COMMONWEALTH OF MASSACHUSETTS
DEPARTMENT OF PUBLIC UTILITIES

PETITION OF THE MASSACHUSETTS MUNICIPAL WHOLESALE ELECTRIC COMPANY PURSUANT TO CHAPTER 775 OF THE ACTS OF 1975 FOR APPROVAL OF THE DEPARTMENT OF PUBLIC UTILITIES TO BORROW FROM TIME TO TIME BY THE ISSUANCE OF BONDS (AND TEMPORARY BONDS, NOTES OR OTHER EVIDENCES OF INDEBTEDNESS) OF A PRINCIPAL AMOUNT NOT IN EXCESS OF $335,000,000 FOR PROJECT NO. 6 PROJECT COSTS ASSOCIATD WITH NUCLEAR GENERATING UNITS KNOWN AS SEABROOK UNIT NOS. 1 AND 2 OF THE PUBLIC SERVICE COMPANY OF NEW HAMPSHIRE AND FOR COSTS RELATED TO STUDY AND DEVELOPMENT ACTIVITY FOR IMPLEMENTING SOURCES OF RENEWABLE ELECTRIC ENERGY.	)	D.P.U. 20248

TESTIMONY OF PAUL L. CHERNICK

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Dated: June 2, 1980

Q: Mr. Chernick, would you please state your name, position, and office address.

A: My name is Paul Chernick. I am employed by the Attorney General as a Utility Rate Analyst. My office is at One Ashburton Place, 19th Floor, Boston, Massachusetts 02108.

Q: Please describe briefly your professional education and experience.

A: I received a S.B. degree from the Massachusetts Institute of Technology in June, 1974 from the Civil Engineering Department, and a S.M. degree from the same school in February, 1978 in Technology and Policy. I have been elected to membership in the civil engineering honorary society Chi Epsilon, to membership in the engineering honorary society Tau Beta Pi, and to associate membership in the research honorary society Sigma Xi. I am the author of <u>Optimal Pricing for Peak Loads and Joint Production: Theory and Applications to Diverse Conditions</u>, Report 77-1, Technology and Policy Program, Massachusetts Institute of Technology. During my graduate education, I was the teaching assistant for courses in systems analysis. I have served as a consultant to the National Consumer Law Center for two projects: teaching part of a short course in rate design and time-of-use rates, and assisting in preparation for an electric time-of-use rate design case.

Q: Have you testified previously as an expert witness?

A: Yes. I have testified jointly with Susan Geller before the Massachusetts Energy Facilities Siting Council and the Massachusetts Department of Public Utilities in the joint proceeding concerning Boston Edison's forecast, docketed by the E.F.S.C. as 78-12 and by the D.P.U. as 19494, Phase I. I have also testified jointly with Susan Geller in Phase II of D.P.U. 19494, concerning the forecasts of nine New England utilities and NEPOOL, and jointly with Susan Finger in Phase II of D.P.U. 19494, concerning Boston Edison's relationship to NEPOOL. I also testified before the E.F.S.C. in proceedings 78-17 and 78-33, on the 1978 forecasts of Northeast Utilities and Eastern Utilities Associates, respectively; jointly with Susan Geller before the Atomic Safety and Licensing Board in Boston Edison Co., et. al, Pilgrim Nuclear Generating Station, Unit No. 2, Docket No. 50-471 concerning the "need for power"; and in D.P.U. 20055 regarding the 1979 forecasts of EUA and Fitchburg Gas and Electric, the cost of power from the Seabrook nuclear plant, and alternatives to Seabrook purchases. I have also submitted prefiled joint testimony with Ms. Geller in the Boston Edison time-of-use rate design case, D.P.U. 19845, but we have not yet testified.

Q: Are MMWEC's estimates of Seabrook capital costs consistent with historical experience?

A: No. Econometric studies by National Economic Research Associates (NERA) and by the Rand Corporation indicate that Seabrook will cost much more than MMWEC claims. This conclusion is also supported by the historical tendency of architect/engineers and utilities to underestimate nuclear construction costs.

Q: Please explain how the NERA study indicates that MMWEC's capital cost estimates are optimistic.

A: The NERA study (Perl, 1978), apparently sponsored by the Atomic Industrial Forum, projects a capital cost of about $2245/kw (in 1990 dollars) for an 1150 mw first unit. This value is based on three very doubtful assumptions:

1. 5.5% general inflation, 1977-1990,
2. 6% real escalation of nuclear costs, 1977-85, and
3. no real escalation of nuclear costs, 1985-90.

Since NERA's study indicates that real nuclear costs actually increased by 10% annually from 1960 to 1977, NERA's inclusion of cost estimates with 6% inflation from 1977 to 1985, and the exclusion of all escalation past that point, is unjustified by the historical record. The 5.5% general inflation assumption seems optimistic as well, at least in the short term. Removing both NERA's inflation and NERA's escalation, we find a 1977 estimate of

$$\frac{2245}{(1.055)^{13} \times (1.06)^{8}} = \$702/\text{kw (1977)}$$

for a first unit and

$$702 \div e^{.26953} = \$536/\text{kw}$$

for a second unit. These figures are comparable to the extremes NERA presents for 1977 actual costs of $396 for an unusually cheap second unit to $902 for an unusually expensive first unit.

Assuming a continuation of historic (10%) real nuclear escalation rates, inflation of 10% annually 1977-83, and 8% thereafter, the Seabrook units would cost:

$$702 \times 1.1^{7.5} \times 1.1^{6} \times 1.08^{1.5} = \$2853/\text{kw}$$

for Seabrook I, in January 1985, and

$$536 \times 1.1^{9.33} \times 1.1^{6} \times 1.08^{3.33} = \$2987/\text{kw}$$

for Seabrook II in November 1986.

The total cost of the project would then be $6.7 billion dollars. If Seabrook II is delayed an additional four years, as PSNH has suggested may be necessary, the modified NERA formula predicts a cost for that unit of

$$536 \times 1.1^{13.33} \times 1.1^{6} \times 1.08^{7.33} = \$5950/\text{kw},$$

which would bring the project cost to $10.1 billion.

Q: Does the Rand study support similar estimates?

A: Yes. In a study prepared for DOE (Mooz, 1978), Rand derived the formula presented as Table 1. The 1976 dollars used in the report are the deflated values of actual annual expenditures, not of the final accounting cost, so the values given by the formula must be inflated to reflect the entire construction period.

Variable Name	Meaning	Co-efficient	Seabrook I [Seabrook II]	Value for Contribution to Cost/kw
Constant				-8885.5
CPIS	date of construction permit	141.34	76.5	10812.5
SIZE	in MW	-.21943	1150	- 252.3
TOWER	cooling tower dummy	92.04	0	0
LOC 1	Northeast	128.12	1	128.12
LN	ln of # of LWR plants built by A/E	-72.422	ln (6) = 1.79 [ln (8) = 2.08]	-129.8 [-150.6]
Cost in 1976 $/kw			Seabrook I Seabrook II	1673.0 [1652.2]

Table 1: Rand Formula Estimate of Seabrook Construction Cost

The Rand study used a steam plant construction deflator which increased in value at 8.01% per year from 1965-77 while the CPI increased only 5.59% per year in that period. Hence, it is appropriate to add 2.4% to the general inflation rates assumed, for steam plant inflation rates of 12.4% from 1977 to 1983 and 10.4% thereafter. The North Atlantic steam plant index actually increased 11.1% from 1976 to 1978. Approximating the average cost index during construction as the average of the index at the time of the purchase of the nuclear steam supply system (1/73) and the index at the time of commercial operation, we have

$1673 \times [(1.111 \times 1.124^{5} \times 1.105^{1.5} + .662) \div 2] =$

\$2487/kw for Seabrook I, January 1985

$1652.2 \times [(1.111 \times 1.124^{5} \times 1.104^{3.33} + .662) \div 2] =$

\$2837/kw for Seabrook II, November 1986

and

$1652.2 \times [(1.111 \times 1.124^{5} \times 1.104^{7.33} + .662) \div 2] =$

\$3949/kw for Seabrook II, November 1989.

These costs imply total project cost of \$6.1 billion to \$7.4 billion. While this methodology agrees well with the NERA projection (with the modifications explained on pp. 3-4, *supra*) for the 1985/86 in-service dates, the difference in treatment of time produces quite different results for the delayed in-service date for Seabrook II.

Since the only time variable which the Rand study recognizes is the date of construction permit issuance, any extraordinary delays in construction (permit suspensions, financial difficulties) have no effect on the real constant dollar cost of the plant; general inflation affects the value of the dollars with which the plant is purchased, but changes in regulatory and industrial conditions are assumed to cause no more real escalation for a delayed plant than for one built at a normal pace. The modified NERA methodology, on the other hand, assumes that only the commercial operation date (COD) effects real costs, so that two plants of similar characteristics, completed in the same year, are assumed to cost the same amount, even if one took 8 years to build, and the other one took 13 years. Therefore, the NERA approach weights construction delays exactly as much as delays in permit issuance; this may overstate the cost of construction delay (by neglecting earlier design, earlier equipment orders, more leisurely construction) or understate it (by neglecting the greater costs of redesigning, reordering, and rebuilding to meet changing requirements; lower labor productivity; the costs of starting and stopping construction; and the cost of AFUDC on early purchases).

Q: How does the past record of A/E cost estimates support the capital cost forecasts of the econometric models?

A: Of the seven licensed nuclear units in New England, it has been possible to obtain the cost estimate histories for only four. However, there is enough data to estimate the magnitude of past errors in A/E cost estimates.

Table 2 presents the cost estimates for each of the four New England plants, and for two other plants, from the time the construction permit was issued to completion. The Connecticut Yankee estimate was fairly accurate, being off by only about 1% per forecast year of construction time. More recent plants' estimates have been less successful. Even Millstone I's estimates were off by 5-8% per year despite the fact that this was a turnkey plant. Millstone II and Pilgrim I cost estimates were even further off, by 7-19% per year; the earliest (post-permit) estimates were off by 16% (Millstone II) and 14.6% (Pilgrim, corrected for fuel assumption), with 3.25 to 4 year expected lead times. The early cost estimates for TM12 were at least as bad as those of the later New England plants, and Cooper's estimates were considerably worse. Applying a 15% annual correction for the forecast lead times for the January 1979 PSNH Seabrook forecasts yields:

$\$1.337 \text{ B} \times 1.15^{4.25} = \$2.422$ billion for Seabrook I,

$\$1.473 \text{ B} \times 1.15^{6.08} = \$3.445$ billion for Seabrook II without delay, and

$\$2.213 \text{ B} \times 1.15^{10.08} = \$9.053$ billion for Seabrook II with a four-year planned delay.

Plant	Estimate Date	Estimated In Service Date	Estimated Time to Completion (Yrs.)	Estimated Cost ($M)	Final Cost ($M)	Final Cost ÷ Estimated Cost	Annual Myopia Factor
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Connecticut [2] Yankee	1963	1967	4	98.5	103.5	1.051	1.012
Millstone 1 [2]	1966	1969	3	87.0	103.0	1.184	1.058
	1968	1969	1	95.8		1.075	1.075
Millstone 2 [3]	11/70	4/74	3.42	240.0	434.0	1.808	1.189
	11/73	8/75	1.75	381.0		1.139	1.079
Pilgrim 1 [4]	6/68	9/71	3.25	131.7	233.153	1.770	1.192
	6/68	9/71	3.25	149.7 [1]		1.557	1.146
	1/70	9/71	1.67	180.6		1.29	1.166
Cooper [5]	7/68	4/72	3.75	109.5	307.143	2.805	1.317
	10/70	7/73	2.75	180.3		1.703	1.214
	4/74	6/74	.17	249.2		1.233	2.508
Three Mile [6] Island 2	12/71	5/75	~~4~~3.42	345	687 [7]	1.991	~~1.169~~ 1.223
	12/77	5/78	.42	659		1.042	1.104

Table 2: Cost Estimate Histories for Six Nuclear Units

Notes: (1) includes $18M for fuel
(2) from IR CL-5, D.P.U. 20055
(3) from IR AG-7, D.P.U. 20279
(4) from IR 33, NRC 50-471
(5) from IR AG-C-19, D.P.U. 20248
(6) from "Review of the TMI-2 Construction Project", Touche Ross & Co., Oct. 1978
(7) not a final cost - based on 11/78 COD

Column (8) is column (7) raised to the inverse of column (4), the annualized tendency to underestimate cost

This correction yields somewhat lower estimates than the econometric techniques for the total plant cost on the current schedule: $5.4 billion. Again, there is divergence on the cost estimate for the delayed Seabrook II schedule, with this approach producing a higher estimate ($11.5 billion) than either of the others.

The propriety of the 15% annual correction is supported by PSNH's recent increase in the Seabrook cost projection by 20%, from $2.852 billion in January 1979 to $3.416 billion in March 1980. Since the plant will almost certainly not be built on PSNH's schedule, even a 15% annual increase in cost estimates would produce a much higher final cost than that predicted by a 15% myopia correction based on projected time to completion. This value is also supported by the annual rates of increase of the cost estimates of 12 plants currently under construction, summarized in Table 3.

Cost Estimates

Plant	Construction Permit Date	Date and Cost ($M)						Compound Annual Increase[1]
Seabrook[2]	7/76	12/76 2015	3/78 2345	1/79 2610	3/80 3160			14.8%
Millstone 3[3]	8/74	1/75 807.5	12/75 1010.0	3/77 1185.0	7/78 2000.0	11/79 2314.3		24.4%
Shoreham[4]	4/73	4/74 506	4/75 699	4/76 699	4/78 1188	4/79 1337	4/80 1581.0	20.9%
Nine Mile Pt. 2[4] [5]	6/74	4/74 511	4/75 700	4/76 1013.4	4/78 1521.6	4/79 1977.4	4/80 2048	31.1%
Vogtle 1 & 2[6]	6/74	12/76 1731.6	10/77 2035.0	10/78 2144.6	10/79 2541.2			14.5%
Catawba 2[6]	8/75	1/78 589.8	10/78 657.6	3/79 692.2				14.7%
Summer 1[6]	3/73	9/73 228.6	1/76 397.5	5/77 504.3				24.1%
WNP 1[7]	12/75							20.9%
WNP 2	3/73							23.5%
WNP 3	4/78							37.0%
WNP 4	2/78							34.7%
WNP 5	4/78							29.3%

Table 3: Escalation Rates in Cost Estimates of Nuclear Plants Currently Under Construction

Notes: (1) From first post-CP estimates to most recent
(2) From IR AG P 18 and Exh. PSC-4, D.P.U. 20055
(3) From IR AG-7, R-65, D.P.U. 20279
(4) From Long Range Plan (149-B Report), New York Power Pool, various years; dates of publication
(5) 1975 was first post-CP estimate; 1980 estimate not adjusted for new in-service date, so 1979 used as most recent.
(6) From IR AG-C-19, D.P.U. 20248
(7) From Appendix A

Q: Have you checked the results of these forecast methodologies against recent experience?

A: Yes. The three methodologies would have predicted the following capital costs for Three Mile Island 2.

modified NERA: $789/kw

Rand: $773/kw

myopia (based on 12/71 estimate): $706/kw

while the actual cost was $825/kw. All three methodologies appear to be somewhat conservative for TMI 2.

Q: Are the cost estimates derived above applicable to MMWEC?

A: Yes. MMWEC has two potential advantages relative to most utilities building nuclear power plants; PSNH is not passing on the full accrued AFUDC to date, and MMWEC has access to low-cost tax-free financing. Neither of these factors appear to result in particularly important reductions in MMWEC's costs.

First, the AFUDC accrued to date is minimal. The $7.4 million figure presented by Mr. Stein on p. 16 of his testimony is only $54/kw; even six years of additional AFUDC at 8% (MMWEC's highest assumed rate) increases this saving only to $85/kw. The savings are therefore only 1-3% of most of the cost estimates I have derived, and no more than 4% of the most optimistic estimate. In addition, Montaup has calculated that its purchase from PSNH, despite the AFUDC exclusion, will be more expensive than the shares it has owned and financed since the inception of the project. (See App. E). Therefore, the circumstances of MMWEC's purchase from PSNH do not indicate that MMWEC is getting any great discount over direct financing.

Second, comparison of Exh. RMC-11 with the data in Exh. AG-173 and AG-175 in D.P.U. 20055 (attached as App. E) indicates that MMWEC's costs for financing during construction of Seabrook are not markedly lower than that of such private companies as Montaup and New Bedford. This observation is confirmed by the inability of the Rand Study (Mooz, 1978, p. 42) to find a statistically significant difference in the costs of privately and publicly owned nuclear plants; the difference that Rand did find was not only statistically insignificant, it was also very small.

Q: Are MMWEC's projected in-service dates for the Seabrook units consistent with historical experience?

A: It seems unlikely that the plants will be completed by the time PSNH expects them to be. Construction periods for nuclear power plants have increased dramatically in the last decade. MMWEC's own analysis (MMWEC 1979), provided as Exh. AG-S-37A in response to discovery, concludes that for each year later the first unit in a nuclear plant loads fuel, it takes 7.1 more months to construct, with an initial value of about 62 months (start of construction to fuel load) in 1973.

Q: Are PSNH and MMWEC COD projections consistent with current experience?

A: PSNH is currently predicting construction durations (CP to COD) of 81 months for Unit 1 and 103 months for Unit II, while Mr. LeMaster variously describes 102 and 124 months as "reasonable" estimates and "conservative" estimates for construction duration. MMWEC actually uses 100 months, to November 1984, for Unit 1. Table 4 presents comparable construction durations for every nuclear unit which has entered commercial operation since 1978, and optimistic estimates of the durations for those scheduled for commercial operation by 1980 in the Electrical World "1980 Nuclear Plant Survey", January 15, 1980.[1/] In order for the estimated durations to be correct on average, the seven unlicensed plants must receive their operating licenses, on the average, by mid-June 1980, and the nine plants not in commercial operation must go commercial only six months after receiving their licenses, as opposed to the 11.6 month average for the last five plants. Even under these optimistic assumptions, the 1980 average durations would be 110 months for first units and 121 months for second units. Therefore, even MMWEC's construction durations are

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1/ For comparison, it is interesting to note that, of the nine plants which the 1978 plant survey predicted a 1978 COD, only 3 went commercial in 1978. Therefore, it is far from certain that all the plants in Table 4 will be commercial this year.

somewhat optimistic for a 1980 COD, and PSNH's durations are extremely optimistic. If the historic trend in construction durations continues, these duration estimates will be much further off for actual 1983 to 1986 COD's, even neglecting any special problems at Seabrook.

Plant	Date of Construction Permit[6]	Date of Operating License[1]	Date of Commercial Operation[1]	Months from Construction Permit to Commercial Operation	Months from Construction Permit to December 15 1980	Months from OL to COD
North Anna 1	2/19/71	11/26/77	6/6/78	88		6
Cook 2	3/25/69	12/23/77	7/1/78	111		7
Three Mile Island 2	11/4/69	2/8/78	12/30/78	110		11
Hatch 2	12/27/72	6/13/78	9/5/79	81		15
Arkansas 2	12/6/72	9/1/78	3/25/80[4]	89		19
Sequoyah 1	5/27/70	~~3/1/80~~[5]* 9/17/80 - full power	NY[2]	~~123~~[3] 135 120		
North Anna 2	2/19/71	~~4/10/80~~[5]* 8/21/80	NY	116[3]		
Diablo Canyon 1	4/23/68	NY	NY		152	
Salem 2	9/25/68	NY 4/18/80*	NY		147	
Diablo Canyon 2	12/9/70	NY	NY		120	
Farley 2	8/16/72	NY 10/23/80*	NY		100	
McGuire1	2/28/73	NY 1/23/81* preop 6/29/81 - full	NY		~~94~~ 136[3]	
Summer	3/21/73	NY	NY		93	
Lasalle 1	9/10/73	NY	NY		87	

Table 4: Construction Durations For Plants Entering Commercial Operation Since 1978, and Those Near Completion.

Notes:
(1) from NRC Gray Books, except as noted
(2) NY = not yet, as of 4/80
(3) assumes COD = OL + 6
(4) Telephone Communication, Arkansas Attorney General
(5) Newspaper reports
(6) Electrical World "1980 Nuclear Plant Survey" 1/15/80

Q: Have past construction duration projections by engineers and utilities been accurate?

A: No, not in general. Table 5 presents construction duration estimate histories for ten plants. These are the only completed plants for which I was able to obtain month and year of at least one post-construction permit estimate of COD. All 20 projections underestimated time to completion; actual times were always at least 18% greater than estimated, and in some cases they were over three times as long as estimated. For the five estimates which were in excess of three years, actual times averaged 70% greater than the estimates.

Plant[1]	Estimate Date	Estimated COD	Estimated Time to Complete (Years)	Actual COD[2]	Actual Time to Complete (Years)	Actual Time / Est. Time
Millstone 2	11/70	4/74	3.42	12/75	5.08	1.49
	11/73	4/75	1.75		2.08	1.19
Pilgrim 1	6/68	9/71	3.25	12/72	4.50	1.38
	1/70	9/71	1.67		2.92	1.75
Cooper	7/68	4/72	3.75	7/74	6.00	1.6
	10/70	7/73	2.75		3.75	1.36
	4/74	6/74	0.17		.25	1.5
TMI 2	12/71	5/75	~~4~~3.42	12/78	7.00	~~1.58~~ 2.05
	12/77	5/78	0.42		1.00	2.38
Crystal River 3[3]	1/75	9/76	1.67	3/77	2.17	1.26
Maine Yankee[3]	5/71	5/72	1.00	12/72	1.58	1.58
Vermont Yankee[3]	7/71	11/71	0.33	11/72	1.33	4.03
Rancho Seco[3]	8/73	10/74	1.17	4/75	1.67	1.43
Salem 1[4]	8/68	3/72	3.58	6/77	8.83	2.47
	9/69	3/72	2.5		7.75	3.10
	1/71	12/73	2.92		6.42	2.20
	7/71	12/73	2.42		5.92	2.45
	7/72	3/75	2.67		4.92	1.84
	7/73	9/75	2.17		3.92	1.81
	7/74	12/76	2.42		2.92	1.21
Hatch 2[3]	12/76	4/79	2.33	9/79	2.75	1.18
	10/78	3/79	0.42		0.92	2.19

Table 5: Tendency of Utilities and A/E's to Underestimate Construction Time For Nuclear Power Plants

Notes:
(1) sources as in Table 3 except as noted
(2) from NRC Gray Book
(3) from IR AG-C-19, D.P.U. 20248
(4) from "Construction Management Audit, Salem 1", May 1977, Theodore Barry & Associates

Q: Have schedule extensions and overruns continued into 1980?

A: Yes. As Table 6 indicates, the schedules for at least 26 units listed in the February Nuclear News are now out of date. About half these units are no longer in the utilities' supply plans; the rest have been rescheduled 1 to 3 years later. This list is by no means comprehensive; the two Marble Hill plants will incur some (as yet unspecified) delay and cost increase due to the recent quality control problems and resultant CP suspension, the Pebble Springs units have been canceled or delayed past 1990 (from previous dates of 1988 and 1990), and other delays have undoubtedly escaped my notice. (Incidentally, the Pebble Springs and WNP delays are incorporated in the 1980 PNUCC forecast which Mr. LeMaster provided in response to discovery.) The cost estimate for Seabrook has also increased since the beginning of the year.

Plant	Old Schedule (2) Cost ($M) and COD	New Schedule Cost ($M) and COD	% Increase (Time from 1/80)
Zimmer	850 1981	1000+ 1982	18%+ 100%
Midlands 1 & 2	1670 3/82 and 11/81	3100 ~~late 1984~~	86% ~~150%~~
Perry 1	5/83	5/84	30%
Perry 2	5/85	5/88	56%
Beaver Valley 2	5/84	5/86	46%
Davis-Besse 1 & 2	88 and 90	cancelled	
Erie 1 & 2	4/86 and 4/88	cancelled	
Greenwood 2 & 3	90 and 92	cancelled	
Pilgrim 2	12/85	1987/88	40%
Forked River	12/83	indefinite (2)	
Jamesport 1 & 2	89 and 90	cancelled	
NYSEG 1 & 2	92 and 94	cancelled ~~(3)~~	
Nine Mile Pt. 2	10/84	11/86	44%
Sterling	4/88	cancelled	
Haven	6/89	cancelled	
WNP 1	12/83	6/85	38%
2	9/81	1/83	80%
3	12/84	6/86	31%
4	6/85	6/86	18%
5	6/86	6/87	16%

Table 6: Some Nuclear Plant Construction Schedule Changes since January 1980.

(1) dates from February 1980 Nuclear News World Nuclear Plant List, presented as part of response to IR AG-L-11.
(2) construction suspended; coal conversion under study.
~~(3) or at least deferred into next century~~

Q: Does the history of errors in forecasting nuclear plant capital cost and COD include plants built by UE&C, the architect/engineer and constructor for Seabrook?

A: Yes. UE&C served as constructor for the Salem and TMI plants, and as both constructor and A/E for WNP1 and 4. In addition, the history of Seabrook itself demonstrates such errors. UE&C has served as A/E for only 4 completed plants and 4 more under construction, and as constructor for 8 completed plants and 5 under construction.

Q: Does PSNH's construction progress support its construction duration estimates, or MMWEC's estimates?

A: No. The Seabrook Quarterly Reports indicate that in the period June 30 - December 31, 1979, PSNH had projected advancing from about 24% completion to 38% completion (14% progress) on Unit 1 and from about 18% completion to 29% completion (11% progress) on the project as a whole. Actual progress was only 8.8% for Unit 1 and 6.7% for the project, or about 60% of the projected rates. The progress in the preceding quarter was even slower.

If construction continues to take about 60% longer than PSNH projects, Unit 1 will be completed in August 1985 and Unit 2 will be completed in September 1989. If the scope of the project changes, completion may be further delayed.

The December 31, 1979, report is the most recent available, and precedes the recent slowdown in construction, announced in March of this year.

Q: Does MMWEC's study of construction time support its projected in-service dates for the Seabrook units?

A: No, quite the opposite. Although the study (Exh. AG-S-37A) determined that nuclear construction duration has been increasing quite rapidly, MMWEC assumes without any real justification that this trend will reverse and construction durations will return to 1976-79 average experience. If the trend continues instead of reversing, the average first plant entering commercial operation in January 1985 and (from MMWEC's assumption) loading fuel in July 1984 would have received a construction permit in October 1972. A second unit entering commercial operation in November 1986 would have received a construction permit in September 1971. These dates are respectively 3.25 years and 4.67 years earlier than Seabrook's construction permit date. Not until July 1993 would the average first unit entering commercial operation be expected to have received a construction permit in July 1976; second units would not reach that expected permit date until June, 1997. The calculations on which these projections are based are provided in App. B.

I have repeated MMWEC's calculation, with two minor modifications. Oconee 3 and Brunswick 1 appear to be "second units" within MMWEC's use of that term (Brunswick 2 was completed before Brunswick 1), so I have applied MMWEC's assumed 24 month adjustment to those units; MMWEC treated them as first units. The MMWEC study does not specifically give the 1979 durations which MMWEC projected on the basis of pre-TMI conditions and utility claims of construction progress, so I have estimated this value as 109 months from MMWEC's Figure 4. My regression (provided in App. B) indicates that historic durations have increased at 7.26 months/year; duration projections based on MMWEC's formula may be somewhat optimistic.

Q: Have any other studies attempted to project nuclear construction duration?

A: Yes. The Rand study (Mooz 1978) derives an equation to estimate the time from construction permit to operating license, in months. In Table 7, this formula is evaluated for the Seabrook units. Including Rand's mean value of 7.5 months from operating license to commercial operation, this projection of past experience indicates that the Seabrook units would be expected to come on line 119 months after issuance of construction permits, or in June of 1986.

Unfortunately, the data base for the Rand projection included estimated dates for operating licenses for ten plants. As Table 8 shows, these estimates were over-optimistic by a considerable amount. A few of these plants may have been delayed somewhat by the accident at TMI 2, but every plant except Farley 2 which was not licensed as of March 1979 was already three to twenty-one months behind Rand's estimate. Since the mean date of construction permit for the plants with estimated durations is 1.4 years later than the mean date for the sample, it is very likely that these underestimates have biased the projection downwards.

Also, neither method for projecting construction duration reflects either the Seabook permit suspensions or PSNH's current or future financial difficulties. To the extent that Seabrook has experienced or will experience an atypical number of delays, its in-service date would be expected to be later than the projections.

Variable Name	Meaning	Co-efficient	Value for Seabrook I	Contribution to construction duration
Constant				-270.8
CPIS	date of construction permit	4.5478	76.5	347.9
SIZE	in MW	.043643	1150	50.2
BW	Babock & Wilcox dummy	13.065	0	
LN	ln of number of LWR Plants built by A/E	-8.0039	1.94 (1)	-15.5
	construction duration, construction permit to operating license, in months or 9 years, 4 months			111.8

Table 7: Calculation of Interval Between Construction Permit and Operating License, Seabrook Units as predicted by Rand Study

(1) average for Seabrook units

	Plant	Application for Construction Permit	Construction Permit Issued	Rand Estimate Of Operating License	Actual Date of Operating License
1.	Diablo Canyon 1	1/67	4/68	6/77	
2.	North Anna 1	3/69	2/71	6/77	11/26/77
3.	TMI 2	4/68	11/69	10/77	2/8/78
4.	Sequoyah 1	10/68	5/70	12/77	2/1/80* 9/17/80
5.	Diablo Canyon 2	6/68	12/70	11/77	
6.	North Anna 2	3/69	2/71	6/78	4/10/80* 8/21/80
7.	Cook 2	12/67	3/69	11/77	12/23/77
8.	Salem 2	10/67	9/68	12/78	[illegible]/18/80*
9.	Sequoyah	10/68	5/70	8/78	
10.	Farley 2	6/70	8/72	10/79	4/18/80*

Table 8: Underestimates of Construction Duration in Rand Study

* Fuel load & test only

Q: Has MMWEC presented any evidence that the historic trends in construction duration will abate or reverse?

A: No. Despite repeated information requests, Mr. LeMaster has been unable to document the derivation of his in-service date projections. He seems to be relying primarily on a secret report performed by an unnamed client, which utilized unspecified data from indeterminant sources, averaged some unknown portion of that data, performed unidentified regressions on other portions of the data, and projected construction durations based on unexplained assumptions and methodologies (AG-20, Q. L-7 Supp.). Therefore, it is not possible to determine whether the study is competently conceived and executed, nor even to determine what the biases of the authors might be. Mr. LeMaster's belief that "this report provides a reasonable basis on which to make...statements regarding the historical duration of construction of nuclear power plants" (IR AG-L-7) must be viewed in the context of the errors in Mr. LeMaster's analysis of construction costs and capacity factors.

MMWEC has certainly not explained how the study manages to project rising historical durations to yield falling future durations. A clue to this discrepancy may lie in the fact that the study used data from 120 plants but only 62 light water reactors went into commercial operation during the study period (1965 to 1978), while two more LWRS and one HTGR loaded fuel in that period but did not go commercial. Therefore, much of the "data", especially for recent years, may be utility estimates of progress to date. Since utilities seem to invariably underestimate nuclear costs and construction times, it is likely that this recent "data" is similarly unrealistic.

Mr. LeMaster claims to have considered a number of other factors (p. 3, LeMaster testimony, IR-AG-L-6), but has been unable to quantify or document the impact of any of these factors on his projection. He does not even seem to be able to specify whether each particular factor increased or decreased the projection.

Q: What is the significance of the in-service dates for the Seabrook units?

A: The in-service date is important for at least three reasons. First, the units will not be displacing oil (or supplying capacity) until they come on line; the more remote that date is, the less valuable the current investment is. Second, the later the units come on line, the higher the associated AFUDC and cost escalation.

Third, some of the factors which have historically increased plant costs over time will continue to operate as the schedule stretches out, so delays in the in-service date may increase the scope (and hence the direct cost) of the project. This last tendency is recognized in the modified NERA formula, which predicts that, if the units come into service 2 years later than currently forecast by MMWEC they will cost $1.1^2 = 1.21$, or 21% more due to real escalation, in addition to $1.08^2 = 1.166$, or 16.6% more due to inflation (at 8%), for a total increase of 41.1% over our previous NERA-based estimates, or about $4027/kw for Seabrook I, $4216/kw for Seabrook II, and $9.5 billion for the entire project. A two-year delay to (1/87 and 11/88) is still much less than the prediction of MMWEC's own trend analysis, which would put the plants in the 1990's.

Q: How did MMWEC select the capacity factor projections used in its analysis of Seabrook's costs?

A: MMWEC apparently used NEPOOL estimates.

Q: Are these estimates based on historical information?

A: MMWEC was unable to provide any documentation for these figures and, so far as we have been able to determine, NEPOOL has never produced any documentation, either. Therefore, it can not be determined what data, if any, were used in setting these capacity factors.

Q: Has MMWEC presented any testimony defending the capacity factors used in the analysis?

A: Yes. Mr. LeMaster's testimony provides historical evidence and argument which attempts to support MMWEC's capacity factors. The data presented, as well as the nature of Mr. LeMaster's supporting arguments, indicate that the estimates are extremely optimistic.

Q: How do Mr. LeMaster's arguments indicate that his estimates are optimistic?

A: Essentially, Mr. LeMaster asks the Commission to believe that future capacity factors are predicted better by historical national availability factors than by historical capacity factors. Before considering Mr. LeMaster's arguments in detail, it may be helpful to consider the role of capacity factors in predicting the cost of Seabrook power.

The capacity factor of a plant is the ratio of its average output to its rated capacity. In other words

$$CF = \frac{\text{Output}}{\text{RC} \times \text{hours}}$$

where CF = capacity factor, and
RC = rated capacity

In this case, it is necessary to estimate Seabrook's capacity factor, so that annual output, and hence cost per kwh, can be estimated.

On the other hand, an availability factor is the ratio of the number of hours in which some power could be produced to the total number of hours.

The difference between capacity factor and availability factor is illustrated in Figure 1. The capacity factor is the ratio of the shaded area in regions A and B to the area of the rectangle, while the availability factor is the sum of the width of regions A, B, and C. Clearly, if the rated capacity is actually the maximum capacity of the unit, the availability factor will always be at least as large as the capacity factor and will generally be larger. Specifically, the availability factor includes the unshaded portion of region B, and all of region C, which are not included in the capacity factor.

Mr. LeMaster observes that the availability and capacity factors for New England nuclear plants "are very similar". Table 9 presents cumulative AF and CF for each New England plant, for a MW-weighted New England average, and for each region reported in Ex. DBL-4. (It should be noted that this Table uses MDC capacity factors, which are artificially inflated for the purposes of the current case.) The difference between AF and CF is larger for the New England average than for some regions, despite the presence in New England of Connecticut Yankee, which shows a difference of only 0.3%. The differences for individual New England plants range up to 14.5% for Pilgrim.

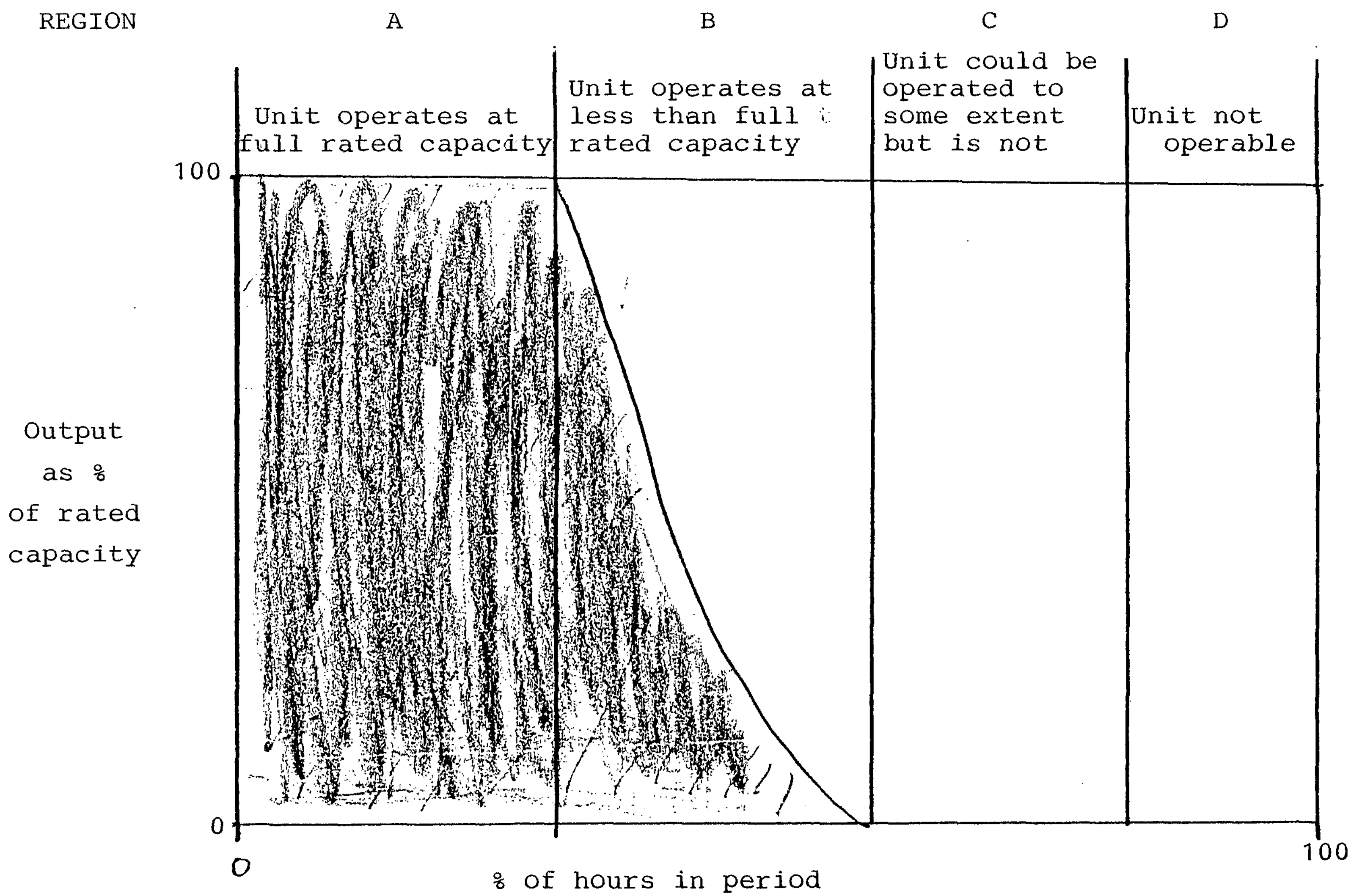

Figure 1: Diagrammatic Description of Availability Factor and Capacity Factor

Plant	Cumulative AF	Cumulative CF	Difference
Yankee Rowe	80.4%	73.6%	6.8%
Conn Yankee	82.5%	82.2%	0.3%
Vermont Yankee	77.9%	68.0%	9.9%
Maine Yankee	79.3%	68.3%	9.0%
Millstone #1	72.0%	63.4%	8.6%
Millstone #2	68.3%	61.1%	7.2%
Pilgrim	68.9%	54.4%	14.5%
New England weighted Average			8.7 ~~8.3%~~
without Conn. Yankee			10.0 ~~9.5%~~
Northeast	70.8	63.1	7.1%
Midwest	74.2	61.1	13.1%
South	66.4	58.2	8.2%
West	63.8	54.9	8.9%

Table 9: Plant and Regional Difference in Availability and Capacity Factors.

From the similarity of AF and CF, Mr. LeMaster concludes that New England nuclear plants are fully base loaded:

> . . . generally, whenever the nuclear plant was available to operate, the utility used it to generate electricity. This suggests in my opinion, that, on an economic basis, it is advantageous for New England utilities to run the installed nuclear capacity as much as possible, whenever that capacity is available.

This conclusion is almost certainly correct. On the basis of fuel costs, nuclear units would be nearly the first units in any utility's dispatch, generally preceded only by run-of-the-river hydro, waste-burning plants, or other units with zero or negative running costs. Therefore, unless the installed nuclear (and cheaper) capacity (net of capacity on maintenance, or forced outage) exceeds at least base demand, plus the available pumped storage, plus inter-ties to higher fuel-cost regions, all available nuclear capacity will be dispatched. The demand/supply conditions which would require the curtailment of nuclear output do not appear to have occurred at all in New England, and have probably not occurred extensively elsewhere in this country, either.

While similarity of AF and CF indicates that a plant does not extensively load follow, the inverse is not necessarily true; a disparity between AF and CF does not imply that the plant load follows. Even if every plant in the country is fully baseloaded, so that region C of Figure 1 is non-existent, and as much of region B is shaded as can be achieved under technical, safety, and regulatory constraints, the differences in these constraints between plants will cause some to have capacity factors very close to their availability factors, and others to have very different factors. Clearly, dispatch economics do not cause the vast disparity between Connecticut Yankee's 0.3% difference and Pilgrim 14.5%. Therefore, different regions of the country, with plants of different ages, different sizes and different designs, and with different luck, will have different discrepancies between their capacity factors and availability factors, even if every plant in the country is fully base loaded.

Proceeding from the undisputed fact that nuclear units are fully base loaded, Mr. LeMaster then concludes that the national or regional availability factors are "the applicable item" to compare with MMWEC's (actually NEPOOL's) capacity factor projections. Absolutely no rationale for this position is provided in Mr. LeMaster's testimony. In response to discovery, he advanced the opinion that a unit's capacity factor "is not only a measure of the plant's availability to provide power but it also is a function of the power level supplied and reflects the sponsoring utility's operating philosophy". (IR

AG-L-71). If Mr. LeMaster has any evidence that Boston Edison has, for philosophical reasons, intentionally reduced Pilgrim's output by over 20%, the Attorney General would be very interested in that evidence. However, Mr. LeMaster admitted on discovery that he has no evidence that any nuclear unit in the country is cycled, load-followed, or otherwise less than fully base-loaded. (IR's AG-L-64 and 74).

Q: Why is availability factor not an appropriate substitute for capacity factor in the calculation of nuclear cost?

A: As Exh. DBL-10 and the footnotes to Exh. DBL-8 and Exh. AG-L-71-1 clearly indicate, the availability factor only distinguishes between hours in which <u>some</u> power is available and those in which <u>no</u> power is available. A unit is considered to be available during an hour whether it is at full power, ramping up to power after an outage, ramping down for a maintenance outage, operating at 80% power due to turbine problems, reducing output to extend core life, limited to 5% power for NRC-mandated tests, or in any other way limited or constrained, so long as <u>any power at all</u> could be generated. Despite Mr. LeMaster's unsupported claims to the contrary, availability factor is not the proper quantity to multiply by rated capacity to yield output; this calculation will not work with any existing plant (for Pilgrim, it would overstate historical output by

27%), and there is no reason to believe that it will work in multiplying historical availability by Seabrook capacity to estimate Seabrook output.

Q: Are the capacity factors presented in Exhibits DBL-4, DBL-5, and DBL-8 the proper capacity factors to use in estimating Seabrook output?

A: No. These capacity factors are calculated from a rated capacity (Maximum Dependable Capacity, or MDC) which is not yet known for the Seabrook units, and which changes over time.[2/]

The MDC is the utility's statement of the unit's "dependable" capacity (however that is defined) at a particular time. Early in a plant's life, its MDC tends to be low until technical and regulatory contraints are relaxed, as "bugs" are worked out and systems are tested at higher and higher power levels. During this period, the MDC capacity factor will generally be larger than the capacity factor calculated on the basis of Design Electric Rating (DER), or Installed or Maximum Generator Nameplate rating (IGN or MGN), which are fixed at the time the plant is designed and built. Furthermore, many plants' MDC's have never reached their DER's or IGN.

2/ Contrary to Mr. LeMaster's testimony (Tr. 14, p. 5) MDC was not the rated capacity used in Exh. DBL-6 and DBL-7, so the capacity factor definition in Exh. DBL-10 does not apply to these tables.

Humboldt Bay has been retired after fourteen years without getting its MDC up to its DER; Connecticut Yankee has not done it in 12 years; nor Big Rock Point in 17 years; nor the Dresden units (1, 2, or 3) in 19 years, 9 years, or 8 years; nor Lacrosse in 11 years; nor Oyster Creek 1 in 10 years. For only about one nuclear plant in five does MDC equal DER, and in only one case (Pilgrim) does the MDC exceed the DER. Therefore, capacity factors based on MDC will generally continue to be greater than those based on DER's.

Now, the use of MDC capacity factors would still present no problem if the MDC's for the Seabrook plants were known for each year of their lives. Unfortunately, these capacities will not be known until Seabrook actually operates and its various problems and limitations appear. All that is known now are an initial estimate of the DER (1150) and IGN (1194). Since it is impossible to project output without consistent definitions of Capacity Factor and Rated Capacity, only DER and IGN capacity factors are useful for planning purposes. Using MDC capacity factors with DER ratings is as inappropriate as multiplying a kilometers/liter fuel efficiency measure by miles to try to estimate gallons of gasoline consumed; the units are different, and in the case of MDC, unknown.

Actually, DER designations have also changed for some plants. The new, and often lower, DER's will produce different observed capacity factors than the original DER's. For example, Komanoff (1978) reports that Pilgrim's original DER was 670MW, equal to its current MDC, not the 655 MW value now reported for DER. Therefore, the CEP capacity factor study uses the original DER ratings, which would seem to be the capacity measure most consistent with the 1150MW expectation for Seabrook. The NRC study avoids this problem through the use of the MGN ratings.

Q: Does MMWEC offer any defense of the MDC capacity factors?

A: Yes. As Mr. LeMaster correctly describes the situation in IR AG-L-68, the MDC is smaller than the DER, the MDC capacity factor is larger than the DER capacity factor, and DER capacity factors reflect those limitations in plant output which cause MDC to be lower than DER. In short, every technical fact mentioned by Mr. LeMaster supports the contention that MDC capacity factors are too high to use in conjunction with a DER capacity to predict plant out put. Nevertheless, he asserts that it is the DER capacity factors which are "artifically low".

Of course, once MDC's are known, the DER capacity factor and the MDC capacity factor can be readily reconciled. If, in a particular year, Seabrook I has a 60% DER capacity factor and a 920 MW MDC, its MDC capacity factor will be 75%, and in either case:

rated capacity x capacity factor x 8760 = 6044.4 GWH

Combining the MDC capacity factor with the DER rating would yield incorrect results in this example 7555.5 GWH, or 25% greater output than actually observed.

Q: Have any studies been performed of the historic capacity factors for operating reactors?

A: Yes. Statistical analyses of the capacity factors of actual operating nuclear plants all utilizing data through 1977, have been performed for the Council on Economic Priorities (CEP) (Komanoff, 1978), a Sandia Laboratories study for the NRC (Easterling, 1979), and the NERA study previously described (Perl, 1978).

The CEP study projects a levelized capacity factor for the first ten years of operation (excluding the first partial year) for Westinghouse 1150 MW reactors at 54.8%, based on a statistical analysis which predicts a 46.1% capacity factor in year 1, rising to 62.3% in year 10. An alternative model found that capacity factors actually peak in year 5, at 59.1%, and slowly decline to 55.2% in year 10, indicating that maturation does not continue to improve capacity factors indefinitely. However, in recognition of an apparent improvement in plants completed after 1973, the 10 year levelized projection is increased by 1.8 percentage points.

The NRC study projects capacity factors on the basis of maximum generator nameplate (MGN), which appears to be 1194 MW for Seabrook. The prediction for an 1194 MW (MGN) PWR, expressed in terms of an 1150 MW DER, would be 51.6% in the second full year of operation, 55.0% in the third full year, and 58.3% thereafter. No further maturation was detected. All results for the first partial year and first full year of operation are excluded. Assuming that first year capacity factors are as good as second year capacity factors, a plant with a 30-year life would average 57.7% over its life.

The NERA study presents capacity factor estimates of 63.6% for 1100 MW PWR's and 63.1% for 1200 MW plants, again excluding initial partial years of operation. These figures appear to represent levelized averages of the values generated by a regression equation, which predicts 1150 MW plant capacity factors of 54.9% in year one, rising to 66.5% in year 30. As previously noted, however, the projection of continued maturation past year 10 (or even year 5) is not supported by the historic record. The NERA projection for year 10 is 65.3% and that for year five is 63.8%.

Therefore an average life-time capacity-factor estimate for units like Seabrook of about 60% would seem reasonable, with 55% and 65% representing (respectively) somewhat conservative and optimistic bounds for average estimates. There is a great deal of variation from the average, however; the NERA and CEP studies could explain only 28% and 33% of the variation in the data, respectively, and the NRC study derives 95% prediction intervals of about 10% in years 2 to 5, 8% in years 2 to 10, and 7.3% for years 2 to 28. Roughly speaking, the NRC results predict that 19 out of every 20 nuclear units of the Seabrook size and type would have lifetime capacity factors between 50.3% and 64.9%, with the 20th unit having a capacity factor outside that range. Actually, the variation would be somewhat larger, due to the greater variation in the first partial year and the first full year.

Q: Is this similarity due to the use of identical methodologies in the studies?

A: No. While the studies all use regression analysis, the specific approaches of the three studies vary. The NRC and CEP studies are limited to reactors of over 400 MW, eliminating data for Yankee Rowe and, for the NRC study, Indian Pt. 1. The NERA study appears to include these smaller plants, which would tend to reduce the apparent relationship between plant size and capacity factor, since even Yankee's capacity factor has been considerably lower than the 98.0% predicted by the NERA formula for a 15-year old plant of 175 MW.

The NRC and NERA data include PWR's manufactured by Combustion Engineering and Babcock & Wilcox, while the CEP study uses only Westinghouse reactors' experience. In the NRC and CEP models, capacity factors are linear functions of size. In the NERA model, capacity factors are linear functions of the inverse of size, and are therefore inherently less sensitive to size differences between the largest plants (e.g., 850 MW to 1150 MW) than between the smaller plants (e.g., 200 MW to 500 MW).

Plant age is modeled discretely in the NRC study (year 2=2, year 3=3, later years = 4), as log of unit age plus one in the CEP study, and as the inverse of the CEP formula in the NERA study.

The CEP study appears to use all applicable data (90 Westinghouse unit-years), whle the NRC study rejects all first year data and all of Palisades' experience, but includes other PWR's. CEP indicates that there were 127 unit-years of PWR data through 1977, of which 32 were first-year data, five more were Palisades' data, and one was omitted from the NRC's data set due to differing definitions of the COD for Trojan; the NRC's 89 unit years are otherwise consistent with CEP's count. The NERA study should have 28 more observations, for Yankee Rowe and Indian Point 1, minus one for the Trojan dispute (in which NERA sides with the NRC), yielding 159 observations. But the NERA study reports that only 125 unit-years were used, without specifying which ones were deleted. In addition, the NERA study uses a dummy variable to capture some of the influence of three under-achieving plants (Palisades, Indian Point 2, and Oconee 1).

As noted above, the NRC study uses MGN capacity factors, while the CEP and NERA studies use DER capacity factors.

Nonetheless, the results are strikingly similar.

Q: Are the Seabrook O & M expense projections presented by MMWEC reasonable?

A: No. Basically, MMWEC has failed to account for the remarkable rate at which nuclear O & M expenses have been increasing over the last decade. Table 10 presents the least-squares estimates for linear and compound (geometric) growth in real 1979 dollars for each nuclear plant in New England. The data utilized is presented in Appendix C along with comparable data for thirteen other plants, computed from Attachment 7 to IR AG-E-10. Since all these trends and data are net of general inflation, it is clear that nuclear O & M is rising much faster than other prices.

There does appear to be some correlation between unit size and O & M, but it does not seem to be very strong. Analysis of a larger data set (such as the thirteen other plants for which data was provided by MMWEC) might clarify the extent of this relationship. To be on the optimistic side, I have left Rowe in the calculation of the New England average, and have not included any 1979 data (except for Millstone 2, where it lowers the trend) which may reflect the impact of the TMI accident.

Plant	Linear: 1980 Value (1)	Linear: Annual Increase (2)	Geometric: 1980 Value (1)	Geometric: Annual real Increase %
Yankee Rowe	9254	588	10705	12.23
Conn. Yankee	13581	739	13319	10.42
Maine Yankee	12786	930	13310	10.77
Vermont Yankee	14224	899	15030	9.34
Millstone 1	17171	715	18685	7.37
Millstone 2	30888	3465	33290	18.67
Pilgrim	22716	1730	23475 (3)	15.72
New England Average	17231	1295	18259 (4)	12.07

Table 10: Least-Squares Projections of Nuclear O & M

(1) as estimated by least-squares equation; 1,000's of 1979 $
(2) 1,000's 1979 $
(3) plus $2311 for refueling; not subject to real escalation
(4) plus $330 for Pilgrim refueling

Each Seabrook Unit O & M in	Linear Extrapolation	Geometric Extrapolation
1985 current $1,000	40,483	55,687
mills/kwh[1]	6.7	9.2
2000 current $1,000	233,649	967,926
mills/kwh	38.7	160.1
2015 current $1,000	1,074,979	16,938,750
mills/kwh	177.8	2802.3
average O & M over 30-yr. life, 1985 $1,000	73,668	450,132
mills/kwh	12.2	74.5

Table 11: Linear and Geometric Extrapolation of New England Nuclear O & M Experience to the Seabrook Units.

(1) assumes 60% capacity factor

As Table 11 demonstrates, the geometric trend cannot continue for the entire expected life of the Seabrook plants; if it did, towards the end of their lives, the plants would cost nearly as much to maintain annually as they did to build, even in real terms. An alternative interpretation of the compound growth extrapolation would be that the plants will become too expensive to continue operating by the end of the century, and will be shut down after only 10 or 15 years. This interpretation is consistent with the experience of such early commercial plants as Humboldt Bay and Indian Point 1, which have left service permanently after only 14 years and 12 years, respectively. The operator of the LaCrosse plant has indicated that it will be shut down between 1987 and 1990, after 18 to 21 years of commercial operation; the operator of Big Rock Point (now 17 years old) has indicated that it may soon follow suit. In all these cases, the retirement was motivated by the cost of meeting regulatory requirements, not by mechanical failure. The retirement of Big Rock would leave Yankee Rowe (shut down most of this year for unscheduled turbine repairs) and Dresden 1 (shut down for over two years for decontamination) as the only survivors of among the pre-1965 commercial plants.

Even the more optimistic linear projection, ignoring the effects of unit size and of the accident at TMI, predicts that O & M will increase from 7 mills/kwh in the first year to 178 mills/kwh in the last year of a 30 year life. These figures are much higher than MMWEC's undocumented estimates.

Q: Is it reasonable to expect that the capital cost of the Seabrook units will remain constant after they go on line?

A: No. The capital costs of the seven nuclear units in New England have increased at the average rate of $11354 per MW per year (1979$), as demonstrated in Appendix D. Allowing for the inflation rates we have been assuming, this would increase to $28783/mw-year by 1990, or 5.5 mills/kwh at a 60% capacity factor. If the same level of real replacements continues and the 8% inflation rate continues, the capital cost of the Seabrook units would increase by about $1.2 billion between their scheduled in-service dates and the year 2000, and by another $3.1 billion between the year 2000 and the end of a 28-year useful life.

Again, MMWEC's data and analysis confirm the existence of a problem MMWEC neglects. Exhibit AG-L-86-1 to Mr. LeMaster's information responses shows that the capital cost of 18 nuclear plants MMWEC analysed increased at an average rate of 2.92%. I have extended this analysis by including Maine Yankee and Millstone 2, and by extending the period under examination, especially by including data for 1978 (or 1979 when that was available). Table 12 presents these additions and revisions, which increase the average rate to 3.06%.

At 2.92%, a nuclear plant will cost 237% as much at the end of a thirty year life as it does at the beginning. At 3.06%, it will cost 247% as much. Recovery of this increase in cost by constant direct contributions would require an annual charge of 4.6% to 4.9% of the initial cost of the plant. If the contributions are credited with 6% interest (MMWEC's assumed short-term rate) the annual charge would be 4.0% to 4.3% of the initial plant cost; at MMWEC's assumed long-term interest rate of 7.5%, the annual contribution would be 3.9% to 4.2%.

Plant	Years Analyzed	Compound Growth Rate
Millstone 1	1970-1979	5.43%
Millstone 2	1975-1979	2.65%
Pilgrim 1	1972-1979	2.24%
Rowe	1968-1978	2.14%
Vermont Yankee	1972-1978	2.44%
Maine Yankee	1973-1978	1.64%
Connecticut Yankee	1968-1978	2.82%

Table 12: Revisions and Additions to Exh. AG-L-86-1.

Q: Has MMWEC properly converted its assumed decommissioning cost into a mills/kwh charge?

A: No. Even considering only CPI inflation, the $26.87 million in 1975$ that Mr. LeMaster takes from the AIF study would be $36.2 million in 1979$ and (assuming 10% inflation to 1983 and 8% thereafter) $915.0M in 2020, when the work would actually be performed. Including 25% contingency, the total would be $1143.7 million.

The $42 million estimate from the NRC study (1978$) would be $46.7 million in 1979$ and $1197 million in 2020. The average of the two sources is then about $1160 million per plant or $1009/kw. Recovery of this amount over a 30-year life would require 6.4 mills/kwh by direct contributions, or 1.4 mills/kwh if interest is accumulated at a 7.5% annual rate.

While inflation does not impact all costs in the same way, there should be some logical relationship between cost indices with similar inputs, such as the indices for general construction, utility construction, steam plant O & M, decommissioning, and fuel disposal. In particular, all these costs are directly and indirectly connected with the CPI. Of course, each commodity or activity is subject to its own supply and demand pressures, and has its own mix of inputs; this explains, for example, how the steam plant construction index could have increased considerably faster than the CPI in the historic period, as I noted earlier. MMWEC's use of 6.5% escalation for decommissioning in the 1975-1980 period (IR AG-L-75) and no escalation past 1980, is inconsistent with any reasonable view of the future, and with MMWEC's own O & M and construction assumptions. MMWEC's inability to explain the differences in its assumed escalation rates for O & M, construction, decommissioning, fuel and fuel disposal, its inability to relate any of these rates to inflation in general indices, and its failure to study the historical relationships between these rates indicate a general lack of accuracy and consistency in its direct case in this proceeding.

Q: Have you been able to determine why MMWEC refers to various of its estimates as "conservative"?

A: No, not really. When asked to explain why estimates of capital costs, in-service dates, nuclear fuel escalation, and nuclear fuel costs were conservative, MMWEC responded, in effect, that they were higher than other values which might have been used, such as PSNH's estimates and Beck's standard assumptions. These responses are consistent with a <u>relative</u> definition of "conservative". A cost estimate of $2000/kw is more conservative (e.g., more cautious) than an estimate of $1000/kw. But that same $1000/kw estimate is more conservative than a $500/kw estimate. So this meaning of conservative indicates very little, except to point out that the highest of the values mentioned was the one used.

MMWEC has refused to explain whether the references to "conservative" are meant to imply the stronger absolute significance of the term. An estimate or design is said to be conservative, without limitation to mere comparison with another estimate or design, if it is more cautious than the best estimate or minimal adequate design. That is, a conservative estimate is very likely to be on the safe side (in terms of cost, the high side) of the actual outcome. I do not believe that any of MMWEC's projections, with the possible exception of oil costs, have any claim (let alone a valid claim) to conservatism. For the most part, MMWEC justifies its projections on the basis of various parties' best estimates, not on intentionally conservative variations of these estimates. Since most of these "best estimates" are actually far more optimistic than historical experience would suggest, they are certainly not conservative.

Mr. LeMaster's contingency allowances do not seem to be based on historical experience; indeed, they appear to be much smaller than the actual overruns experienced by past plants at Seabrook's stage of construction. Large portions of the contingency are assumed to be immune from both escalation and accrual of AFUDC. It is difficult to see how appropriate contingency levels can be determined without recognition of these cost components.

Q: Can you make any general observations regarding the factual basis for MMWEC's projections?

A: Yes. Very few of the cost components are based on historical data. When MMWEC does use "data", it often is projected, rather than actual values; this is true for core cost, for contingency, for the interval between first and second units, and apparently for the schedule projections of the secret study. In several cases, the projected data utilized is no longer consistent with the official projections of the utility building the plant.

MMWEC and Beck have access to considerable amounts of data, as evidenced by IR AG-C-19 and Exh. AG-S-37A, for example. It is difficult to understand why this data has not been better organized and more fully analyzed. Beck indicated that it had not even determined for how many nuclear plants it possessed cost estimates. If Beck collated that data into cost estimate histories, it should be able to improve considerably on my myopia analysis, and perhaps derive a reasonable and useful methodology for projecting contingencies. It would appear that neither Beck nor MMWEC has made any effort to do so.

Q: Have you calculated the total cost per kwh of power from Seabrook implied by the preceding results?

A: An optimistic projection of the total cost of power from Seabrook would be on the order of 10¢/kwh, as derived in Table 13. This projection assumes MMWEC's projected in-service dates, my more optimistic projection of interim replacements, linear real escalation of O & M, a carrying charge of 12% and MMWEC's estimates of transmission costs, base decommissioning costs, nuclear fuel costs and disposal and A & G. The fundamental assumption underlying this cost estimate is that costs will continue to change over time in the same way that they have changed in the past. At this point, that assumption seems rather optimistic.

The value of 10¢/kwh is also dependent on average (or slightly better) capacity factors, on O & M following a linear trend rather than an exponential trend, on a somewhat optimistic schedule, and on a 30-year useful plant life. If any of these expectations are not realized, the cost per kwh could be much larger. In addition, this calculation does not include any allowance for insurance expenses of any sort.

\$2672			\$/kw capital (1)
x .12			carrying charge (2)
	=	320.6	\$/kw - year capital
\$73,668,000			\$/year average O&M 1985\$
÷ 1,150,000			kw
x 1.08^5	=	94.2	\$/kw-yr O&M 1990\$
\$1403,000			\$/year for MMWEC share
÷ .06 x 2,300,000			of transmission costs (3)
	=	10.2	\$/kw-year transmission
\$173,000			\$/year MMWEC A&G (3)
÷ .06 x 2,300,000	=	1.3	\$/kw-yr A&G
		455.1	\$/kw-yr fixed costs
÷ .6 x 8760	=		60% capacity factor
		8.66¢/kwh	
		+ 0.14¢/kwh	decommissioning
		+ 0.95¢/kwh	fuel (3)
		9.75¢/kwh	total cost/kwh

Table 13: Total Cost of Seabrook Power to MMWEC, 1990

Notes: (1) Assumes most optimistic value
(2) Testimony of Ian Forbes, E.F.S.C. 79-1
(3) MMWEC estimates

Q: Do these estimates include any effect of the accident at Three Mile Island?

A: No. The only impact of Three Mile Island recognized above is the delay of the in-service dates of a few of the plants listed in Table 4, which does not explicitly affect the total cost calculations above. If legislative, regulatory, or other reaction to the accident extends construction times, increases initial capital costs, increases fuel cycle costs, accelerates interim replacements or the growth in O & M, or lowers capacity factors, the cost of power from Seabrook will tend to be greater than the estimates given above.

Q: Is it reasonable to assume that the accident at Three Mile Island was a unique occurrence?

A: The industry does not seem to think so. The premium for the replacement power insurance offered by Nuclear Electric Insurance Limited (NEIL) in Exh. AG-L-81A appears to be based on an accident rate of about one per hundred reactor years, if they are assuming that all such accidents remove the reactor from service for over 2-1/2 years, the maximum payment period. Alternatively, NEIL may be expecting shorter 1-year outages at the rate of three per hundred reactor years.

If units under construction come on line in the order listed in the February, 1980 Nuclear News World List of

Nuclear Power Plants (IR AG-L-11), then about 120 plants will be operating before Seabrook 2 and (at a 1% unit-year accident probability) the probability of getting through a year without a major accident is only 31.1%, so about two years in every three would see at least one accident. Even if the accident probability is only one in 200 reactor-years, and even if only 100 reactors are on line, the probability of no accidents in a year is still only 60.6%; an accident would still be expected at least every third year.

Q: Does this conclude your testimony?

A: Yes.

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Appendix A

Cost Estimate Histories, Washington Public Power Supply System Projects; Salem 1, 2, and 3; TMI 2; Millstone 2 and 3.

First post-construction permit estimats denoted by (1)

WNP NO. 1
PROJECT BUDGET HISTORY

($ in millions)	Preliminary Estimate*	First Official Estimate**	1977 Budget	1978 Budget	1979 Budget	Revised 1979 Budget	1980 Budget
Effective Date of Budget	1-1-73	1-1-76 (U)	1-1-77	1-1-78	7-1-78	1-18-79	7-1-79
Commercial Operation Date	9-80	3-81	9-81	12-82	12-82	12-83	12-83
Plant Construction	$ 481	$ 813	$ 910	$ 1,034	$ 1,114	$ 1,218	$ 1,580
Nuclear Fuel	38	89	103	177	175	232	204
Interest, Financing, and Reserves	143	302	333	413	412	566	557
Total Funding Requirements	662	1,204	1,346	1,624	1,701	2,016	2,341
Less Amounts Funded by BPA	29	57	140	255	283	455	419
WPPSS Funding Requirements	$ 633	$ 1,147	$ 1,206	$ 1,369	$ 1,418	$ 1,561	$ 1,922

DAT; 2/25/80

* The preliminary estimates were made at the time of obtaining preliminary financing and were based on broad conceptual design criteria and incomplete detail design work on the project. The preliminary estimates were made prior to contracts for the issuance of the first long-term permanent financings were signed and before plant sites were selected.

* The First Official Estimates were made as the time of issuing the first long term permanent financing for the project. This was the first time that a significant amount of engineering was available to prepare detail estimates of the project cost.

($ in millions)

WNP NO. 2
PROJECT BUDGET HISTORY

	Preliminary Estimate*	First Official Estimate**	1975 Budget	1976 Budget	1977 Budget	1978 Budget	1979 Budget	Revised 1979 Budget	1980 Budget
Effective Date of Budget	1-1-71	6-1-73(a)	1-1-75	1-1-76	1-1-77	1-1-78	7-1-78	1-18-79	7-1-79
Commercial Operation Date	9-77	9-77	6-78	12-78	6-80	9-80	12-80	9-81	9-81
Plant Construction	$ 288	$ 367	$ 494	$ 611	$ 849	$ 954	$ 1,059	$ 1,224	$ 1,348
Nuclear Fuel	34	37	39	56	59	82	74	77	54
Interest, Financing, and Reserves	83	100	129	228	283	287	312	442	420
Total Funding Requirements	405	504	662	895	1,191	1,323	1,445	1,743	1,822
Less Amounts Funded by BPA	20	28	48	101	226	246	273	403	382
WPPSS Funding Requirements	$ 385	$ 476	$ 614	$ 794	$ 956	$ 1,077	$ 1,172	$ 1,340	$ 1,440

DAT; 2/25/80

* The preliminary estimates were made at the time of obtaining preliminary financing and were based on broad conceptual design criteria and incomplete detail design work on the project. The preliminary estimates were made prior to contracts for the issuance of the first long-term permanent financings were signed and before plant sites were selected.

** The First Official Estimates were made as the time of issuing the first long term permanent financing for the project. This was the first time that a significant amount of engineering was available to prepare detail estimates of the project cost.

WNP NO. 3
PROJECT BUDGET HISTORY

($ in millions)	Preliminary Estimate*	First Official Estimate**	1977 Budget	1978 Budget	1979 Budget	Revised 1979 Budget	1980 Budget
Effective Date of Budget	1-1-74	1-1-76	1-1-77	1-1-78	7-1-78 (1)	1-18-79	7-1-79
Commercial Operation Date	9-81	3-82	5-83	9-83	1-84	12-84	12-84
Plant Construction	$ 547	$ 920	$ 1,012	$ 1,083	$ 1,169	$ 1,275	$ 1,637
Nuclear Fuel	34	53	64	71	71	101	65
Interest, Financing, and Reserves	208	429	406	407	407	573	554
Total Funding Requirements	789	1,402	1,482	1,561	1,647	1,949	2,256
Less Amounts Funded by BPA	33	42	91	109	134	260	217
Less Amounts Funded by Private Utility Joint Owners	227	408	432	456	482	572	661
WPPSS Funding Requirements	$ 529	$ 952	$ 959	$ 996	$ 1,031	$ 1,117	$ 1,378

DAT; 2/25/80

* The preliminary estimates were made at the time of obtaining preliminary financing and were based on broad conceptual design criteria and incomplete detail design work on the project. The preliminary estimates were made prior to contracts for the issuance of the first long-term permanent financings were signed and before plant sites were selected.

* The First Official Estimates were made as the time of issuing the first long term permanent financing for the project. This was the first time that a significant amount of engineering was available to prepare detail estimates of the project cost.

WNP NO. 4
PROJECT BUDGET HISTORY

($ in millions)	Preliminary Estimate*	First Official Estimate**	1978 Budget	1979 Budget	Revised 1979 Budget	1980 Budget
Effective Date of Budget	1-1-75	2-1-77	1-1-78	7-1-78 (1)	1-18-79	7-1-79
Commercial Operation Date	3-82	3-83	6-84	6-84	6-85	6-85
Plant Construction	$ 723	$ 966	$ 1,066	$ 1,102	$ 1,205	$ 1,512
Nuclear Fuel	63	171	194	196	229	224
Interest, Financing, and Reserves	223	473	568	567	765	776
Other Authorized Costs	-0-	-0-	42	50	52	68
Total WPPSS Funding Requirements	$ 1,009	$ 1,610	$ 1,870	$ 1,915	$ 2,251	$ 2,580

DAT; 2/25/80

* The preliminary estimates were made at the time of obtaining preliminary financing and were based on broad conceptual design criteria and incomplete detail design work on the project. The preliminary estimates were made prior to contracts for the issuance of the first long-term permanent financings were signed and before plant sites were selected.

* The First Official Estimates were made as the time of issuing the first long term permanent financing for the project. This was the first time that a significant amount of engineering was available to prepare detail estimates of the project cost.

WNP NO. 5
PROJECT BUDGET HISTORY

($ in millions)	Preliminary Estimate*	First Official Estimate**	1978 Budget	1979 Budget	Revised 1979 Budget	1980 Budget
Effective Date of Budget	1-1-75	2-1-77	1-1-78	7-1-79 (1)	1-18-79	7-1-79
Commercial Operation Date	9-83	11-84	3-85	7-85	6-86	6-86
Plant Construction	$ 865	$ 1,111	$ 1,173	$ 1,235	$ 1,341	$ 1,627
Nuclear Fuel	50	195	184	190	226	201
Interest, Financing, and Reserves	295	645	607	647	865	852
Other Authorized Costs	-0-	-0-	54	57	60	73
Total Funding Requirements	1,210	1,951	2,018	2,129	2,492	2,753
Less Amounts Funded by Private Utility Joint Owners	-0-	184	189	199	236	258
WPPSS Funding Requirements	$ 1,210	$ 1,767	$ 1,829	$ 1,930	$ 2,256	$ 2,495

DAT; 2/25/80

* The preliminary estimates were made at the time of obtaining preliminary financing and were based on broad conceptual design criteria and incomplete detail design work on the project. The preliminary estimates were made prior to contracts for the issuance of the first long-term permanent financings were signed and before plant sites were selected.

* The First Official Estimates were made as the time of issuing the first long term permanent financing for the project. This was the first time that a significant amount of engineering was available to prepare detail estimates of the project cost.

PUBLIC SERVICE ELECTRIC AND GAS COMPANY
SALEM PROJECT

EXHIBIT IX-1

TABULATION OF ESTIMATES FOR
SALEM NUCLEAR GENERATING STATION UNITS NO. 1,2, AND 3

Date of Estimate	Estimate Title	Kilowatts Net	Amount*	$/KW Net	Service Dates
8/1/68	Salem Official Estimate**	2,262,000	342,300,000	151	
	One 1090 Net MWe Unit				3/72
	One 1112 New MWe Unit				3/73
	Three 20 Net MWe Gas Turbines				5/71
9/1/69	Salem Revised Estimate***	2,262,000	430,000,000	190	
	One 1090 New MWe Unit				3/72
	One 1112 New MWe Unit				3/73
	Three 20 Net MWe Gas Turbines				5/71
1/4/71	Salem Operating Study Estimate***	2,242,000	500,000,000	223	
	One 1090 Net MWe Unit				12/73
	One 1112 Net MWe Unit				12/74
	One 40 New MWe Gas Turbine				5/71
7/1/71	Salem Revised Estimate***	2,245,000	550,000,000	245	
	One 1090 New MWe Unit				12/73
	One 1115 Net MWe Unit				12/74
	One 40 Net MWe Gas Turbine				6/71
7/1/72	Salem Revised Estimate***	2,245,000	685,000,000	305	
	One 1090 Net MWe Unit				3/75
	One 1115 Net MWe Unit				3/76
	One 40 Net MWe Gas Turbine				6/71
7/1/73	Salem Revised Estimate***	2,245,000	800,000,000	356	
	One 1090 Net MWe Unit				9/75
	One 1115 Net MWe Unit				9/76
	One 40 Net MWe Gas Turbine				6/71
7/1/74	Salem Revised Estimate***	2,245,000	1,045,000,000	465	
	One 1090 Net MWe Unit				12/76
	One 1115 Net MWe Unit				5/79
	One 40 Net MWe Gas Turbine				6/71
7/1/77	Salem Revised Estimate***	2,245,000	1,210,000,000	539	
	One 1090 Net MWe Unit				6/77
	One 1115 Net MWe Unit				5/79
	One 40 Net MWe Gas Turbine				6/71

* These amounts do not include the Switchyard, Fuel, or Allowance for Funds Used During Construction.

** Estimate did not include escalation.
*** Includes Estimated Escalaton to Job Completion.

Table 18: From Construction Management Audit of Salem Nuclear Generating Station Unit No. 1., Theodore Barry and Associates, May 1977

TMI-2 COST ESCALATION*

- 21 cost and in-service date estimates were prepared for TMI-2 between 1969 and 1977:
  - Total cost escalated from $190M to $659M** or an increase of $469M (247%). 687
  - In-service date slipped from 5/73 to 5/78** or a 5-year total slippage. 12/78
- Cost and schedule escalation occurred consistently on a year-to-year basis from 1969-1974:
  - Cost escalation continued during 1975-1977, however, at a reduced pace.
  - In-service date of 5/78 has not changed since 9/74.
  - Reduced rate of cost escalation and reliability of in-service date correlates with date (9/74) that TMI-1 began commercial operation.

SUMMARY OF COST/SCHEDULE ESTIMATES

Year	Number of estimates	Initial cost	Ending cost	Annual escalation	In-service date	Annual I.S.D. slippage (months)
1969	Original	$190M	$ --	$ --	5/73	--
1969	2	190M	214M	24M	5/74	12
1970	4	214M	285M	71M	5/74	--
1971	3	285M	345M	60M	5/75	12
1972	2	345M	465M	120M	5/76	12
1973	1	465M	525M	60M	5/77	12
1974	3	525M	580M	55M	5/78	12
SUBTOTAL	16	190M	580M	390M	5/78	60
1975	1	580M	630M	50M	5/78	--
1976	2	630M	637M	7M	5/78	--
1977	2	637M	659M	22M	5/78	--
TOTAL	21	$190M	$659M	$469M	12/78 5/78	60

* Escalation is defined as an increase in dollar cost or delay of an in-service date over a previous estimate. This term and its explanation is used in the same sense throughout this report.

** Estimates as of 12/77 are subject to change by the company.

Note: This entire section of the construction review report was prepared prior to the final delay caused by the malfunctioning of certain safety values. The current in-service estimated date is November 1978 and the total cost approximately $687 million. √

Table 17: From Review of the Three Mile Island - Unit 2 Construction Project, Touche Ross & Co., October 1978

Data Request
Atty. Gen.-7

WESTERN MASSACHUSETTS ELECTRIC COMPANY
Docket No. DPU 20279

RESPONSE TO ATTORNEY GENERAL
DATA REQUEST DATED 1/18/80

Q-R-66, Page 1 of 1
Witness Responsible:
B. E. Curry

Q-R-66: Please provide the month for each of the estimated dates and each of the estimated inservice dates in CL&P's response to A.G. information request CL-5 in DPU 20055 (copy attached).

Response: This information for Connecticut Yankee and Millstone Unit 1 is not currently available in the form requested. The in-service date for Connecticut Yankee was January 1, 1968, while the in-service date for Millstone Unit 1 was December 28, 1970.

For Millstone Unit 2, whose in-service date was December 26, 1975, the months applicable to construction estimates and estimated in-service dates are as follows:

Millstone Unit 2

Date of Estimate	Estimated In-Service Date	Estimated Plant Cost (millions of $)
November, 1967	April, 1974	141.0
November, 1970	April, 1974	240.0
November, 1973	August, 1975	381.0
December, 1975	December, 1975	434.0

MAR 3 1980

Millstone Unit III - 1150 MW (total plant)
History of Cost Estimates
Millions of Dollars

Date of Estimate	In Service Date	Cash	AFUDC	Total
July 1971	March 1978	343.3	56.7	400.0
September 1972	May 1979	367.6	76.5	444.1
March 1973	May 1979	540.0	110.0	650.0
January 1975	May 1979	639.3	168.2	807.5
December 1975	May 1982	733.4	276.6	1,010.0
March 1977	May 1982	872.2	312.8	1,185.0
July 1978	May 1986	1,343.6	656.4	2,000.0
November 1979	May 1986	1,343.6	970.7	2,314.3

Data Request
Atty. Gen. -7
R-65 Page 2 of 2

Appendix B

Calculations Based on Results of MMWEC Nuclear Power-Duration Study

(Exh. AG-S-37A in Discovery)

From AG-S-37A

for a first unit

duration $= F - S = 62 + 7.1\,(F)$ in months

where F = fuel load date (or FLD) $- 1973.5$
S = construction start $- 1973.5$

and $F - S = \frac{62}{12} + \frac{7.1}{12}\,(F)$ in years

rearranging terms

$$.408\,F = 5.17 + S$$
$$F = 12.66 + 2.45\,S$$
$$S = .408\,F - 5.17$$

for Seabrook 1

1/85 COD ⇒ 7/84 FLD ⇒ $F = 11$ ⇒ $S = -0.682$ ⇒
construction start at 1972.82 = October 1972

$S = 1976.5 = 3$ ⇒ $F = 20.01$ ⇒ 1993.0 FLD = January 1993
⇒ July 1993 COD

for a second unit

$$F - S = 2 + 5.17 + .592F$$
$$= 7.17 + .592F$$

so $F = 17.57 + 2.45S$

$S = .408F - 7.17$

Seabrook 2

1986.83 COD ⇒ 1986.33 FLD ⇒ $F = 12.83$
⇒ $S = -1.94$ = July 1971

$S = 3$ ⇒ $F = 24.92$ ⇒ FLD = 1997.92 = Dec 1997 ⇒
COD = June 1998

Appendix C

Real O & M Trends

Current dollar values were converted to 1967 dollars by the following CPI values:

1967	1.000
1968	1.042
1969	1.098
1970	1.163
1971	1.213
1972	1.253
1973	1.331
1974	1.477
1975	1.612
1976	1.705
1977	1.815
1978	1.955
1979	2.174

Nuclear Plant Operation and Maintenance Costs, Excluding Fuel, in 1967 Dollars ($000)

	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978
Humboldt	$ 559	588	532	763	716	687	724	757	1,161	--	--
San Onofre	1,421	1,799	1,923	1,988	2,808	4,387	3,764	5,377	6,152	4,480	5,952
Millstone #1	--	--	--	2,684	6,127	5,736	6,640	7,484	8,235	6,963	4,843
Conn. Yankee	1,964	1,883	3,851	2,703	2,992	4,772	3,341	5,819	5,524	5,206	4,469
Dresden	--	--	--	--	7,296	6,799	11,328	20,406	17,650	14,875	17,356
Quad. Cities	--	--	--	--	--	4,726	6,236	9,167	9,808	9,783	8,504
Pilgrim #1	--	--	--	--	--	3,604	6,450	4,553	9,755	8,441	7,256
Big Rock	830	850	913	1,044	1,127	1,192	1,532	1,603	1,867	2,824	1,865
Palisades	--	--	--	--	601	2,374	7,974	5,956	5,776	3,619	7,873
Monticello	--	--	--	--	2,049	3,761	3,506	5,415	3,876	6,121	4,674
Oyster Creek	--	--	1,679	2,553	3,094	4,742	7,230	7,636	6,099	8,172	8,128
Nine Mile Point	--	--	1,475	2,275	2,853	3,399	4,232	3,604	3,126	5,368	3,265
Ginna	--	--	--	3,620	3,258	2,657	3,650	4,092	4,314	4,376	5,022
Robinson	--	--	--	--	1,421	3,463	3,236	3,945	3,462	3,779	7,343
Surry	--	--	--	--	--	3,833	6,688	9,473	8,678	8,803	9,884
Point Beach	--	--	--	--	--	2,740	3,540	3,821	3,866	4,415	3,784
Yankee Rowe	1,441	1,458	1,340	1,438	2,324	1,831	2,674	2,827	2,918	3,838	3,914
Vermont Yankee						3,724	3,853	4,766	4,641	5,386	5,724
Maine Yankee						3,031	3,543	3,909	3,085	4,638	5,533
Millstone #2									6,972	9,895	12,664

Plant	Linear a	Linear b	Linear r (2)	Linear 1980	Exponential a	Exponential b	Exponential r (2)	Exponential 1980
Yankee Rowe	-17376.9	270.42	.888	4256.7	.48199	.1154	.897	4924.0
Conn. Yankee	-20965.5	340.15	.653	6246.9	2.2036	.0991	.301	6126.7
Maine Yankee	-28345.7	427.84	.676	5881.5	1.7051	.1023	.655	6122.3
Vermont Yankee	-26537.0	413.50	.968	6543.0	5.4380	.0893	.933	6913.7
Millstone 1	-18419.7	328.98	.218	7898.4	29.015	.0711	.245	8594.8
Millstone 2	-11304.0	1593.90	.708	14208.0	.01728	.1712	.724	15313.0
Pilgrim	-54264.6	795.63	.819	9385.8	.09137	.146	.820	10798.2
+ refueling				1063.0				1063.0

All through 1978, from MMWEC data, except Millstone 2 1975-79 from NU data (1979 = $11362 in 1967$) and Pilgrim 1973-78, data same as MMWEC, but with refueling expense disaggregated - (see testimony of Chernick and Geller, D.P.U. 19845).

Appendix D

Interim Replacement Calculations

All data from FPC/FERC Form 1 and data provided by NU in D.P.U. 20055.

All costs discounted to 1967 dollars; all expressed in hundreds of dollars. See Appendix C for deflators.

Average discounted replacements for each unit was divided by unit capacity (MW DER) to derive a $/MW figure.

Plant	DER	Average 1967 $/MW
Massachusetts Yankee	175	3544
Vermont Yankee	514	5704
Connecticut	575	3769
Maine Yankee	825	2750
Millstone I	660	5306
Millstone II	870	10019
Pilgrim	655	5440
Average		5223

The average is equivalent to $11355/MW in 1979 dollars.

Year	Connecticut Yankee Annual Interim Replacement	Connecticut Yankee Discounted Replacement		Yankee Rowe Annual Interim Replacement	Yankee Rowe Discounted Replacement
1968	-	-			
1969	$ 156,134	1421.985		69-68 $ 51,205	466.35
1970	1,955,294	16,812.50		70-69 13,046	112.175
1971	290,152	2392.01		71-70 634,441	5230.35
1972	150,617	1202.05		72-71 1,229,716	9814.17
1973	224,045	1683.28		73-72 1,006,041	7558.54
1974	12,207,957	82,653.74		74-73 1,966,958	13,317.25
1975	2,730,463	16,938.36		75-74 1,627,434	10,095.74
1976	9,586,346	56,224.90		76-75 464,902	2726.70
1977	2,818,466	15,528.74		77-76 1,765,929	9729.64
1978	4,273,396	21,858.80		78-77 579,991	2966.705
	AVERAGE	21,671.64		AVERAGE	6201.76

Year	Maine Yankee: Annual Interim Replacement	Maine Yankee: Discounted Replacement	Vermont Yankee: Annual Interim Replacement	Vermont Yankee: Discounted Replacement
1973			73-72 12,439,096	93,456.77
1974	74-73 1,848,741	12,516.865	74-73 676,472	4580.04
1975	75-74 12,636,280	78,388.83	75-74 581,248	3605.76
1976	76-75 1,358,980	7970.56	76-75 8,147,235	47,784.37
1977	77-76 1,384,393	7627.51	77-76 2,493,531 (1)	13,738.05
1978	78-77 1,356,670	6939.49	78-77 2,493,531 (1)	12,754.06
	AVERAGE	22,688.65	AVERAGE	29,320.00

(1) 1976-78 increase divided by two: 1977 value not available

Millstone 1

Year	Annual Interim Replacement	Discounted Replacement
1971	1,374,975	11,335.325
1972	590,138	4,709.80
1973	3,009,757	23,288.93
1974	(417,158)	(2824.36)
1975	1,244,794	7722.05
1976	23,917,491	140,278.54
1977	2,818,466	15,528.74
1978	15,667,875	80,142.58
	AVERAGE	35,022.70

Millstone 2

Annual Interim Replacement	Discounted Replacement
9,087,209	53,297.41
24,434,860	134,627.33
14,385,311	73,582.15
AVERAGE	87,168.98

PILGRIM 1

	Interim Replacements (1000$)		Discounted Replacements
1975	482	2990	2,990
1976	4,976	29,180	29,180
1977	16,139	88,920	88,920
1978	4,189	21,430	21,430
	Average:	35,630	35,630

Q 25. Please provide a detailed breakdown of the total of $84.2 million purchase price from Connecticut Light and Power Company and the $59.6 million purchase price from Public Service of New Hampshire.

A 25. New Bedford intends to purchase a 3.02443% interest in the Seabrook Units from Connecticut Light and Power Company and a 2.1739% interest in the Seabrook Units from Public Service of New Hampshire. The following represents a breakdown of total costs, thru the dates of commercial operations, associated with those purchases:

	Connecticut Light and Power	Public Service Company of New Hampshire
Investment in Unit	$55,196,000	$39,673,000
1st Fuel Core	5,745,000	4,130,000
Subsequent Fuel	4,054,000	2,914,000
AFUDC	19,164,000	12,840,000
Total	$84,159,000	$59,557,000

Q 26. Do these figures assume that Seabrook 1 and Seabrook II go on line as scheduled in 1982 and 1984, respectively.

A 26. No, these updated cost figures assume that the units will go on line in 1983 and 1985, respectively.

Q 27. What will be the effect on the purchase price if the purchase from the Connecticut Light and Power Company is delayed?

A. 27. For each month of delay, the purchase price to New Bedford would increase by $186,900 per month which represents the added cost of carrying the investment and assumes no other cost increases.