of analysis of this factor.

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-- The DES is flawed in not looking at the total interrelated energy picture. For example, the high use of geothermal, solar, oil shale, etc. in other areas reduces the world and US demand for high marginally priced oil and other synthetic substitutes, and thus reduces the cost of, say, oil to New England. This in turn would reduce the economic value of nuclear power in comparison with coal or oil.

- The effect of using domestic sources of alternatives to nuclear power on military expenditures, the balance of payment problems, and inflation due to OPEC pricing, is vital in today's context to an economic analysis of such use. Some serious attention should be given to these factors in the DES.

The NRC staff eliminates as feasible substitutions for the 2 nuclear power plants all alternatives except coal. In Table 3, I indicate, on a scale of 10 optimum, my evaluation of the adequacy of the staff analysis, and in some items my agreement with the Staff conclusion. I add specific comments below.

Power purchased from Canada: the incremental hydro unit is so large relatively to the small Canadian market, that there is advantage for the Canadian provinces to send this power to US cheaply for several years. This would affect the amount and timing of nuclear power in New England, depending on prices and estimates of future need by Canadians of their hydro. The DES needs more analysis.

Modernization, in view of the reversed fuel to total generating cost of power, should be given more attention in the DES.

Natural Gas: the DES is not aware that in the past 3 years the natural gas deficit has become a surplus, and that in New England eg, the gas companies are advertising for new customers. The DES should revise its analysis.

Solar: The DES treatment here is not too profound. For example, I use 1100 kwh a month in my house. Half is for electric hot water. If I can get 60 to 80 percent of this from solar, the drop in need for electricity is great. Even if the solar substitutes for oil or gas, the interrelated demands for fuel will affect the supply and price of oil or coal for electricity generation.

TABLE 3: Non-Coal alternatives to Nuclear Power, Evaluation of NRC Staff Positions

lternative & Page No.	Approx. Value MW	Adequacy of NRC Analysis 10=Optimum	My position on NRC staff rejection
-2 Power purchase from Canada		8	agree, generally
-2 Modernization of older fossil plants	600	4	More anal. needed
-2 Baseloading peaking capacity		8	
-3 Oil	0	8	
-4 Natural Gas	0	7	Analysis too spar and superficial
-5 Hydro	2300	5	
-5 Magnetohydrodynamics (MHD)		9	I agree
-6 Fuel Cells, 1990		4	I agree with rese vations
-7 Oil Shale	2.5 MBD	5	NRC too Negative
-7 Ge thermal		8	I agree with reservations
3 Solid Waste, municipal	2300	6	NRC too negative
9 Fu ion, commercial by 2,000 AD		9	agree generally
10 Solar		9	too negative
-12 Photovoltaics		8	
-13 Wind		7	
-15 Cogeneration		7	
Total	5200		
	+ 2.5 MBD oil		

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IV. COMPARATIVE ECONOMICS OF NUCLEAR AND COAL GENERATION

As a general comment on the health effects of nuclear and coal plants, particularly coal, they are too nebulous, too little is known as yet today, to factor them into cost comparisons. I am not sure these areas are for me to comment on, in any case. (pp. 9-17 to 9-26).

My main comment will be on Appendix D on the coal-nuclear comparison. I will not repeat comments where they have already been made above.

1. No. of units. The DES assumes 2 x 1150 MW nuclear units and 3 x 767 units for coal. There are already 1350 coal units, and a number at 1,000 ±. Using 2 x 1150 for coal as well would *pari passu* with nuclear, reduce the relative cost of coal, and might come close to eliminating the advantage of nuclear given by NRC staff (15% at 60% CF).

2. The only mention of using Eastern coal (p. D-9) is for high sulfur coal. There are billions of tons of Eastern low sulfur coal -- this availability should have been analyzed.

3. Capital costs: the NRC comparison is of a high sulfur Eastern coal with FGD with nuclear. The investment cost ratio of coal to nuclear is 83%. I would like to cite an excellent study of coal versus nuclear by Exxon's Research and Engineering Division. This private internal study was made available to me. Unlimited resources were put into the study by Exxon. It shows an investment ratio for a New England plant for nuclear and high sulfur Eastern coal of 72%.

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I suggest further analysis by DES of the investment factor, because th Exxon ratio would come close to wiping out the nuclear advantage of NRC staff. Furthermore, for Appalachian low sulfur coal without FGD - a possibility I have criticised the NRC study for neglecting -- its ratio is only 53%.

4. O & M: I have already commented on this above, and need not repeat here.

V. CONCLUSION

I could submit numerous significant annotations on the DES, but have covered the more important ones.

The conclusion of my analysis of the DES is that its omissions of coverage, and its defects of assumptions, methodologies, numbers, note of other studies such as the Exxon study, and overall coverage are so great as to require a rejection of the study as it now stands.

With investments of 3 to 6 billion dollars, a more adequate NRC study is warranted.

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