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Comparative Study and Evaluation of Advanced Cycle Systems

AF-664, Volume 2, Part 2
Research Project 235-1

Final Report, February 1978

Prepared by

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Appendix D

DETAILS OF NET PRESENT WORTH APPROACH

The Net Present Worth Method is described in general terms in Section 6; it consists of four distinct computational steps:

- Generation Phase Diagram Program
- Optimized Generation Expansion Program
- Impact of Intangibles Computation
- Net Present Worth Program

These programs are described in detail in this appendix and lists of the input data are presented for each of the cases considered in this study.

D.1 GENERATION PHASE DIAGRAM PROGRAM

Generation phase diagrams summarize in one plot the year by year variation of interceptions on a series of screening curve plots. Phase diagrams define in each year the cycle alternatives yielding the lowest costs of electricity and the capacity factor ranges in which each cycle is most competitive.

Screening curves are actually cost of electricity functions. Cost of electricity (COE) is given by:

$$COE = \frac{C_{CAP} \times FCR \times 1000}{F} + \frac{C_{FUEL} \times HR}{1000} + \frac{C_{OMF} \times 1000}{F} + C_{OMV}$$

where:

- COE - 30 year levelized cost of electricity (mills/kWh)
- C_{CAP} - plant capital cost (\$/kWe)
- FCR - 30 year levelized fixed charge rate (18%/yr)
- F - capacity factor (h/yr)
- C_{FUEL} - 30 year levelized fuel cost, using inflation rate appropriate to particular fuel and 10% interest (\$/MBtu)
- HR - cycle full load heat rate (Btu/kWh)
- C_{OMF} - 30 year levelized fixed O&M cost using 6½% escalation and 10% interest (\$/kW-yr)
- C_{OMV} - 30 year levelized variable O&M cost using 6½% escalation and 10% interest (mills/kWh)

As discussed in Section 3, this a "life cycle" cost of electricity which expresses in an average way the investment and operating costs attributable to each unit of energy produced over the

entire 30 yr life of the power plant. To screen for the lowest cost options from among a group of cycles one could plot the COE as a function of capacity factor F . This is somewhat awkward because COE vs. F is a hyperbola; however, the function

$$\Phi = \text{COE} \times F$$

is a straight line with respect to F and is the function customarily used in screening plots.

Figure D-1 is a typical screening plot for four candidate cycles; it shows that cycles 1, 2, and 3 are the lowest cost alternatives. Thus for a utility application requiring 0 to 2000 h/yr of operation, Cycle 1 would have the lowest life cycle cost. Between 2000 and 5000 h/yr, Cycle 2 would be least expensive; for application beyond 5000 h/yr, Cycle 3 is most economical.

Figure D-1. Screening Curve Example

If screening curve plots are computed for a number of years, the capacity factor interception points can be plotted vs. year to make up a generation phase diagram as described in Section 6. Conceptually this is quite simple, but in practice it is time consuming and more suitable for analysis by computer.

The generation phase diagrams in this study were calculated using programs developed at EPRI*; these programs are not reproduced here. The basic computational logic can be described with reference to Figure D-1 as follows:

1. In year X, the program computes the ϕ intercepts at $F=0$ for all the candidates (intercepts are shown as a, b, c, and d in Figure D-1). The program chooses the cycle with the smallest intercept (smallest life cycle cost); in this case, Cycle 1 at a.
2. The program computes the intercepts (e, f, and g) of Cycle 1 with all of the other candidates and chooses the cycle with the smallest intercept, Cycle 2 at e. The program records that Cycle 1 is the lowest cost option for $F=0$ to 2000 h/yr in year X.
3. The program computes all of the intercepts of Cycle 2 with the other cycles (excluding Cycle 1). These are h and i. The program notes that h is the smaller, and records that Cycle 2 is the lowest cost option for $F=2000$ to 5000 h/yr in year X.
4. The program repeats this process for Cycle 3, and finds that the lowest (and only) intercept is at j with $F > 8760$ h/yr; the program concludes that Cycle 3 is the lowest cost option for $F=5000$ to 8760 h/yr in year X.
5. The program reports these results and repeats steps 1 through 4 for succeeding years until the study time span is complete.

Generation phase diagrams are presented in Appendix F for the Phase 3 cycles. The input data for these calculations are listed in the following tables.

Capital cost, efficiency and O&M cost data are summarized for the Phase 3 cycles in Table D-1.

Several scenarios for fuel cost escalation patterns were considered as shown in Table D-2. The base case numbers are the fuel costs specified for the Phase 3 study by EPRI. The middle three scenarios represent the situations in which one fuel type escalates 1%/yr faster than anticipated while the others are unchanged. The last scenario shows semiclean liquid (SCL) fuel prices tracking an average between the capital escalation rate and the coal escalation rate. In the other scenarios, SCL was assumed to follow the coal price escalation rate.

*Private communication from Oliver Guildersleeve (EPRI) to Bruce Pomeroy (GE), February 1977.

Table D-1
POWER PLANT DATA - PHASE 3

Cycle Name*	Plant Capital Cost** M\$	Heat Rate at Full Load Btu/kWh	Operation and Maintenance Costs †			
			Current Cost		Levelized Cost	
			Fixed (\$/kWyr)	Variable (mills/kWh)	Fixed (\$/kWyr)	Variable (mills/kWh)
STAFB	447	9536	2.68	1.75	5.04	3.29
GTWCCE	474	7759	1.25	1.83	2.35	3.44
OCMHD	477	7068	1.37	1.50	2.58	2.82
STSCRB	591	10736	2.44	2.18	4.59	4.10
GTCC	282	8014	1.44	1.29	2.71	2.43
GT	116	11013	0.53	1.37	1.00	2.58
STLWR	776	10400	2.67	0.68	5.02	1.28

*Power plants are described in Appendices B and C; names are defined as follows:

STAFB - Steam (3500 P/1000 F/1000 F), AFB, Coal

GTWCCE - Gas Turbine (Water Cooled) Combined, Low Btu Gasifier, Coal

OCMHD - Open Cycle MHD, Coal

STSCRB - Steam, Scrubbers, Coal

GTCC - Conventional Gas Turbine, Combined, Oil/SCL

GT - Conventional Gas Turbine Oil/SCL

STLWR - Steam, Light Water Reactor, Uranium

**Year 2000 plant cost expressed in 1975 dollars (Appendices B and C); capital escalates at 6½%/yr; capital charges to cost of electricity are 18%/yr (30 yr levelized fixed charge rate)

† Year 2000 O&M costs expressed in 1975 dollars; O&M costs escalate at 6½%/yr; levelization factor is constant at 1.882 for 30 yr levelization at 6½% inflation and 10% interest

Table D-2
FUEL PRICES AND INFLATION RATES* - PHASE 3

1975 Price \$/MBtu	Fuel	Fuel Price Inflation Scenarios									
		Base Case		Coal Inflation		Oil Inflation		Uranium Inflation		SCL Inflation	
		I**	F	I	F	I	F	I	F	I	F
0.94	Coal	7.2	COAL	8.2	COAL1	7.2	COAL	7.2	COAL	7.2	COAL
0.97 †	MHD (Coal/IBtu)	7.2	MHDCO	8.2	MHDCO1	7.2	MHDCO	7.2	MHDCO	7.2	MHDCO
3.50	Semiclean Liquid	7.2	SCL	8.2	SCL1	7.2	SCL	7.2	SCL	6.8	SCL2
0.52	Uranium	7.4	NUC	7.4	NUC	7.4	NUC	8.4	NUC1	7.4	NUC
1.85	Oil										
	1975 to 1990	8.5	OIL	8.5	OIL	9.5	OIL1	8.5	OIL	8.5	OIL
	1991 to 2000	9.5		9.5		10.5		9.5		9.5	
	2001 to 2030	10.5		10.5		11.5		10.5		10.5	

*Cost of electricity calculations in Appendices B.1, B.3, B.4 and C use the base case prices

**I - Inflation rate (%/yr)

F - Fuel data file identification

† Includes cost of IBtu gas used in seed regeneration for open cycle MHD

Table D-2 also lists the fuel data file names associated with each scenario. For the base case, these files are COAL, MHDCO, SCL, NUC and OIL; a partial listing of the contents of these files is presented in Table D-3. MHDCO is basically a coal price file, but also includes an allowance for the cost of LBtu gas purchased over the fence for seed recovery in the open cycle MHD plant. Two costs are presented for each fuel type; these are the current (inflated dollar) fuel cost and a 30 yr levelized cost (in current dollars). The levelization factors are constant for most of the fuels as shown below.

<u>Fuel</u>	<u>Cost Levelization Factor*</u>	<u>Period</u>
COAL	2.0406	1975-2030
MHDCO	2.0406	1975-2030
NUC	2.0893	1975-2030
SCL	2.0406	1975-2030
OIL	2.4637	1975
	2.8695	1990
	3.0921	2000

Table D-3
FUEL PRICES - BASE CASE - PHASE 3

Date	Fuel Data File Identification									
	COAL		MHDCO		NUC		OIL		SCL	
	P*	L	P	L	P	L	P	L	P	L
1975	0.94	1.92	0.97	1.98	0.52	1.09	1.85	4.56	3.50	7.14
1980	1.33	2.72	1.37	2.80	0.74	1.55	2.78	7.10	4.96	10.11
1985	1.88	3.84	1.94	3.97	1.06	2.22	4.18	11.23	7.01	14.31
1990	2.67	5.44	2.75	5.62	1.52	3.17	6.29	18.05	9.93	20.26
1995	3.77	7.70	3.90	7.95	2.17	4.53	9.90	29.38	14.06	28.69
2000	5.35	10.91	5.52	11.26	3.10	6.47	15.59	48.20	19.90	40.62
2005	7.57	15.44	7.81	15.94	4.43	9.25	25.68	79.40	28.18	57.50
2010	10.71	21.86	11.06	22.56	6.33	13.22	42.30	130.81	39.89	81.40
2015	15.17	30.95	15.65	31.94	9.04	18.89	69.69	215.50	56.48	115.24
2020	21.47	43.82	22.16	45.22	12.92	26.99	114.82	355.02	79.95	163.15
2025	30.40	62.03	31.37	64.01	18.46	38.57	189.15	584.88	113.19	230.97
2030	43.04	87.82	44.41	90.62	26.38	55.11	311.62	963.56	160.74	326.99

*P - current dollar price of fuel in \$/MBtu

L - levelized price over 30 years from date of listing, e.g., year 2000 listing levelized over 2000 to 2030 (current dollars)

*Base case

The factor for oil changes with time because of the three tiered escalation pattern specified by EPRI.

In running the base case, all units burning liquid fuel were allowed to burn oil up to the year in which the levelized price equaled the price of semiclean liquid (SCL) derived from coal (1995). All units installed after 1994 burned SCL. The current dollar prices for these fuels cross over in 2009.

Table D-2 indicates that six new fuel data files were generated to run the fuel escalation rate parametric analysis. A partial listing of the files is given in Table D-4.

Table D-4
FUEL PRICES - PARAMETRIC VARIATION OF ESCALATION RATES - PHASE 3

Date	COAL1		MHDCO1		SCL1		OIL1		NUC1		SCL2	
	P*	L	P	L	P	L	P	L	P	L	P	L
1975	0.94	2.16	0.97	2.23	3.50	8.05	1.85	5.19	0.52	1.23	3.50	6.82
1980	1.39	3.21	1.44	3.31	5.19	11.94	2.91	8.48	0.78	1.84	4.86	9.47
1985	2.07	4.76	2.13	4.91	7.70	17.71	4.58	14.07	1.16	2.75	6.76	13.16
1990	3.07	7.05	3.16	7.28	11.42	26.26	7.22	23.72	1.74	4.11	9.39	18.29
1995	4.55	10.46	4.69	10.79	16.93	38.95	11.89	40.45	2.61	6.15	13.07	25.41
2000	6.74	15.51	6.96	16.01	25.10	57.76	19.59	69.44	3.91	9.21	18.13	35.31
2005	10.00	23.00	10.32	23.74	37.23	85.66	33.76	119.68	5.85	13.79	25.19	49.06
2010	14.83	34.12	15.30	35.21	55.21	127.03	58.18	206.25	8.75	20.64	35.00	68.17
2015	21.99	50.59	22.69	52.21	81.88	188.38	100.26	355.43	13.10	30.89	48.63	94.72
2020	32.61	75.03	33.65	77.42	121.42	279.37	172.78	612.54	19.60	46.23	67.57	131.62
2025	48.36	111.27	49.90	114.82	180.07	414.30	297.77	1055.62	29.34	69.19	93.89	182.88
2030	71.72	165.01	74.01	170.28	267.03	614.39	513.16	1819.21	43.92	103.56	130.46	254.11

*P - current dollar price of fuel in \$/MBtu

L - levelized price over 30 years from date of listing, e.g., year 2000 listing levelized over 2000 to 2030 (current dollars)

The liquid fuel changeover dates are different for each scenario as shown below.

<u>Scenario</u>	<u>Date of Changeover From Oil to SCL</u>
Base Case	1995
Coal Inflation	2009
Oil Inflation	1986
Uranium Inflation	1995
SCL Inflation	1991

The levelization factors also change in response to the variation of escalation rates.

Generation phase diagrams have also been computed for the Phase 1 cycles which are listed in Table D-5 and described in Appendix A. The cycle data are summarized in Table D-6. Except for the LMFBR, capital cost was assumed to escalate at $6\frac{1}{2}$ percent for all plants. The breeder cost includes both the expense of the basic power plant and an allowance for fuel inventory, which causes the overall cost to escalate faster than $6\frac{1}{2}$ percent as shown below

Year	LMFBR Plant Capital Cost (\$/kWe)	
	Current Dollars	Constant Dollars*
1975	839	839
1980	1177	859
1990	2347	913
2000	5507	1141

Operation and maintenance costs are also presented in Table D-6. In the Phase 1 screening, these costs were assumed to have only a variable component.

Fuel prices for the Phase 1 cycles are shown in Tables D-7 and D-8. Note that the coal, oil, uranium and semiclean liquid base prices are different from those used in the Phase 3 calculations. The escalation rates are also different. For instance, the coal price 0.95 \$/GJ is (1 \$/MBtu) in 1975 with $6\frac{1}{2}$ percent inflation instead of the Phase 3 values of 0.89 \$/GJ (0.94 \$/MBtu) and 7.2 percent.

*base year 1975, $6\frac{1}{2}$ % GNP deflator

Table D-5
IDENTIFICATION OF PHASE 1 POWER CYCLES

Cycle Name	Cycle Description	Fuel
STAFBP1	Advanced steam, atmospheric fluidized bed furnace	Coal
STCONV	Advanced steam, conventional furnace	No. 6 oil
STHTGR	Advanced steam, high temperature gas-cooled reactor	Nuclear
LMFBR	Advanced steam, liquid metal fast breeder reactor	Nuclear
GTARG	Advanced open cycle gas turbine, recuperative, air cooled	High-Btu gas derived from coal
GTARO	Advanced open cycle gas turbine, recuperative, air cooled	No. 6 oil
GTACC	Advanced open cycle gas turbine, combined cycle, air cooled	Low-Btu gas derived from coal
GTWCCG	Advanced open cycle gas turbine, combined cycle, water cooled	Low-Btu gas derived from coal
GTWCCS	Advanced open cycle gas turbine combined cycle, water cooled	Liquid semiclean fuel derived from coal
CO2AFB	Closed cycle gas turbine, supercritical carbon dioxide, atmospheric fluidized bed	Coal
HEAFB	Closed cycle gas turbine, helium, atmospheric fluidized bed	Coal
HEHTGR	Closed cycle gas turbine, helium, high temperature gas-cooled reactor	Nuclear
OCMHDP1	Open cycle plasma MHD	Coal
PLSMHD	Closed cycle plasma MHD, conventional furnace	Coal
LMMHD	Liquid metal MHD, atmospheric fluidized bed	Coal
MVTAFB	Metal vapor turbine, atmospheric fluidized bed	Coal
TRMION	Thermionic, conventional furnace	Coal
FCLOTH	Fuel cell, low temperature	Hydrogen derived from coal
FCLOTO	Fuel cell, low temperature	No. 6 oil
STSCRBP1	Conventional steam with stack gas scrubbing (reference case for base load and midrange)	Coal
GTP1	Simple cycle gas turbine (reference case for peaking)	High-Btu gas derived from coal

Table D-6
POWER PLANT DATA - PHASE 1

Cycle Name*	Date of First Commercial Service	Plant Capital Cost** M\$	Heat Rate at Full Load Btu/kWh	Operation and Maintenance Costs†			
				Current Cost		Levelized Cost	
				Fixed \$/kWyr	Variable mills/kWh	Fixed \$/kWyr	Variable mills/kWh
STAFBP1	1987	553	9104	0	2.89	0	5.44
STCONV	1987	499	8799	0	2.89	0	5.44
STHTGR	1985	728	8687	0	3.48	0	6.55
LMFBR	2000	1141	8984	0	4.33	0	8.15
GTARG	1985	177	9302	0	1.80	0	3.39
GTARO	1980	189	9896	0	3.09	0	5.82
GTACC	1984	390	9431	0	3.20	0	6.02
GTWCCG	1987	355	9671	0	3.30	0	6.21
GTWCCS	1988	233	7264	0	2.42	0	4.55
CO2AFB	1995	1184	9563	0	2.58	0	4.86
HEAFB	1987	615	10804	0	2.53	0	4.76
HEHTGR	1990	801	9353	0	3.51	0	6.61
OCMHDP1	1997	807	7068	0	3.20	0	6.02
PLSMHD	2000	861	7422	0	4.83	0	9.09
LMMHD	1991	1636	9302	0	3.20	0	6.02
MVTAFB	1992	912	8776	0	4.30	0	8.09
TRMION	1997	867	7724	0	5.23	0	9.84
FCLOTH	1992	224	6681	0	4.70	0	8.85
FCLOTO	1992	568	8033	0	4.70	0	8.85
STSCRBP1	-	569	9202	0	2.53	0	4.76
GTP1	-	137	11534	0	2.30	0	4.33

*See Table D-5 for plant identification key

**Year 2000 plant cost expresses in 1975 dollars (Appendix A)

Capital cost escalates at 6½%/yr, except for LMFBR (see text)

Capital charges to cost of electricity are 18%/yr (30 yr levelized fixed charge rate)

† Year 2000 O&M costs expressed in 1975 dollars; O&M costs escalate at 6½%/yr; levelization factor is constant at 1.882 for 30 yr levelization with 6½% escalation and 10% interest

Table D-7
FUEL PRICES AND INFLATION RATES - PHASE 1

1975 Price \$/MBtu	Fuel	Fuel Price Inflation Rate (%/yr)	Fuel Data File Name
1.00	Coal	6.5	COALP1
2.20	Oil	6.5	OILP1
3.00	HBtu Gas	6.5	HBTUP1
2.07	Semiclean Liquid	6.5	SCLP1
2.88**	Hydrogen Derived from Coal	6.5	H2P1
0.53	Uranium for HTGR	Variable	NUCHP1
0.21	Uranium for LMFBR	Variable	NUCLP1

*These prices and inflation rates were used in Phase 1 and are used in Appendices A and F.1 for the cost of electricity and generation phase diagram calculations for the Phase 1 cycles

**H₂ price is 2.88 \$/MBtu, effective price in fuel cell operation is 3.39 \$/MBtu which includes cost of O₂ and credit for purge recovery

Table D-8
FUEL PRICES - PHASE 1

Date	Fuel Data File Name													
	COALP1		OILP1		HBTUP1		SCLP1		H2P1		NUCHP1		NUCLP1	
	P*	L	P	L	P	L	P	L	P	L	P	L	P	L
1975	1.00	1.88	2.20	4.14	3.00	5.65	2.07	3.90	3.39	6.38	0.53	1.16	0.21	0.31
1980	1.37	2.58	3.01	5.67	4.11	7.74	2.84	5.34	4.64	8.74	0.72	1.76	0.26	0.38
1990	2.57	4.84	5.66	10.65	7.72	14.52	5.32	10.02	8.72	16.40	1.51	4.27	0.40	0.53
2000	4.83	9.09	10.62	19.99	14.48	27.26	9.99	18.81	16.36	30.79	4.11	9.82	0.59	0.61

*P - current dollar price of fuel in \$/MBtu

L - levelized price over 30 years from date of listing, e.g., year 2000 listing levelized over 2000 to 2030

D.2 OPTIMIZED GENERATION PLANNING PROGRAM

Estimates for market penetration and capacity factors were obtained in this study by performing an expansion in time of an idealized utility system. A computer program entitled "Optimized Generation Planning" (OGP-4) developed by General Electric's Electric Utility Systems Engineering Department was used to accomplish this task. The program is marketed by General Electric as a tool to assist utility customers in planning system expansions. Further, it has also been used to investigate the impact of advanced technologies on the utility industry*, as in the present study.

Figure D-2 lists the major input parameters to the computation which are of four types:

- Utility System at Start of Study. These variables describe the system composition and past history up to the year in which the expansion is to begin.
- Power Plant Data (New Units). A description of the power plants available in the marketplace during the period of the study. This is the "shopping list" from which the system additions will be selected.
- Economic Data. These variables affect the cost of power, and the relative importance of investment vs. production costs.
- Study Constraints. These are background information and include most of the variables expressing the limitations on the study and the goals for system performance. These variables also control the output of information from OGP.

The program adds power plants each year in such a way as to minimize the levelized system costs while meeting the load with the required system reliability. The calculation generates a large amount of output information which describes the system characteristics and operation at one year intervals. In this study, we are primarily interested in the market penetration and capacity factor outputs as shown in Figure D-2.

Figure D-3 describes the major steps performed by OGP in expanding the system. First, a reliability analysis is performed to estimate the MW of capacity which must be added during the year in question (year *i*) to meet the new load, replace plants retiring in year *i*, and provide for a reserve margin. Then a tentative list of plants is selected which equal or slightly exceed the MW required. The system reliability algorithm then combines the new plants with existing plants and computes a loss of load probability (LOLP) for the new system. One of the program options not used in this study is shown as the next step in Figure D-3. If selected, this option reviews the LOLP and adds or deletes some of the new plants to achieve a fixed LOLP goal. In the present study, this option was deleted and the system was designed to a fixed 20% reserve margin.

*studies in progress at EPRI

*Loss of load probability (not used in this study, 20% installed reserve was maintained)

Figure D-2. Input and Output from Optimized Generation Planning (OGP) Program

* Iteration on LOLP was not used in these calculations; system was expanded with a fixed 20% reserve margin.

Figure D-3. Optimized Generation Planning Program
Logic Flow Diagram

After computing reliability, OGP then computes the production costs for year i using levelized fuel and O&M costs. Investment costs are also computed for the new additions.

Several passes are made through this calculation, each corresponding to a different list of plant additions in year i. The plant selection algorithm proposes the successive lists using a tree logic which follows permutations in the lists only so far as they continue to decrease costs. Additional permutations are considered until all allowable plant types have been considered at least once. Only rarely are all possible combinations of types considered in any given year. When the permutations are complete, the algorithm selects that one which gives the lowest total cost in year i (investment + levelized production costs). The accepted list of additions is the market penetration for each unit type in year i.

Following the selection process, another production costing run is made on the new system using current dollar values for fuel and O&M costs. This describes how the units would actually be dispatched in year i and provides the capacity factors for that year.

The load model used in this study is described in Table D-9. In the beginning, Scenario D was used exactly as reported in the PTI report; however, in the later years of the expansion, the utility system included so many units that it exceeded OGP's current storage and manipulative capacities. The initial system was split to correct this. All results reported in Appendix F are for this split system model.

Table D-9
UTILITY SYSTEM AT START OF STUDY - LOAD DATA

Demand Curves	Scenario D Load Shape Data*, Approximate Annual Load Factor 59%
Demand Growth Rate	5.6%** Starting in 1986
Yearly Peak Load in 1985	Scenario D - 26,248 MW Split System - 13,124 MW

*Synthetic Electric Utility Systems for Evaluating Advanced
Technologies, Power Technologies Incorporated, Schenectady,
N.Y., EPRI Report No. EM-285, February 1977

**Specified by EPRI

Table D-10 shows the existing mix for Scenario D, and Table D-11 presents the mix as used in this study. For the split system, the number of MW of capacity in place in 1985 is roughly half of that for Scenario D. The system has been split in such a way that it has about the same percentages of each unit type in 1985, and it has roughly the same retirement schedule for these units as in Scenario D. Units installed earlier than 1956 are not shown in Tables D-10 and D-11 because under the assumption of 30 year plant life, these units will not be on the system in 1985.

Power plant data for the units described in Table D-11 are listed in Table D-12. The new units available to OGP for expansion are described in Table D-13. These are the plants discussed in Appendixes B and C. General specifications concerning both old and new units are summarized in Table D-14. The commitment rules are used to describe the cycling capabilities of the various plants.

The economic data listed in Table D-15 are identical to the Phase 3 data discussed in Appendix D.1 with reference to the generation phase diagrams.

The study constraints are listed on Table D-16. Note that the time spans for the first and last scenarios are 39 years while the Minimum Competition cases are only 20 years each. The No New Technology case had to be run for the full time period in order to get a complete background for the rest of the study. The Crowded Market case also needed the full time span because of the staggered entry times for the three advanced cycles. It was not considered necessary to run the full time span under Minimum Competition because 20 years is enough time to get through the startup transient and to begin to see predictable trends in the market penetration and capacity factors.

The other study constraints are shown in Table D-17.

Table D-10

UTILITY SYSTEM AT START OF STUDY - EXISTING MIX - SCENARIO D*

Year Installed	Plant Type and Size (MW)										Capacity Added MW	
	Nuclear		Steam - Coal				Steam - Oil					GT - Oil
	800	1200	200	400	600	800	200	400	600	800		50
1956			1				1					400
57			1				1					400
58							2					400
59			2									400
1960			2				2					800
61			1				1					400
62							2					400
63			2									400
64			2				1					600
1965			4	1								1200
66			3				1					800
67			3				1					800
68					1		1					800
69			2								4	600
1970	1		1	1			1				8	2000
71				1							4	600
72					1						12	1200
73				1							10	900
74				1	1						2	1100
1975									1		10	1100
76										1	12	1400
77								1	1		2	1100
78		1							1		6	2100
79						1	1					1200
1980		1									4	1400
81		1									6	1500
82		1									4	1400
83		1									8	1600
84		1									4	1400
Totals	8000 MW		9400 MW				6200 MW				4800 MW	28400 MW
Percent	28.2		33.1				21.8				16.9	100

*Synthetic Electric Utility Systems for Evaluating Advanced Technologies, Power Technologies Inc., Schenectady, N.Y., EPRI Report EM-285, February 1977. This system was too large to be useful in the present study.

Table D-11

UTILITY SYSTEM AT START OF STUDY - EXISTING MIX - SPLIT SYSTEM

Year Installed	Plant Type and Size (MW)										Capacity Added MW	
	Nuclear		Steam - Coal				Steam - Oil					GT - Oil
	800	1200	200	400	600	800	200	400	600	800		50
1956			1									200
57							1					200
58			1									200
59							2					400
1960			1									200
61												0
62			1									200
63							1					200
64			2				2					800
1965			1									200
66			3									600
67												0
68			1	1	1							1200
69							1				2	300
1970	1		1								4	1200
71											2	100
72				1							6	700
73					1						4	800
74				1	1							1000
1975									1		6	900
76										1	8	1200
77									1			600
78								1			4	600
79		1				1						2000
1980											2	100
81											2	100
82		1									2	1300
83		1									4	1400
84											2	100
Totals	4400 MW		6200 MW				3800 MW				2400 MW	16,800 MW
Percent	26.2		36.9				22.6				14.3	100

Table D-12
POWER PLANT DATA - OLD UNITS*

Unit Type - Fuel Type	Unit Rating MW	Heat Rate (Full Load) Btu/kWh	Outage Rates		Minimum Load		O&M Costs	
			Forced %	Planned %	% (1)	% (2)	Fixed \$/kWyr	Variable mill/kWh
Nuclear	800	10400	15	13.4	50	95	2.67 ⁽³⁾	0.68 ⁽³⁾
	1200	10400	15	13.4	50	95	2.67 ⁽³⁾	0.68 ⁽³⁾
Steam - Coal	800	8750	24	13.4	40	91	2.44 ⁽⁴⁾	2.18 ⁽⁴⁾
	600	8900	21	12.3	25	82	2.44 ⁽⁴⁾	2.18 ⁽⁴⁾
	400	9000	13	12.3	25	84	2.44 ⁽⁴⁾	2.18 ⁽⁴⁾
	200	9500	7.4	9.9	25	82	2.44 ⁽⁴⁾	2.18 ⁽⁴⁾
Steam - Oil	800	9100	24	13.4	40	91	1.22 ⁽⁵⁾	1.09 ⁽⁵⁾
	600	9300	21	12.3	25	82	1.22 ⁽⁵⁾	1.09 ⁽⁵⁾
	400	9400	13	12.3	25	84	1.22 ⁽⁵⁾	1.09 ⁽⁵⁾
	200	9900	7.4	9.9	25	82	1.22 ⁽⁵⁾	1.09 ⁽⁵⁾
GT-Oil	50	14000	24	4.9	100	100	0.53 ⁽⁶⁾	1.37 ⁽⁶⁾

*Power plants added before 1985; except where noted, the data source is Synthetic Electric Utility Systems for Evaluating Advanced Technologies, Power Technologies Inc., Schenectady, N.Y., EPRI Report EM-285, February 1977.

(1) minimum load (MW)/full load (MW)

(2) minimum load efficiency/full load efficiency

(3) chosen to be the same as the new unit, STLWR

(4) chosen to be the same as the new unit, STSCRB

(5) O&M costs for oil fired plant taken to be half of coal fired

(6) chosen to be the same as the new unit, GT

Table D-13
POWER PLANT DATA - NEW UNITS*

Unit Type - Fuel Type	Unit Rating MW	Heat Rate (Full Load) Btu/kWh	Outage Rates		Minimum Load		O&M Costs		Plant Capital Cost \$/kW	Date of First Commercial Service
			Forced %	Planned %	% (1)	% (2)	Fixed \$/kWyr	Variable mill/kWh		
STAFB - Coal	814	9536	9	9	20	75	2.68	1.75	447	1988
GTWCCE - Coal	640	7759	12	9	20	87	1.25	1.83	474	1996
OCMHD - Coal+IBtu Gas	1932	7068	20	15	60	85	1.37	1.50	477	2003
STSCRB - Coal	747	10736	18	9	20	75	2.44	2.18	591	----
GTCC - Oil/SCL ⁽³⁾	417	8014	10	9	20	87	1.44	1.29	282	----
GT - Oil/SCL ⁽³⁾	76	11013	12	4	30	70	0.53	1.37	116	----
STLWR - Uranium	1000	10400	15	15	50	95	2.67	0.68	776	----

*Power plants treated as automatic additions by OGP from 1985 onward; data extracted from Appendixes A, B and C

(1) minimum load (MW)/ full load (MW)

(2) minimum load efficiency/full load efficiency

(3) units of these types added before 1995 burn oil, thereafter units burning semiclean liquid are installed

NOTE: STAFB - Steam (3500 P/1000 F/1000 F), AFB, Coal

GTWCCE - Gas Turbine, (Water Cooled) Combined, Low-Btu Gasifier, Coal

OCMHD - Open Cycle MHD, Coal

STSCRB - Steam, Scrubbers, Coal

GTCC - Conventional Gas Turbine, Combined, Oil/SCL

GT - Conventional Gas Turbine, Oil/SCL

STLWR - Steam, Light Water Reactor, Uranium

Table D-14
POWER PLANT DATA

Power Plant Life:	30 years, all types
Commitment Rules*	<p>Rule 1 - If the unit is committed, it must run all week before it can be considered for shutdown. This includes the following plant types: Old Units - Nuclear, Steam - Coal, Steam - Oil New Units - STLWR, STAFB, GTWCCE, OCMHD, STSCR</p> <p>Rule 2 - If committed for weekday, must run all day. If committed for weekend, must run all weekend. Old Units - none New Units - GTCC</p> <p>Rule 3 - If committed, must run all hours of commitment zone period (4 to 8 hrs) Old Units - GT New Units - GT</p>

*OGP input variable is KCYCLE = 1(Rule 1), 2(Rule 2), 3(Rule 3)

Table D-15
ECONOMIC DATA

	Percent	Period
Discount Rate	10.0	1975-2055
Inflation Rates		
Capital Costs	6.5	1975-2055
O&M Costs	6.5	1975-2055
Fuel Costs		
Coal (0.94 \$/MBtu)*	7.2	1975-2055
Uranium (0.52 \$/MBtu)	7.4	1975-2055
Semiclean Liquid (3.50 \$/MBtu)	7.2	1975-2055
Coal + IBtu Gas (0.97 \$/MBtu)**	7.2	1975-2055
Oil (1.85 \$/MBtu)	8.5	1975-1990
	9.5	1991-2000
	10.5	2001-2030
Fixed Charge Rate on Investment	18.0	1975-2055
Levelization Period: 30 years		

*Price in 1975

**Fuel + seed recovery medium for MHD plant

Table D-16
STUDY CONSTRAINTS - TIME SPAN

Scenario		Start Date	End Date
No New Technology	Run No. 1	1986	2005
	Run No. 2	2005*	2024
Minimum Competition			
	STAFB	1987**	2006
	GTWCCE	1995**	2014
	OCMHD	2002**	2021
Crowded Market	Run No. 1	1987**	2006
	Run No. 2	2006**	2025 †

*Started one year early to assure continuity with Run No. 1

**Started one year earlier than availability of advanced cycle to assure continuity with background expansion (No New Technology)

† Goal not achieved (actual end: 2022) because number of units in system exceeded array capacity of the OGP program.

Table D-17
STUDY CONSTRAINTS - MISCELLANEOUS

OGP Input Variable	Value	Definition/Action
		Reserve
PRGOAL	20	Use fixed reserve goal (20%), <u>not</u> fixed loss of load probability (LOLP)
MONPR	0	Use peak load month as basis for reserve computation
KEYPRC	0	Compute reserve as $\frac{\text{Capacity} + \text{Contracts} - \text{Load}}{\text{Load}}$
		Spinning Reserve
SPRES	-1	Calculate as 100% of largest unit not on maintenance in month being studied
		Emergency Excess Capacity - Selling Power
EXMXP	1.00	Sell excess power at rate of 20 mills/kWh (7.2% inflation rate) when sum of minimum generation exceeds demand
EXDMWH	20.0	
EXRATE	1.072	
		Buying Power
CSTENG	40.0	When unable to supply demand buy power from neighboring utility at 40 mills/kWh (7.2% inflation rate)
EERATE	1.072	
		Control of Unit Selection
		Gas turbines will be lumped in pairs to reduce number of units in computer arrays
PCTRM	0.1	Percent trim code; option to meet minor MW deficiency by installing gas turbines instead of unit size being evaluated; gas turbines added when deficiency is less than 10% of unit size being evaluated
MIX	1	Permission to add a mixture of unit types in each year
FAIL	0	Add new units automatically rather than manually
MATOR	1	Use mature outage rates to select minimum cost of expansion
RANFOR	-1	Use random forced outage rates in optimum passes only
SHKFOR	1	No shakedown period on new units; use mature forced and planned outage rates throughout
SHKPOR	1	
MNTPKM	0	Maintenance scheduling - use normal mode
		Output Control
KODE(7)	0	Compute loss of load probability for optimum expansion
KEYENV	0	Omit environmental discharge calculations
KOSTPC	1	Compute production costs for optimum expansion
NKODE(1)	1	Define variable O&M units as \$/MWh
KODE2(20)	-1	Print annual production cost summary for optimum types only
KPCUMT	1	Print cumulative fuel, O&M, and investment costs in summary No. 1
KEYSUM	0	Print summary No. 3

D.3 IMPACT OF INTANGIBLES COMPUTATION

Basic Approach to Intangibles

Each cycle considered in this study has been rated according to 26 evaluation criteria, as described in Section 7 and Appendix G. In the various postulated scenarios (sets of competing cycles in the market), these evaluation criteria have several different effects:

- Three of the 26 evaluation criteria affect the R&D phase for a cycle. These three criteria are cost of R&D required, R&D time required, and probability of development success.
- The remaining 23 evaluation criteria affect commercial application of the cycles. Three of these criteria directly determine the cost of electricity generated by installations of a cycle: plant capital cost, plant O&M requirements, and power plant efficiency.
- Several of the 23 evaluation criteria which affect commercial application influence the amount of capacity installed for a cycle, as estimated by the OGP program for each scenario. These include all evaluation criteria which also determine cost of electricity and all evaluation criteria which determine operating characteristics (electric performance, part load efficiency, capability for load change, minimum unit load, and unit rating).
- All 23 evaluation criteria which affect commercial application have an intangible effect upon market penetration. When utilities make decisions for addition or replacement of generation capacity, they consider intangible factors in addition to the tangible factors reflected in OGP.

It is this last type of effect which is addressed by the Impact of Intangibles computation.

In this analysis, the defined society which is to bear the costs and receive the benefits is the United States including the public, private, and commercial sectors, not just the utility industry. Accordingly, it may seem inconsistent to account for the intangible effects of the evaluation criteria by their impact upon utility installation decisions. However, this is consistent with defining the costs and benefits as those which accrue to the entire American society, for society cannot receive the benefit of a new generation cycle unless the utility industry is willing to install it. The objectives perceived for the utility industry (e.g., low transmission costs, good financial position, good public relations, good system frequency, high service reliability) closely parallel the objectives perceived for society as a whole.

Effects of intangibles are entered into the Net Present Worth analysis through the following steps:

1. For each scenario considered, OGP is run to obtain the market penetration for each cycle, neglecting intangible effects. This penetration is expressed as f_{Ok} for cycle k.

2. The 23 evaluation criteria which affect commercial application through intangibles are used to establish a market penetration multiplier for each cycle. This multiplier is expressed as f_{Mk} for cycle k. Determination of f_{Mk} is discussed below.
3. The resulting derated market penetrations for the cycles present in each scenario are then normalized, thus making up the total market. This produces the market penetration, f_k , for cycle k, when both tangible and intangible effects are considered.

Note that steps 1 and 3 must be repeated for each scenario, while step 2 is scenario independent. Step 2 is where intangible effects are taken into account.

Rationale for Market Penetration Multiplier

Consider now how the market penetration multiplier, f_{Mk} , is obtained for every cycle k. For simplicity, assume for the moment that only one evaluation criterion exists. Every generation addition decision by a utility may be conceived as an event which is influenced by the intangible aspects of the evaluation criterion. Suppose that this evaluation criterion is fair or poor for cycle k, but good for all other competing cycles. This will cause some (but not all) acquisition decisions which would otherwise have selected cycle k to select some other cycle instead. After many such decisions have been made, the market penetration multiplier, f_{Mk} , is given by the following ratio:

$$f_{Mk} = \frac{\text{(actual capacity installed for cycle k)}}{\text{(capacity which would have been installed for cycle k without intangible effects)}}$$

Suppose that two evaluation criteria exist, rather than one. Let cycle k be rated fair or poor in regard to both criteria, while all other cycles are rated good in regard to both criteria. Again, each acquisition decision which would have selected cycle k without consideration of intangibles may select some other cycle instead. But now there is an interplay between the two evaluation criteria. Their effects may be independent, fully correlated, or partially correlated. As illustrations, consider the following contrived examples:

- A. Evaluation criterion 1 makes cycle k unsuitable for use west of the Mississippi River, thereby leaving (say) 60% of its potential applications. Criterion 2 makes cycle k unsuitable for peaking use, thereby leaving (say) 85% of its potential applications. Assuming that peaking applications are equally prevalent in different parts of the U.S., it is seen that $0.60 \times 0.85 = 0.51$ or 51% of the

potential applications for cycle k will actually be installed. This is a case of independence, since it is assumed that peaking is independent of geography.

- B. Evaluation criterion 1 makes cycle k unsuitable for use west of the Mississippi River, as in Example A, thereby leaving 60% of its potential applications. Evaluation criterion 2, however, is now redefined so that it makes cycle k unsuitable for use in California, thereby leaving (say) 85% of its potential applications. Obviously, criterion 1 dominates criterion 2, and 60% of the potential applications for cycle k will actually be installed -- not 51% as in Example A. This is a case of full correlation, since one criterion is completely determined by the other.
- C. Evaluation criterion 1 makes cycle k unsuitable for use west of the Mississippi River, as in Examples A and B, thereby leaving 60% of its potential applications. Evaluation criterion 2 is now redefined so that it makes cycle k unsuitable for use near active geological faults, thereby leaving (say) 85% of its potential applications. Most, but not all, active faults occur west of the Mississippi. The percentage of potential applications of cycle k which will actually be installed lies somewhere between 51% and 60%, depending upon the geographical distribution of sites with active faults. This is a case of partial correlation, since one criterion is partially determined by the other.

From the foregoing examples, two conclusions are evident:

1. The intangible effects of the evaluation criteria upon market penetration are multiplicative, not additive.
2. The multiplicative nature is modified by the correlation between the criteria.

Note that "correlation" can be represented by the statistical "correlation coefficient," defined such that $-1 \leq \rho \leq 1$; $\rho = 0$ implies independence, $\rho = 1$ implies full correlation.

Mathematical Form for Market Penetration Multiplier

An approximation was developed to represent correlation effects in the market penetration multiplier. Consider two random variables x_1 and x_2 , where $x_1 = 1$ if a potential application is acceptable according to criterion 1 and $x_1 = 0$ if not acceptable; likewise for x_2 and criterion 2. The exact expression for the joint probability p_{12} that a site is acceptable for both criteria is

$$p_{12} = \sqrt{p_1 p_2} \left\{ \sqrt{p_1 p_2} + \rho_{12} \sqrt{(1-p_1)(1-p_2)} \right\} \quad (D-1)$$

where p_1 is the probability that a site is acceptable for criterion 1 alone, p_2 is the probability that a site is acceptable for criterion 2 alone, and ρ_{12} is the correlation coefficient between criteria 1 and 2. It was found that, over a wide range of values, Equation D-1 is closely approximated by

$$p_{12} \approx \text{MIN}(p_1, p_2) \left\{ \text{MAX}(p_1, p_2) \right\}^{(1 - \sqrt{\rho_{12}})} \quad (\text{D-2})$$

This approximation was developed to allow easy extension to the general case of more than two evaluation criteria. Its extension is as follows:

$$p \approx \text{MIN}(p_i) \cdot \left\{ \prod_{i \neq \text{min}} p_i \right\}^{(1 - \sqrt{\rho})} \quad (\text{D-3})$$

where ρ is the average pairwise correlation coefficient between the various evaluation criteria. Three special cases of Equation D-3 are of interest:

$$\begin{array}{lll} \rho = \text{MIN}(p_i) & \text{if } \rho = 1 & (\text{fully correlated}) \\ \rho = \sqrt{\text{MIN}(p_i) \cdot \prod p_i} & \text{if } \rho = 1/4 & (\text{partly correlated}) \\ \rho = \prod p_i & \text{if } \rho = 0 & (\text{independent}) \end{array}$$

Assumed Numerical Values

In order to calculate numerical values for the market penetration multiplier, using Equation D-3, it is necessary to assume:

- The average pairwise correlation coefficient ρ
- The market penetration multiplier, p_i , when the criterion i is good, fair, and poor respectively, and all other criteria are good.

Judgement was exercised to assess the average pairwise correlation coefficient ρ . Some evaluation criteria are rather highly correlated, as are electrical performance and capability for load change. Others are almost independent, as are life and byproducts. Note that there are 253 pairs among the 23 evaluation criteria which affect intangible aspects of market penetration. After considering selected pairs from this rather large number, it was subjectively concluded that the average correlation is closer to independence than to full correlation. Hence, the following value was selected:

$$\rho = 1/4 \quad (\text{D-4})$$

Accordingly, the expression for the market penetration multiplier (Equation D-3) simplifies to

$$f_{Mk} = \sqrt{\text{MIN}(p_{ik}) \cdot \prod p_{ik}} \quad (\text{D-5})$$

where the probability p has been replaced by the market penetration multiplier f_{Mk} . Also, the market penetration, p_i , for evaluation criterion i has been replaced by p_{ik} , to emphasize that its value depends upon the cycle k . This form was used as the basis for market penetration computations. Bear in mind its implicit assumption of $\rho = 1/4$.

Consider now how values were assigned to the p_{ik} when the evaluation criterion i is rated fair. In the Direct Weighting Method, importance weightings were developed for the evaluation criteria. These numerical values were used as the basis for assigning values to the p_{ik} . It was assumed that, when the criterion i for cycle k is fair and all other criteria are good, the loss of market penetration is proportional to the importance weighting*, w_i :

$$1 - p_{ik} = k_p w_i \quad \text{when } \underline{\text{fair}} \quad (D-6)$$

where k_p is the constant of proportionality. A value was assigned to k_p by considering what happens when all criteria for cycle k are rated fair. Using Equation D-5 for f_{Mk} produces

$$\begin{aligned} f_{Mk} &= 0.52 & k_p &= 1, \text{ all criteria } \underline{\text{fair}} \\ f_{Mk} &= 0.75 & k_p &= 1/2, \text{ all criteria } \underline{\text{fair}} \end{aligned}$$

Since it seems reasonable that a cycle would lose half its potential market if all its criteria are fair, the value selected for the proportionality constant was:

$$k_p = 1 \quad (D-7)$$

Hence, for every evaluation criterion,

$$p_{ik} = 1 - w_i \quad \text{when } \underline{\text{fair}} \quad (D-8)$$

In order to assign values to the p_{ik} when the evaluation criterion i is poor, the criteria were divided into two categories: hard and soft. A hard criterion is one which has a severe effect on market penetration if poor; a soft criterion has a much milder effect. The following criteria were identified as hard:

- Criterion 13, Hardware Materials Availability
- Criterion 15, Plant Safety
- Criterion 24, Environmental Intrusion
- Criterion 25, Availability of Fuels and Additives

All other criteria are deemed soft. It is doubtful that any of the hard criteria would completely negate use of a cycle if poor, so it was decided to set

* w_i = normalized impact fraction for market penetration (from Table 7-4)

$$p_{ik} = 0.5 \quad \text{hard criteria, } \underline{\text{poor}} \quad (\text{D-9})$$

For all soft criteria, it was noted that fair is defined as lying roughly midway between good and poor, so it was decided to make the loss of market twice as great when poor as when fair:

$$p_{ik} = 1 - 2w_i \quad \text{soft criteria, } \underline{\text{poor}} \quad (\text{D-10})$$

Values which result from Equations D-8, D-9, and D-10 for the p_{ik} of all evaluation criteria are listed in Table D-18.

Table D-18
VALUES FOR p_{ik} OF THE EVALUATION CRITERIA

Criterion Number	w_i^*	p_{ik} When Evaluation Is:		
		Good	Fair	Poor
4	0.12	1.0	0.88	0.76
5	0.01	1.0	0.99	0.98
6	0.08	1.0	0.92	0.84
7	0.03	1.0	0.97	0.94
8	0.04	1.0	0.96	0.92
9	0.01	1.0	0.99	0.98
10	0.01	1.0	0.99	0.98
11	0.07	1.0	0.93	0.86
12	0.05	1.0	0.95	0.90
13**	0.01	1.0	0.99	0.50
14	0.01	1.0	0.99	0.98
15**	0.05	1.0	0.95	0.50
16	0.07	1.0	0.93	0.86
17	0.10	1.0	0.90	0.80
18	0.01	1.0	0.99	0.98
19	0.06	1.0	0.94	0.88
20	0.04	1.0	0.96	0.92
21	0.03	1.0	0.97	0.94
22	0.05	1.0	0.95	0.90
23	0.01	1.0	0.99	0.98
24**	0.04	1.0	0.96	0.50
25**	0.08	1.0	0.92	0.50
26	0.02	1.0	0.98	0.96

* w_i = normalized impact fraction for market penetration (from Table 74, Section 7)

**Hard evaluation criteria with $p_i = 0.50$ when poor

Normalization

After the market penetrations for the various cycles in a scenario have been derated by the market penetration multipliers, it is necessary to normalize the market penetrations to refill the complete market. This is done by expanding the derated market penetration of each cycle by the same factor c_f , to achieve

$$\sum_k f_k = 1 \quad (D-11)$$

The condition of Equation D-11 is satisfied by selecting c_f as follows:

$$\sum_k c_f f_{Ok} f_{Mk} = 1$$

whence

$$c_f = 1 / \sum_k f_{Ok} f_{Mk} \quad (D-12)$$

where f_{Ok} is the OGP market penetration for cycle k in a given scenario, and f_{Mk} is the market penetration multiplier determined from Equation D-5 (same for all scenarios). The normalization multiplier, c_f , is the same for all cycles in a given scenario, but has a different value for each scenario.

D.4 NET PRESENT WORTH PROGRAM

Introduction

In brief, the present worth approach estimates the net present worth of undertaking the R&D programs for each scenario considered. Net present worth is defined as the difference between the worths of benefits and costs:

$$W_{\text{net}} = W_{\text{benefits}} - W_{\text{costs}} \quad (\text{D-13})$$

The benefits of successful R&D on a cycle consist of savings if a scenario were to come to pass in the future instead of the scenario with only current power generating cycles (No New Technology). These benefits are modified to account for the impacts of such factors as R&D time, market penetration, capacity factor. The costs consist of the cost of the R&D programs for new cycles in a scenario.

Two questions which must be addressed are these: "Whose benefits?" "Whose costs?" These questions are answered by defining the society to which the cost-benefit analysis is applied: "In a cost-benefit analysis we are concerned with the economy as a whole with the welfare of a defined society, and not any smaller part of it."* The society to which this cost-benefit analysis is applied might be defined as limited to the utility industry, but such a narrow definition has been deemed too restrictive. Instead, the defined society has been assumed to be the entire society of the United States. Thus, for example, this cost-benefit analysis has included all R&D costs, even though the majority of such costs might be borne by governmental agencies rather than the utility industry. (In the long run, all R&D costs are borne by the American public, either through passthrough from the utility industry or by taxation.) As a second example, this analysis has not included property and income taxes upon the utilities (except in some sensitivity runs), as such taxes are merely a transfer payment from one segment of the United States society to another. As a third example, all savings which accrue from installing a new cycle have been included in the analysis, since such savings benefit not only the utility industry but also American society as a whole, whether they are reflected in lowered electricity rates or paid in dividends to utility shareholders.

Two economic criteria must be satisfied for the results of a cost-benefit analysis to be positive with regard to a particular proposed project (in this case, with regard to a new cycle):

1. Benefits shall exceed costs ($W_{\text{net}} > 0$ in Equation D-13).
2. Distributional changes shall not be too regressive.

*Ref. D-1, p. 11

Criterion 1 is quantitative, but Criterion 2 is qualitative and involves social judgments. Hence, this cost-benefit analysis has been conducted by invoking the concept of the "potential Pareto improvement":

"Pareto improvement" - some members of the defined society will be better off, and none will be worse off.

"Potential Pareto improvement" - through cost-free transfers of goods or money, every member of the defined society can be made better off.

On the assumption that future political processes can bring about appropriate redress if some members of the United States society are made worse off by implementation of a proposed cycle, Criterion 2 has been ignored. Each candidate cycle has been analyzed solely on the basis of Criterion 1, that is, its benefits must exceed its costs. This is at present a theoretical point, though, since no gross distributional changes have been identified as a result of the implementation of new cycles.

The present worth approach compares candidate cycles on the basis of Equation D-13 alone. That is to say, all decision criteria have successfully been incorporated into a single objective function. There are several forms in which a single objective function can be written, for example:

Benefits/Costs ratio

Equivalent rate of return

Net present worth (Equation D-13)

The Benefits/Costs ratio has been applied often but is not used in this analysis. This ratio is appealing in that it does not require that benefits and costs be expressed in the same units; but it can be demonstrated that optimizing this ratio is not the same as optimizing net present worth. It is argued here that the net present worth to United States society is what should be maximized, rather than an artificial construct such as the Benefits/Costs ratio or the equivalent rate of return.

Two types of uncertainties could be considered:

1. Uncertainties in estimated parameters for each candidate cycle, such as capital cost, efficiency, fuel cost, operating and maintenance cost.
2. Uncertainties in general economic parameters, such as escalation rates, demand for electric energy, and time at which a new cycle becomes obsolete.

These two types of uncertainties could be treated in two different ways. First, they could be propagated through the cost-benefit model to obtain the expected value of net present worth,

and then make the assumption that expected net present worth is a valid guide to decision making (i.e., that the utility function of the United States society is linear). Second, sensitivity analyses could be performed without attempting to impart subjective probabilities to variations of parameters. Because of the complexity of the net present worth model, treatment of uncertainties has been limited to a few sensitivity analyses (note that each variational run requires rerunning the OGP program).

Since this analysis has been applied to impacts upon the entire United States society, it has been necessary to consider externalities or "spillover effects." An externality is defined thus: An externality "is not deemed to be a deliberate creation of its producer but an incidental, or unintended, by-product of apparently legitimate economic activity," which incurs neither cost nor gain for its producer.* Externalities from generation of electric power include stack emissions, heat rejection to bodies of water, and impacts of mining. It has been assumed in this analysis that all externalities will be "internalized" to the utility industry, in the following two ways: through imposition of environmental quality constraints and hence through increases in costs for abatement equipment, and through general price increases to reflect such requirements as restoration of strip-mined areas.

No attempt has been made to model the economic interactions between advanced cycles and the rest of the economy. Such interactions include increased demand for electric energy if a cycle brings significant savings, and (conversely) exceptional price escalations if a cycle demands significant portions of the world's resources for a particular material (uranium excepted, since essentially the only use for uranium will be power production).

In summary, the present worth approach has consisted of the following steps:

1. Define a set of mutually exclusive and exhaustive evaluation criteria for advanced cycles.
2. Construct a deterministic cost-benefit model of the form of Equation D-13, based upon the following set of parameters:

- R&D program costs
- Time to first installation
- Time to last installation
- Market penetration (from OGP)
- Capacity factor (from OGP)
- Capital cost
- Fuel cost and efficiency
- Operating and maintenance cost, fixed and variable
- Discount rate

*Ref. D-1, p. 89

3. Develop expressions for the impact of intangible criteria from Step 1 upon the model parameters of Step 2.
4. Computerize the model.
5. Conduct sensitivity runs of the model to consider limited alternate economic futures.

Discounting and Escalation

The term "present worth" implies that all future benefits and costs have been discounted to their present value (for this study, the "present" has been taken as the year 1975). This raises an immediate question: what discount rate will be used?

A high discount rate implies that benefits and costs far in the future are accorded little weight; a low discount rate implies the opposite. There is an economic argument that prevailing interest rates reflect the consensus of society as to the importance of the future, so the interest rate on money should be used as the discount rate. However, this is clouded by the effects of inflation. The prevailing interest rate includes both a factor by which the money market is accounting for projected inflation and a factor which represents the "true" interest rate.

A discount rate of 10% has been assumed in this study. This is assumed to include:

- 6.5% for inflation
- 3.5% "true" interest rate

Hence, after correcting for inflation, the present-worth (1975) of one dollar in the year 2000 is assumed to be

$$W = 1.035^{-25} = 42\phi$$

Similarly, the present worth of one dollar in the year 2025 is 1.035^{-50} , or 18¢, and the present worth of one dollar in the year 2050 is 1.035^{-75} , or 8¢. This illustrates the impact of discounting, whereby benefits or costs far in the future have little effect upon present-worth.

In any cost-benefit analysis, the value to be used for the discount rate is a matter of question. Much higher discount rates than the (true) discount rate of 3.5% assumed here are often used. For instance, the President's Office of Management and Budget specifies a "true" discount rate of 10% (after correcting for inflation) in their Circular OMB A-94; this value is based upon typical private returns on investment after taxes. Also, there are some arguments that the "social" discount rate differs from the "monetary" discount rate.

If all costs escalate at the same rate, and if the discount rate is corrected for inflation as discussed above, then inflation becomes arbitrary. Whatever value is used for inflation, the present worth will be the same. A general inflation rate of 6.5% was used in this analysis. However, certain fuels are assumed to inflate at rates other than 6.5%.

The cost-benefit computer program has been arranged so that each cost element (capital, O&M, and fuel) for each candidate cycle can have its own inflation rate. This allows the flexibility of assuming that certain costs will escalate at rates higher or lower than the general inflation rate. To date, a special escalation treatment has been accorded only to fuels.

It should be noted that, throughout this cost-benefit analysis, all costs and benefits were taken at their instantaneous values. Levelized costs were not employed in this analysis, though identical results would be obtained if they were used and the model modified accordingly.

Assumptions

Following is the list of the major assumptions which underlie the deterministic cost-benefit model.

1. A given candidate cycle will be ready for commercial application at a time T_1 years from the present, at which time the first installation occurs. T_1 is generally different for each cycle, depending upon the amount of R&D required.
2. R&D costs are incurred at a constant yearly rate between the present and T_1 , beyond which time no further R&D costs are incurred. This assumption is not wholly realistic since actual R&D costs would taper off before T_1 but not cease after T_1 ; but, since R&D costs have a minor impact and since the two deviations from reality tend to cancel, this assumption is believed to be justified.
3. The newly developed cycle will displace a fraction, f_j , of all additions in each year from T_1 to T_2 . The fraction f_j depends upon the application mode (base load, midrange, peaking) and upon such factors as electrical characteristics, siting flexibility, and materials requirements; it is determined by OGP. In reality, the fraction of additions for a given cycle would not suddenly jump from 0 to f_j , nor would it suddenly drop to 0 after the last installation; but "rounding the shoulders" of the installation curve would have a minor impact.
4. At time T_2 from the present, every new cycle being considered will be superseded by some future technology. No installations of a new cycle would take place after T_2 , though units in place would continue to be used throughout their remaining lifetimes.
5. No new cycle is installed unless it is economically competitive, even though it may be developed.

6. The plant factor or capacity factor, F_j , is the same for all units of a new cycle in the "j"th year. It is determined by OGP.
7. All cycles have the same lifetime, L , as do all units based upon present technology.
8. Demand for electric energy grows at a predetermined rate, independent of any savings which may be produced by a new cycle.

Shown below is a sketch which illustrates the times T_1 , T_2 , and L .

Present Worth of Costs

On the "cost" side of the cost-benefit relation (Equation D-13) appears only one item: R&D costs. Expressions for the present worths of these costs are needed for the cost-benefit model.

By Assumption 2, it is presumed that the R&D costs are spread evenly over time period T_1 , starting from the present. Hence, the yearly R&D cost is $C_{R\&D}/T_1$, where $C_{R\&D}$ is the total cost of the R&D program. The present worth of the R&D costs is then obtained by integrating the expenditure rate, multiplied by the present-worth factor:

$$\begin{aligned}
 W_{R\&D} &= - \int_0^{T_1} \frac{C_{R\&D}}{T_1} (1+r)^{-t} dt \\
 &= - \frac{C_{R\&D}}{T_1} \frac{1}{\ln(1+r)} \left[1 - (1+r)^{-T_1} \right]
 \end{aligned}
 \tag{D-14}$$

where

$W_{R\&D}$ = present worth of R&D program (negative, since it is a cost)

$C_{R\&D}$ = total cost of R&D program

T_1 = time to first installation = end of R&D program

r = discount rate, per annum

Present Worth of Benefits (Savings)

Only one item appears as a benefit in Equation D-13: the savings which arise from installing a new cycle instead of a current cycle. By Assumption 5 above, the new cycle will be installed in a given year if those units would produce a positive saving but not otherwise. Hence, the savings which will be realized from units installed (or not installed) in year j are expressed by comparing the present worths of two scenarios, with and without a new cycle respectively.

Taking the present-worth of all costs of electricity from time of first installation (T_1) to time of last installation (T_2), there results for a scenario

$$W_{COE} = \int_{T_1}^{T_2} (1+r)^{-t} C_f(t) dt \quad (D-15)$$

The future worth of cost of electricity for units installed in year t , $C_f(t)$, cost elements: capital cost, fuel cost, and O&M cost:

$$\begin{aligned} C_f(t) &= \sum_k [C_{f(cap)k}(t) + C_{f(O\&M)k}(t) + C_{f(fuel)k}(t)] \\ &= \Delta C(t) \sum_k f_k(t) \{C_{cap,k}(t) \\ &\quad + \int_0^L [C_{FOM,k}(t+\tau) + C_{VOM,k}(t+\tau) F_k(t+\tau)] (1+r)^{-\tau} d\tau \\ &\quad + \int_0^L HR_k C_{fuel,k}(t+\tau) F_k(t+\tau) (1+r)^{-\tau} d\tau \} \end{aligned} \quad (D-16)$$

where

$\Delta C(t)$ = additions to energy generation capacity in year t , including additions to replace retired units

$f_k(t)$ = market penetration of "k"th cycle in year t

$F_k(t)$ = plant factor in year t of cycle k

- $C_{cap,k}(t)$ = capital costs (\$/kW) for units of cycle k installed in year t
 $C_{fuel,k}(t+\tau)$ = input fuel costs (mills/kWh heat) for units installed of cycle k in year t at τ years after installation
 $C_{O\&M,k}(t+\tau)$ = operating & maintenance costs (mills/kWh elec) for units of cycle k installed in year t at τ years after installation
 L = plant lifetime, years
 HR_k = heat rate (fuel in to electricity out) for cycle k

The present worth computer program uses numerical integration to evaluate these three equations, using a step of $h = 5$ years. Thus, all data are prepared in 5 year steps, starting with 1975. The two integrals in Equation D-16 are particularly easy to evaluate, since L is equal to 30 years and hence is an even multiple of h (5 years). Simpson's rule produces

$$\int_0^L f(\tau) d\tau \approx \frac{h}{3} [f(0) + 4 f(h) + 2 f(2h) + 4 f(3h) + 2 f(4h) + 4 f(5h) + f(6h)]$$

since $L/h = 30/5 = 6$.

However, the integral in Equation D-15 presents three aspects which must be taken into consideration:

1. The number of steps, $n = \text{INTEGER} [(T_2 - T_1)/h]$, may be an odd number, but Simpson's rule requires that n be even.
2. The lower limit of integration, T_1 , may not occur at a multiple of h from the present (that is, at 1980, 1985, 1990, etc.). Since the upper limit, T_2 , does occur at a multiple of h , this means that the integration interval is not a multiple of h — much less an even multiple.
3. The integrand contains $f(t)$, which is generally not differentiable. This means that the parabolic fit upon which Simpson's rule is based is poor.

The first difficulty, that n may be an odd integer, is taken into account by using ordinary Simpson's rule to compute

$$\int_0^{mh} f(t) dt \approx \frac{h}{3} [f(0) + 4 f(h) + 2 f(2h) + 4 f(3h) + \dots + 4 f((m-2)h) + 2 f((m-1)h) + f(mh)] \quad (D-17)$$

where m is the last even integer contained in n ($m = n$ if n is even, $m = n - 1$ if n is odd). Then, by fitting a parabola to the last three points and integrating, the following integral is added to the result from Equation D-17

$$\int_{(n-1)h}^{nh} f(t) dt \approx \frac{h}{12} [5 f((n-2)h) + 8 f((n-1)h) - f(nh)] \quad (D-18)$$

The second difficulty, that T_1 may not occur at a multiple of h , is taken into account by starting the integration of Equation D-17 at T_0 , where T_0 is defined as the first multiple of h which equals or exceeds T_1 . It is then necessary to add the integral from T_1 to T_0 . This is accomplished by fitting a parabola to the three points $f(-1)$, $f(0)$, $f(1)$, where $f(0)$ is defined as occurring at T_0 , as sketched.

Integrating this parabola from T_1 to T_0 produces the following result, which is to be added to the result from Equation D-17:

$$\begin{aligned} \int_{-(T_0 - T_1)}^0 f(t) dt &\approx \frac{(T_0 - T_1)^2}{12 h} [2(T_0 - T_1)/h + 3] f(-1) \\ &+ (T_0 - T_1) [1 - (T_0 - T_1)^2/(3h^2)] f(0) \\ &+ \frac{(T_0 - T_1)^2}{12 h} [2(T_0 - T_1)/h - 3] f(1) \end{aligned} \quad (D-19)$$

This procedure obtains $\int_{T_1}^{T_0} f(t) dt$, even though no data point is available at $f(T_1)$. However, all scenarios have been chosen so that they begin at the end of 1985; thus this second difficulty has been circumvented.

The third difficulty is that the integrand is not differentiable because it contains $f(t)$. Physically, economic conditions could change in such a way that installation of a new cycle did not provide a saving compared to the base cycle prior to a breakeven time t_{BE} , but will provide a saving after t_{BE} , or vice versa. Ordinary Simpson's rule fits a parabola to three consecutive data points; the fit would be poor if the function contains a point where it is not differentiable. This difficulty has been circumvented by averaging OGP outputs over periods about 10 years in length.

Generation Capacity for Electric Energy

The expression for cost of electricity, Equation D-15, consists of the present worth of all generation costs for a scenario. The costs in a particular year depend upon the number of installations in that year, as shown by the presence of $\Delta C(t)$ in Equation D-16, where $\Delta C(t)$ symbolizes the additions to electric energy generation capacity in year t (including additions to replace retired units). Hence, it is necessary to construct a representation of $\Delta C(t)$.

Begin with some representation of the electric energy generated year by year, denoted $E(t)$. Historically, $E(t)$ has been well fitted by an exponential or "doubling" curve:

$$E(t) = E_0 2^{t/t_D} \quad \text{for } t \leq 0 \quad (D-20)$$

where

- $E(t)$ = demand for electric energy in year t , MW-yr
- E_0 = electric energy generated in 1975 $\approx 216,000$ MW-yr
- t_D = doubling time prior to 1975 ≈ 11 yr
- t = time in years, referred to 1975 as $t = 0$

Electric generation capacity is installed in year t for two purposes: to meet the growth in demand at that time and to replace units retired at that time. The units retired in year t were installed L years previously, where L is the lifetime (assume same for all units), that is, they were installed in year $t-L$. But the units installed in year $t-L$ were likewise installed

both to meet the growth in demand in year $t-L$ and to replace units retired in year $t-L$, which had been installed in year $t-2L$. Thus, the addition of electric generation capacity in year t may be expressed by an infinite series:

$$\Delta C(t) \cong \dot{C}(t) + \sum_{j=1}^{\infty} \dot{C}(t-jL) = \sum_{j=0}^{\infty} \dot{C}(t-jL) \quad (D-21)$$

Growth Replacement

where

$$\dot{C}(t) = \frac{dC(t)}{dt} = \text{Rate of change of installed capacity}$$

The above model for $\dot{C}$ assumes that electricity has always been generated, though at a vanishingly small rate at times far in the past, when in reality generation was zero before the late nineteenth century. However, the departure from reality is trivial. For example, using E_0 and t_D as given below Equation D-20, the model gives the following generation:

<u>Year</u>	<u>MW-yr Generated</u>	
1975	216,000	
1950	44,699	
1925	9,250	
1900	1,914	
1875	396	} Trivial compared to 1975
1850	82	
1825	17	
1800	4	

First, consider $\dot{C}$ for times in and prior to 1975. Assume that capacity is proportional to energy generated. The sum of the derivatives of the exponential model is

$$\begin{aligned} \sum_{j=1}^{\infty} \dot{C}(t-jL) &= \sum_{j=1}^{\infty} \frac{d}{dt} \left[C_0 2^{(t-jL)/t_D} \right] \\ &= \sum_{j=1}^{\infty} \frac{C_0}{t_D} (\ln 2) 2^{-jL/t_D} 2^{t/t_D} \\ &= \frac{C_0}{t_D} (\ln 2) \frac{2^{-L/t_D}}{1-2^{-L/t_D}} 2^{t/t_D} \end{aligned} \quad (D-22)$$

where:

$$C_0 = \text{capacity at end of 1975} = 480 \text{ GW.}$$

This expression applies only to replacements installed when $t \leq L$ (that is, for installations in or before the year 2005); but by a change of index it may also be used for $\sum_{j=2}^{\infty} \dot{C}(t-L)$, as needed for units installed from 2005 to 2035.

Next, consider $\dot{C}$ for times after 1975. There is serious question whether the demand for electric energy will continue to double every 11 years; in fact, it has not in the two years subsequent to 1975. Thus, the model has the ability to change the doubling time in 1975 (actually, at any year between 1975 and 1985). For instance, the values used as reference cases are:

$$t_{D1} = \text{doubling time in and prior to 1975} = 11 \text{ years (6.5\% growth rate)}$$

$$t_{D2} = \text{doubling time after 1975} = 12.72 \text{ years (5.6\% growth rate)}$$

Note that doubling time t_D and growth rate g are related by the following expressions:

$$t_D = \frac{\ln 2}{\ln(1+g)} \quad (D-23a)$$

$$g = 2^{1/t_D} - 1 \quad (D-23b)$$

Combining equations D-21 and D-22 leads to the following expression for capacity additions between 1975 and 2005:

$$\begin{aligned} \dot{C}(t) = & \frac{C_0}{t_{D2}} (\ln 2) 2^{t/t_{D2}} \quad (\text{growth}) \\ & + \frac{C_0}{t_{D1}} (\ln 2) \frac{2^{-L/t_{D1}}}{1 - 2^{-L/t_{D1}}} 2^{t/t_{D1}}, \quad (\text{replacement}) \end{aligned} \quad (D-24)$$

$$0 < t < L - t_0$$

where t_0 is the number of years from growth rate change until 1985 (10 years if the change occurs in 1975). Since all scenarios start at the end of 1985, for convenience define $t=0$ at that time, and redefine:

$$C_0 = \text{capacity at end of 1985} = 827.7 \text{ GW}$$

For installations after 2005, equation D-24 must be modified to reflect the fact that units installed 30 years previously were installed when doubling time was t_{D2} instead of t_{D1} . After appropriate algebraic manipulation, this leads to

$$\dot{C}(t) = \frac{C_0}{t_{D2}} (\ln 2) (1 + 2^{-L/t_{D2}})^{t/t_{D2}} + \frac{C_0}{t_{D1}} (\ln 2) \frac{2^{-L/t_{D1}}}{1 - 2^{-L/t_{D1}}} 2^{(t-L)/t_{D1}}, \quad (D-25)$$

$L - t_0 < t < T_2$

The installed capacity for cycle k in year t may be obtained from the expressions for capacity addition rate (Equations D-24 and D-25) and from the market penetration fraction for cycle k (from OGP). All scenarios begin at the end of 1985 and run through the end of 2024, so $T_2 = 39$ years. All units have a lifetime of $L = 30$ years. Hence, units installed in 1986 and later are retired in 2016 and later, as sketched.

Accordingly,

$$C_k(t) = \begin{cases} \int_0^t \dot{C}(t) f_k(t) dt, & 0 < t < L \\ \int_0^t \dot{C}(t) f_k(t) dt - \int_0^{t-L} \dot{C}(t) f_k(t) dt, & L < t < T_2 \\ \int_0^{T_2} \dot{C}(t) f_k(t) dt - \int_0^{t-L} \dot{C}(t) f_k(t) dt, & T_2 < t < T_2 + L \\ 0, & \text{otherwise} \end{cases} \quad (D-26)$$

where $\dot{C}(t)$ is obtained from equation D-24 or D-25, as appropriate, and $f_k(t)$ is the market penetration fraction for cycle k in year t, from OGP.

Energy Generated by Scenario Units

If all numbers were precise, the capacity of cycle k units in year t obtained from Equation D-26 would satisfy the following relation:

$$\sum_k F_k(t) C_k(t) = E(t) \quad (D-27)$$

where

$F_k(t)$ = capacity factor for cycle k in year t , from OGP

$C_k(t)$ = installed capacity of cycle k in year t , from Eq. D-26

$E(t)$ = energy generated by scenario units in year t

However, Equation D-27 will never be satisfied precisely, primarily because of "noise" in OGP outputs of $F_k(t)$ and of market penetration $f_k(t)$, which enters into the calculation of $C_k(t)$. Thus, a correction is applied to $F_k(t)$ to make Equation D-27 true:

$$C_F(t) = \frac{E(t)}{\sum_k F_k(t) C_k(t)} \quad (D-28a)$$

$$\widehat{F}_k(t) = C_F(t) F_k(t) \quad (D-28b)$$

where $\widehat{F}_k(t)$ is the corrected value of $F_k(t)$, and $C_F(t)$ is the correction factor.

In order to compute the correction factor by Equation D-28a, it is necessary to know $E(t)$, the energy generated by scenario units. ("Scenario units" are defined as those units installed during the course of a scenario, from the end of 1985 through the end of 2024. They exclude pre-scenario units, namely those installed in and prior to 1985, and post-scenario units, namely those installed in and after 2025.)

Figure D-4 shows the energy generated by scenario units. Note that, from the end of 1985 through the end of 2015, energy is generated partly by pre-scenario units and partly by scenario units. From the end of 2015 through the end of 2024, all electric energy is generated by scenario units. From the end of 2024 through the end of 2054, energy is generated partly by scenario units and partly by post-scenario units. What is needed is an expression for the height of the shaded region.

The model for total electric energy generated has already been discussed: exponential growth with doubling time of 11 years prior to end of 1975; exponential growth with doubling time of

Figure D-4. Growth of Energy Demand

12.72 years after 1975. More generally, let the doubling time be t_{D1} prior to $1985-t_0$, and t_{D2} after $1985-t_0$ (note that $t_0=10$ years if the change in doubling time occurs at the end of 1975). Then the total electric energy generated is given by

$$E(t) = \begin{cases} E(-t_0) 2^{(t+t_0)/t_{D1}}, & t < -t_0 \\ E(-t_0) 2^{(t+t_0)/t_{D2}}, & t > -t_0 \end{cases}$$

where $t=0$ at the end of 1985 (when all scenarios begin). It is more convenient to refer energy to 1985 than to $1985-t_0$; note that

$$E(-t_0) = E_0 2^{-t_0/t_{D2}}$$

where

$$\begin{aligned} E_0 &= \text{energy generated at end of 1985} \\ &= E_{1975} \left(2^{(t_0-10)/t_{D1}} \right) \left(2^{t_0/t_{D2}} \right) \\ &= (216 \text{ Gw-yr/yr}) 2^0 2^{10/12.72} \\ &= 372.5 \text{ Gw-yr/yr} \end{aligned}$$

Combining the preceding expressions produces the following expression for total electric energy generated:

$$E(t) = \begin{cases} E_0 2^{(t_0/t_{D1} - t_0/t_{D2})} 2^{t/t_{D1}}, & t < -t_0 \\ E_0 2^{t/t_{D2}}, & t > -t_0 \end{cases} \quad (D-29)$$

This expression serves as the basis for determining the energy generated by scenario units, though it applies to all units. It must be manipulated for each of several time periods.

Period 1, $0 < t < L-t_0$. This period begins on 1 Jan 1986 and ends on 31 Dec 2005. Defining $E_s(t)$ as the energy generated by scenario units, it is obvious that

$$E_s(t) = \int_0^t \dot{E}_s(t) dt$$

But $\dot{E}_s(t)$, the rate of change of energy generation by scenario units, is comprised of energy growth rate plus replacement rate of pre-scenario units:

$$\dot{E}_s(t) = \dot{E}(t) + \sum_{j=1}^{\infty} \dot{E}(t - jL)$$

using the same reasoning as applied previously to Equation D-22. Inserting Equation D-29 produces

$$\begin{aligned} \dot{E}_s(t) &= \frac{E_0}{t_{D2}} (\ln 2) 2^{t/t_{D2}} + \sum_{j=1}^{\infty} \frac{E_0}{t_{D1}} (\ln 2) 2^{(t_0/t_{D1} - t_0/t_{D2})} 2^{(t-jL)/t_{D1}} \\ &= E_0 \ln 2 \left\{ \frac{2^{t/t_{D2}}}{t_{D2}} + \frac{2^{t/t_{D1}}}{t_{D1}} \frac{2^{-L/t_{D1}}}{1 - 2^{-L/t_{D1}}} 2^{(t_0/t_{D1} - t_0/t_{D2})} \right\} \end{aligned}$$

Then, integrating $\dot{E}_s(t)$ produces

$$\begin{aligned} E_s(t) &= \int_0^t \dot{E}_s(t) dt \\ &= E_0 \left\{ 2^{t/t_{D2}} - 1 + \frac{2^{t/t_{D1}} - 1}{\frac{L}{t_{D1}} - 1} 2^{(t_0/t_{D1} - t_0/t_{D2})} \right\} \quad (D-30) \end{aligned}$$

Period 2, $L-t_0 < t < L$. This period begins on 1 Jan 2006 and ends on 31 Dec 2015. It differs from Period 1 in that the units being replaced were installed after the change in doubling time, not before. Hence

$$\begin{aligned}
\dot{E}_s(t) &= \dot{E}(t) + \dot{E}(t-L) + \sum_{j=2}^{\infty} \dot{E}(t-jL) \\
&= \frac{E_0}{t_{D2}} (\ln 2)^2 2^{t/t_{D2}} + \frac{E_0}{t_{D2}} (\ln 2)^2 2^{(t-L)/t_{D2}} \\
&\quad + \sum_{j=2}^{\infty} \frac{E_0}{t_{D1}} (\ln 2)^2 2^{(t_0/t_{D1} - t_0/t_{D2})} 2^{(t-jL)/t_{D1}} \\
&= E_0 (\ln 2)^2 \left\{ \frac{2^{t/t_{D2}}}{t_{D2}} (1 + 2^{-L/t_{D2}}) \right. \\
&\quad \left. + \frac{2^{t/t_{D1}}}{t_{D1}} 2^{(t_0/t_{D1} - t_0/t_{D2})} \frac{2^{-2L/t_{D1}}}{1 - 2^{-L/t_{D1}}} \right\}
\end{aligned}$$

Then $E_s(t)$ is found by integration:

$$\begin{aligned}
E_s(t) &= E_s(L-t_0) + \int_{L-t_0}^t \dot{E}_s(t) dt \\
&= E_s(L-t_0) + E_0 \left\{ (1 + 2^{-L/t_{D2}}) (2^{t/t_{D2}} - 2^{(L-t_0)/t_{D2}}) \right. \\
&\quad \left. + \frac{2^{t/t_{D1}} - 2^{(L-t_0)/t_{D1}}}{L/t_{D1} - 1} 2^{-L/t_{D1}} 2^{(t_0/t_{D1} - t_0/t_{D2})} \right\} \quad (D-31)
\end{aligned}$$

where $E_s(L-t_0)$ is to be obtained from Equation D-30.

Period 3, $L < t < T_2$. This period begins on 1 Jan 2016 and ends on 31 Dec 2024. During this period, all energy is generated by scenario units. Hence

$$E_s(t) = E_0 2^{t/t_{D2}} \quad (D-32)$$

Period 4, $T_2 < t < 2L-t_0$. This period begins on 1 Jan 2025 and ends on 31 Dec 2035. During this period, part of the energy is generated by post-scenario units and part by scenario units. As in Periods 2 and 3, replacements during this period are the second replacement since change in doubling time. $E_s(t)$ is most readily found by subtracting energy for post-scenario units from total energy:

$$E_s(t) = E(t) - \int_{T_2}^t \dot{E}_{\text{post}}(t) dt$$

But $\dot{E}_{\text{post}}(t)$ during this period is just the same as $\dot{E}_s(t)$ during Period 2, since in both periods the replacements are the second replacement since change in doubling time. Thus

$$\begin{aligned}
 E_s(t) &= E(t) - \int_{T_2}^t E_0 \ln 2 \left\{ \frac{2^{t/t_{D2}}}{t_{D2}} (1 + 2^{-L/t_{D2}}) \right. \\
 &\quad \left. + \frac{2^{t/t_{D1}}}{t_{D1}} 2^{(t_0/t_{D1} - t_0/t_{D2})} \frac{2^{-2L/t_{D1}}}{1 - 2^{-L/t_{D1}}} \right\} \\
 &= E_0 \left\{ 2^{t/t_{D2}} - [(2^{t/t_{D2}} - 2^{T_2/t_{D2}})(1 + 2^{-L/t_{D2}}) \right. \\
 &\quad \left. + \frac{2^{t/t_{D1}} - 2^{T_2/t_{D1}}}{1 - 2^{-L/t_{D1}}} 2^{(t_0/t_{D1} - t_0/t_{D2})}] \right\} \quad (D-33)
 \end{aligned}$$

Period 5, $2L-t < t < T_2+L$. This period begins on 1 Jan 2036 and ends on 31 Dec 2054, when the last scenario unit is retired. As in Period 4, part of the electric energy is generated by post-scenario units and part by scenario units. Period 5 differs from Period 4 in that replacements during Period 5 are the third replacement since change in doubling time, instead of the second replacement. $E_s(t)$ can be found by subtracting energy for post-scenario units from total energy:

$$\begin{aligned}
 E_s(t) &= E(t) - E_{\text{post}}(t) \\
 &= E(t) - [E_{\text{post}}(2L-t_0) + \int_{2L-t_0}^t \dot{E}_{\text{post}}(t) dt]
 \end{aligned}$$

Since current replacements are the third replacement since doubling time changed from t_{D1} to t_{D2} , $E_{\text{post}}(t)$ is given by

$$\begin{aligned}
 \dot{E}_{\text{post}}(t) &= \dot{E}(t) + \dot{E}(t-L) + \dot{E}(t-2L) + \sum_{j=3}^{\infty} \dot{E}(t-jL) \\
 &= E_0 \ln 2 \left\{ \frac{2^{t/t_{D2}}}{t_{D2}} (1 + 2^{-L/t_{D2}} + 2^{-2L/t_{D2}}) \right. \\
 &\quad \left. + \frac{2^{t/t_{D1}}}{t_{D1}} 2^{(t_0/t_{D1} - t_0/t_{D2})} \frac{2^{-3L/t_{D1}}}{1 - 2^{-L/t_{D1}}} \right\}
 \end{aligned}$$

Also, $E_{\text{post}}(2L-t_0)$ is the difference between total energy generation at $2L-t_0$ and generation by scenario units at that time:

$$E_{\text{post}}(2L-t_0) = E_0 2^{(2L-t_0)/t_{D2}} - E_s(2L-t_0)$$

where $E_s(2L-t_0)$ is to be obtained from Equation D-33. Combining the above expressions leads to

$$\begin{aligned} E_s(t) = & E_s(2L-t_0) + E_0 \left\{ 2^{t/t_{D2}} - 2^{(2L-t_0)/t_{D2}} \right. \\ & - \left(2^{t/t_{D2}} - 2^{(2L-t_0)/t_{D2}} \right) (1 + 2^{-L/t_{D2}} + 2^{-2L/t_{D2}}) \\ & \left. - \left(2^{t/t_{D1}} - 2^{(2L-t_0)/t_{D1}} \right) \frac{2^{-3L/t_{D1}}}{1 - 2^{-L/t_{D1}}} 2^{(t_0/t_{D1} - t_0/t_{D2})} \right\} \quad (D-34) \end{aligned}$$

Accordingly, the energy generated by scenario units in year t , $E_s(t)$, can be found by selecting the proper period for year t and computing $E_s(t)$ from the corresponding equation (Eqs D-30 through D-34). Then $E_s(t)$ is used in Equation D-28a to compute the correction factor $C_F(t)$, which is applied to the OGP values for capacity factor $F_k(t)$ via Equation D-28b to yield the corrected capacity factors $\hat{F}_k(t)$.

However, the preceding analysis makes an implicit assumption: constant capacity factors for all units, whether they be pre-scenario units, scenario units, or post-scenario units. In fact, it is known that older units are dispatched less often, so their capacity factors decrease with time. Examination of OGP outputs shows that pre-scenario units have an average capacity factor of 0.45 in 1985 (when they are last installed), and that this drops to 0.40 in 2015 (when the last of them is retired). The decrease is approximately linear:

$$F_{\text{pre}} = 0.45 - 0.05 (t/30) = 0.45 - t/600, \quad 1985 \text{ thru } 2015$$

This means that more energy must be generated by scenario units during that period, in order to maintain the total constant. The increment to scenario-unit energy is

$$\Delta E_s(t) = -\Delta F_{\text{pre}}(t) C_{\text{pre}}(t)$$

but the installed capacity of pre-scenario units is

$$C_{\text{pre}}(t) = C(t) - C_s(t) \approx C_0 2^{t/t_{D2}} - \frac{C_0}{E_0} E_s(t)$$

Hence, the increment to $E_s(t)$ is

$$\Delta E_s(t) = \frac{t}{600} C_0 (2^{t/t_{D2}} - E_s(t)/E_0), \quad 0 < t < L \quad (D-35)$$

in the same units as $E_s(t)$, namely GW-yr/yr. This increment is to be added to the results from Equations D-30 and D-31 (it is zero for the periods covered by equations D-32 through D-34).

Taxes

Typical computations of cost of electricity include an annual fixed charge of 18% on capital cost. This 18% includes:

- interest
- repayment of capital over 30-year life
- insurance
- property and income taxes
- retirement dispersion

The annual payment for 10% interest (6 1/2% for inflation, 3 1/2% "true" interest) and 30-year life is

$$\frac{r}{1 - (1 + r)^{-L}} = \frac{0.10}{1 - 1.10^{-30}} = 10.6\%$$

Thus, insurance, taxes, and retirement dispersion account for $18 - 10.6 = 7.4\%$ of the annual charge. This means that C_{cap} should be multiplied by $18/10.6 = 1.70$ if taxes, insurance, and retirement dispersion are to be included in the analysis. However, taxes have not been included (except in sensitivity runs) because they represent a transfer payment from one segment of society (utilities, or ultimately their stockholders and all consumers of electricity via passthrough) to another (all recipients of benefits from governments), and these two segments have a large degree of commonality. But insurance should be included, as it represents the expected loss of capital equipment due to catastrophes. It has been assumed that insurance increases capital cost C_{cap} by 1%. This reduces the multiplier for insurance and taxes from 1.70 to 1.69 for taxes alone. C_{cap} is adjusted thusly:

$$C_{cap} = C'_{cap} (1 + k_{insur}) (1 + k_{retdisp}) k_{tax}$$

where

- k_{insur} = insurance adder = 0.01
- $k_{retdisp}$ = retirement dispersion adder = 0.0056
- k_{tax} = multiplier for taxes = 1 if taxes are omitted; 1.69 if taxes are considered

Source Listings of Net Present Worth Programs

Table D-19 is a listing of the time-sharing program "WORTH". This program reads the data files listed in Tables D-23 through D-26. Its output is written into a file whose name is specified by the user at execution; the output file can subsequently be listed at the time-sharing terminal or at a line printer.

This program is written in the Algol language, mainly for two reasons: first, because of the capability of Algol for both string manipulation and handling of arithmetic expressions; and second, because the block structure of Algol is particularly amenable to the extensive logic required in this program. Extensive comment statements are included, so that the program is self-documenting.

Upon running the program, the user will be asked the following questions at the terminal:

- FILENAME CONTAINING OGP OUTPUTS? The response should be one of the data files for OGP outputs of a scenario, as listed in Table D-23 or Table D-24. Note: it is necessary to run the No New Technology Scenario (data file SCEN-NNT) before running any other scenario, as it creates a reference file against which savings are computed for other scenarios.
- OUTPUT FILENAME? Name of file under which output will be stored.
- YEARS BETWEEN OUTPUT STEPS? The program makes calculations on an annual basis internally, but the output is printed only in the step specified by the user. If the answer is "1" then output will appear for every year, but the output file will be lengthy. A typical answer is "5".
- ADJUST FOR INTANGIBLES (T OR F)? If the answer is "T" (True) then the program will adjust market penetration for intangibles. If the answer is "F" (False) then these adjustments will be omitted, and the market penetrations will be same as in the OGP output.
- CONSIDER TAXES (T OR F)? If the answer is "T" then capital costs will be increased by a factor of 1.69, leading to the 18% fixed-charge rate which is based upon consideration of income and property taxes. If the answer is "F" then this multiplier is 1, so that taxes are not considered.

When all calculations have been made and the output file is complete, the word "FINISHED" will be printed at the terminal.

Table D-19

NET PRESENT WORTH PROGRAM — TIME SHARING VERSION

J.J.FLECK1/CYCLES3/WORTH

09/10/77

12:08 PM

```

00010 OPTION SBUF=2;
00020 BEGIN
00030 COMMENT... "WORTH"
00040     THIS PROGRAM CALCULATES THE 1985 WORTH OF ALL COSTS
00050     ASSOCIATED WITH R&D AND ELECTRICITY GENERATION , BASED
00060     UPON MARKET PENETRATION AND CAPACITY FACTORS FROM "OGP".
00070     '
00080     JOEL J FLECK
00090     8 JUNE 1977     REVISED 7 SEP 1977
00100     ;
00110 REAL TD1, TD2, GROWTH1, GROWTH2, ENERGY0, CAPY0,
00120     FTAX, FINSUR, FRETDISP, R,
00130     WGENTOT, WRDTOT, WNETTOT, WSAV;
00140 INTEGER LIFE, T2, T0, I, J, K, NPERIOD, OUTSTEP, NSTEPS1, NSTEPS2;
00150 STRING SCENARIO, SCENFILE, OUTFILE, OUTFILE1, HEADFMT, HEADFMT0,
00160     CYCLESFMT;
00170 BOOLEAN NONEW, INTANG, TAXES;
00180 REAL ARRAY MKTPEN, CAPFAC[1:9, 1:5], MP[1:9, 1:39], CF[1:9, 1:69],
00190     !MARKET PENETRATION & CAPACITY FACTOR AT <<<MIDYEAR>>>!
00200     CRD, ERD, T1, CCAPO, ECAP, CFOMO, EFOM, CVOMO, EVOM, CFUELO,
00210     EFUEL, HR[1:9], EOIL[1:3], JOIL[1:2],
00220     !CYCLE DATA ON COSTS, ESC RATES, T1, HEAT RATE!
00230     DELTAC[0:39], CAPY[1:10, 0:69],
00240     !CAPACITY GROWTH RATE & CAPACITY AT <<<YEAREND>>>!
00250     CCAPI[1:9, 0:39], CFOM, CVOM, CFUEL[1:9, 0:69],
00260     !COSTS FOR CAP, VAR O&M, FIXED O&M, & FUEL AT <<<YEAREND>>>!
00270     WGEN, WNET, WRD[1:9];
00280     !1975 WORTHS OF GENERATION, R&D, & NET COSTS PER CYCLE!
00290 INTEGER ARRAY PEREND[1:5], JYEAR[0:69, 1:2];
00300 STRING ARRAY CYCLE[1:9], EC[1:9, 1:26];
00310     '
00320 PROCEDURE WRITEHEAD(FILE,FMT); VALUE FILE,FMT; STRING FILE,FMT;
00330 COMMENT... WRITES PAGE HEADINGS;
00340     BEGIN
00350     WRITE (FILE, FMT);
00360     WRITE (FILE, CYCLESFMT, CYCLE)
00370     END PROCEDURE WRITEHEAD;
00380     '
00390 COMMENT... SET CONSTANTS;
00400     BEGIN
00410     LIFE := 30;                !LIFETIME OF EVERY CYCLE, YEARS!
00420     ENERGY0 := 216000;        !1975 ELEC ENERGY GENERATION, MW-YR!
00430     CAPY0 := 480000;          !1975 CAPACITY, MW!
00440     T2 := 39;                 !YEARS FROM 1985 TO LAST INSTALLATION!
00450     T0 := 10;                 !YRS FROM GROWTH CHANGE (1975) TO 1985!
00460     GROWTH1 := .065;           !ELEC ENERGY GROWTH RATE THRU 1975!
00470     GROWTH2 := .056;           !ELEC ENERGY GROWTH RATE 1976 & AFTER!
00480     TD1 := LOG(2) / LOG(1 + GROWTH1); !DOUBLING TIME!
00490     TD2 := LOG(2) / LOG(1 + GROWTH2); !DOUBLING TIME!

```

Table D-19 (Cont'd)

```

00500 I:=1; FOR EOIL(I) := .085, .095, .105 DO I:=I+1;
00510                                     !ESCALATION RATES FOR OIL!
00520 I:=1; FOR JOIL(I) := 5, 15 DO I:=I+1;
00530                                     !YRS FROM 1985 WHEN OIL ESC CHANGES!
00540 FTAX := 0.69;                       !0.69 IF TAXES ARE CONSIDERED, 0 IF NOT!
00550 FINSUR := .01;                      !INSURANCE MULTIPLIER ON CAPITAL COSTS!
00560 FRETDISP := .0056;                  !RETIRMENT DISPERSION MULT ON CAP COSTS!
00570 R := 0.10;                         !DISCOUNT RATE!
00580 END;
00590 '
00600 COMMENT... READ MARKET PENETRATION AND CAPACITY FACTOR FROM OGP
00610 FOR THIS SCENARIO;
00620 BEGIN
00630 PRINTF ("("OFIENAME CONTAINING OGP OUTPUTS")");
00640 INPUTF ("(A)", SCNFILE);
00650 OPENSFR (SCNFILE, "", "/CYCLES3/OGP-OUT/"*SCNFILE*",R");
00660 READ (SCNFILE, "(A)", SCNERROR, SCENARIO);
00670 READ (SCNFILE, "(V)", SCNERROR, NPERIOD);
00680 COMMENT... READ YEARS IN WHICH PERIODS END;
00690 BEGIN
00700 INTEGER ARRAY DATA(1:NPERIOD);
00710 READ (SCNFILE, "(9X,*INTSTR(NPERIOD)*"V)", SCNERROR, DATA);
00720 FOR J:=1 STEP 1 UNTIL NPERIOD DO PEREND(J) := DATA(J) - 1985;
00730 END;
00740 COMMENT... READ MARKET PENETRATIONS AND CAPACITY FACTORS;
00750 FOR K:=1 STEP 1 UNTIL 9 DO
00760 BEGIN
00770 REAL ARRAY DATA(1:2*NPERIOD);
00780 READ (SCNFILE, "(8X,*INTSTR(2*NPERIOD)*"V)", SCNERROR, DATA);
00790 FOR J:=1 STEP 1 UNTIL NPERIOD DO
00800 BEGIN
00810 MKTPEN(K,J) := DATA(2*J-1);
00820 CAPFAC(K,J) := DATA(2*J)
00830 END J
00840 END K;
00850 GOTO ENDSCEN;
00860 '
00870 *** SCNERROR: ***
00880 BEGIN
00890 PRINTF ("("OFIENAME", A, "", FATAL ERROR:""/
00900 6X, ""INSUFFICIENT DATA..."")",
00910 SCNFILE);
00920 GOTO LAST
00930 END;
00940 '
00950 *** ENDSCEN:; ***
00960 END READING OGP OUTPUT FILE;
00970 '
00980 COMMENT... READ DATA FILES FOR ALL 9 CYCLES;
00990 BEGIN
01000 BOOLEAN DATAERROR;
01010 DATAERROR := FALSE;

```

Table D-19 (Cont'd)

```

01020   FOR K:=1 STEP 1 UNTIL 9 DO
01030       BEGIN
01040           INTEGER I, LN;
01050           STRING CRITFILE, COSTFILE, DUMMY;
01060           '
01070           COMMENT... READ CRITERIA FILE FOR CYCLE K;
01080           CRITFILE := "CRIT" * INTSTR(K);
01090           OPENSHP (CRITFILE, "", "/CYCLES3/CRITERIA/"*CRITFILE*",R");
01100           READ (CRITFILE, "(A)", CRITERIOR, DUMMY);
01110           FOR I:=1 STEP 1 UNTIL 26 DO  !I = CRITERION NUMBER!
01120               BEGIN
01130                   READ (CRITFILE, "(I2, 1X, A1)", CRITERIOR, LN, EC[K,I]);
01140                   IF LN/=I THEN
01150                       BEGIN
01160                           PRINTF ("("OFILE "", A, "", FATAL ERROR:""/
01170                               6X, ""LINE "", A, "" IS NUMBERED "", A)",
01180                               CRITFILE, INTSTR(I), LN);
01190                           DATAERROR := TRUE
01200                       END;
01210                   IF EC[K,I]/="G" AND EC[K,I]/="F" AND EC[K,I]/="P" THEN
01220                       BEGIN
01230                           PRINTF ("("OFILE "", A, "", FATAL ERROR:""/
01240                               6X, ""LINE "", A, "" HAS ILLEGAL DATUM "",
01250                               1H"", A, 1H"""),
01260                               CRITFILE, INTSTR(I), EC[K,I]);
01270                           DATAERROR := TRUE
01280                       END
01290                   END I;
01300           CLOSE (CRITFILE);
01310           GOTO READCOST;
01320           '
01330           '... CRITERIOR: ...'
01340           BEGIN
01350               PRINTF ("("OFILE "", A, "", FATAL ERROR:""/
01360                   6X, ""TOO SHORT; ONLY "", A, "" LINES..."")",
01370                   CRITFILE, INTSTR(I-1));
01380               CLOSE (CRITFILE);
01390               DATAERROR := TRUE
01400           END;
01410           '
01420           '... READCOST:; ...'
01430           COMMENT... READ COST-DATA FILE FOR CYCLE K;
01440           COSTFILE := "COST" * INTSTR(K);
01450           OPENSHP (COSTFILE, "", "/CYCLES3/COSTDATA/"*COSTFILE*",R");
01460           READ (COSTFILE, "(A)", COSTERROR, CYCLE[K]);
01470           READ (COSTFILE, "(A3, 3V)", COSTERROR, DUMMY, CRD[K], ERD[K],
01480               T1[K]);
01490           READ (COSTFILE, "(A3, 2V)", COSTERROR, DUMMY, CCAPO[K],
01500               ECAPI[K]);
01510           READ (COSTFILE, "(A3, 2V)", COSTERROR, DUMMY, CFOMO[K],
01520               EFOM[K]);
01530           READ (COSTFILE, "(A3, 2V)", COSTERROR, DUMMY, CVOMO[K],

```


Table D-19 (Cont'd)

```

01540      EVOM(K));
01550      READ (COSTFILE, "(A4, 2V)", COSTERROR, DUMMY, CFUEL0(K),
01560      EFUEL(K));
01570      READ (COSTFILE, "(A2, 1V)", COSTERROR, DUMMY, HR(K));
01580      CLOSE (COSTFILE);
01590      GOTO ENDK;
01600      '
01610      '*** COSTERROR: ***'
01620      BEGIN
01630      PRINTF ("("OFILE ", A, ", ", FATAL ERROR:""/
01640      6X, "INSUFFICIENT DATA..."")",
01650      COSTFILE);
01660      CLOSE (COSTFILE);
01670      DATAERROR := TRUE
01680      END;
01690      '
01700      '*** ENDK: ***'
01710      END K;
01720      '
01730      IF DATAERROR THEN
01740      BEGIN
01750      PRINTF ("("OPROGRAM ABORTED DUE TO ERRORS IN DATA..."")");
01760      GOTO LAST
01770      END
01780      END READING DATA FILES FOR CYCLES;
01790      '
01800      COMMENT... OPEN OUTPUT FILE, SET UP OUTPUT PRINTING STEPS, AND
01810      CREATE HEADING FORMATS;
01820      BEGIN
01830      INTEGER LSCEN, INDENT;
01840      INTEGER ARRAY LCYCLE(1:18);
01850      '
01860      PRINTF ("("OOUTPUT FILENAME"")");
01870      INPUTF ("(A)", OUTFILE);
01880      OPENT (OUTFILE, "", "/CYCLES3/OUTPUT/"*OUTFILE);
01890      ENDFILE (OUTFILE);
01900      '
01910      COMMENT... SETUP FOR OUTPUTS;
01920      PRINTF ("("OYEARS BETWEEN OUTPUT STEPS"")");
01930      INPUT (OUTSTEP);
01940      NSTEPS1 := T2%OUTSTEP + (IF MOD(T2,OUTSTEP)>0 THEN 1 ELSE 0);
01950      !NR. OUTPUT STEPS FROM TO TO T2!
01960      NSTEPS2 := (T2+LIFE)%OUTSTEP + (IF MOD(T2+LIFE,OUTSTEP)>0
01970      THEN 1 ELSE 0); !NR. OUTPUT STEPS FROM TO TO T2+LIFE!
01980      FOR J:=0 STEP 1 UNTIL NSTEPS2 DO
01990      JYEAR(J,1) := JYEAR(J,2) := J*OUTSTEP;
02000      JYEAR(NSTEPS1,1) := T2;
02010      JYEAR(NSTEPS2,2) := T2+LIFE;
02020      !JYEAR = YEARS FROM TO TO "J"TH OUTPUT STEP!
02030      '
02040      COMMENT... CREATE HEADING FORMATS;
02050      HEADFMTO := "(1H1, 52X, "SCENARIO-INDEPENDENT QUANTITIES"/

```

Table D-19 (Cont'd)

```

02060      53X, 31(1H*))"; !PAGE HEADING FMT FOR SCEN-IND OUTPUTS!
02070      LSCEN := LENGTH (SCENARIO);
02080      INDENT := 67 - LSCEN/2;
02090      FOR K:=1 STEP 1 UNTIL 9 DO
02100          BEGIN
02110              LCYCLE[2*K] := LENGTH (CYCLE[K]);
02120              LCYCLE[2*K - 1] := 10 - LCYCLE[2*K]
02130          END;
02140      ENCODES (HEADFMT, !PAGE HEADING FMT FOR SCEN-DEP OUTPUTS!
02150          "(" (1H1,"", I2, "X,"", I2, "H", A, ""/"",
02160              I2, "X,"", I2, "(1H*))"""),
02170          INDENT-1, LSCEN, SCENARIO, INDENT, LSCEN);
02180      ENCODES (CYCLESFMT, !COLUMN TITLES FMT (CYCLE ACRONYMS)!
02190          "(" (1H0/ 26X"", 9("","", I2, "X, A"", I2), ""/"",
02200              ""26X"", 9("","", I2, "X,"", I2, "(1H-)"", ""))"""),
02210          LCYCLE, LCYCLE);
02220      END;
02230      *
02240      COMMENT... ADJUST R&D COST FOR PROBABILITY OF DEVELOPMENT SUCCESS.
02250      WRITE UNADJUSTED AND ADJUSTED VALUES IF "NNT" SCENARIO;
02260      BEGIN
02270          *
02280          COMMENT... PRINT HEADING FOR SCENARIO-INDEPENDENT QUANTITIES,
02290              BUT ONLY IF "NO NEW TECHNOLOGY" SCENARIO;
02300          NONEW := SEARCH (SCENARIO, "NO NEW", 1, 1) > 0;
02310          IF NONEW THEN WRITEHEAD (OUTFILE, HEADFMT0);
02320          *
02330          COMMENT... ADJUST R&D COSTS AND WRITE RESULTS;
02340          IF NONEW THEN WRITE (OUTFILE, "(2X/ 6X, "R&D COST (M$):""/
02350              9X, "BEFORE ADJUSTMENT"", 9F10.1)", CRD);
02360          FOR K:=7 STEP 1 UNTIL 9 DO
02370              CRD[K] := CRD[K] * (2 - (IF EC[K,3]="G" THEN 0.95
02380                  ELSE IF EC[K,3]="F" THEN 0.80 ELSE !EC="P"! 0.65));
02390          IF NONEW THEN WRITE (OUTFILE, "(9X, "AFTER ADJUSTMENT "",
02400              9F10.1)", CRD);
02410          *
02420          COMMENT... SET R&D COST TO ZERO FOR CYCLES NOT IN SCENARIO;
02430          IF SEARCH(SCENFILE,"NNT",1,1)>0 THEN CRD[7]:=CRD[8]:=CRD[9]:=0;
02440          IF SEARCH(SCENFILE,"AFB",1,1)>0 THEN CRD[8] := CRD[9] := 0;
02450          IF SEARCH(SCENFILE,"CC",1,1)>0 THEN CRD[7] := CRD[9] := 0;
02460          IF SEARCH(SCENFILE,"MHD",1,1)>0 THEN CRD[7] := CRD[8] := 0
02470          END;
02480          *
02490          COMMENT... ADJUST MARKET PENETRATION FOR INTANGIBLES;
02500          BEGIN
02510              REAL ARRAY P[4:26, 1:3], FM[1:9], CF[1:NPERIOD],
02520                  MPOUT[0:10, 1:NSTEPS1];
02530              *
02540              PRINTF ("("OADJUST FOR INTANGIBLES? (T OR F)""");
02550              INPUT (INTANG);
02560              *
02570              COMMENT... SET VALUES FOR P MULTIPLIERS;

```

Table D-19 (Cont'd)

```

02580 IF INTANG THEN
02590 BEGIN
02600 FOR I:=4 STEP 1 UNTIL 26 DO P[I,1] := 1; !"G"!
02610 I:=4; FOR P[I,2] := .88, .99, .92, .97, .96, .99, .99,
02620 .93, .95, .99, .99, .95, .93, .90, .99, .94, .96,
02630 .97, .95, .99, .96, .92, .98 DO I := I+1; !"F"!
02640 FOR I:=4 STEP 1 UNTIL 26 DO
02650 P[I,3] := IF I=13 OR I=15 OR I=24 OR I=25 THEN 0.50
02660 ELSE 1 - 2*(1 - P[I,2]) !"P"!
02670 END;
02680 ,
02690 COMMENT... CALCULATE THE MULTIPLIER FOR INTANGIBLES, FM(K);
02700 FOR K:=1 STEP 1 UNTIL 9 DO
02710 IF INTANG THEN
02720 BEGIN
02730 REAL PMIN, PKI;
02740 ,
02750 FM(K) := PMIN := 1; !INITIALIZE!
02760 FOR I:=4 STEP 1 UNTIL 26 DO
02770 BEGIN
02780 PKI := P[I, IF EC(K,I)="G" THEN 1 ELSE IF EC(K,I)="F"
02790 THEN 2 ELSE !EC="P"! 3];
02800 FM(K) := FM(K) * PKI;
02810 PMIN := IF PKI<PMIN THEN PKI ELSE PMIN
02820 END I;
02830 FM(K) := SORT (PMIN * FM(K))
02840 END INTANG=TRUE
02850 ELSE
02860 FM(K) := 1; !INTANG=FALSE!
02870 ,
02880 COMMENT... WRITE MARKET PENETRATION MULTIPLIERS.
02890 (IF THIS IS THE "NNT" SCENARIO, WRITE SCENARIO-DEPENDENT
02900 QUANTITIES ON A SCRATCH FILE UNTIL ALL SCENARIO-INDEPENDENT
02910 QUANTITIES HAVE BEEN WRITTEN ON THE OUTPUT FILE. OTHER-
02920 WISE, WRITE ALL SCEN-DEP QUANTITIES ON THE OUTPUT FILE.);
02930 IF NONEW THEN OPENS("SCRFILE");
02940 OUTFILE1 := IF NONEW THEN "SCRFILE" ELSE OUTFILE;
02950 COMMENT... WRITE HEADING FOR SCENARIO-DEPENDENT QUANTITIES;
02960 WRITEHEAD (OUTFILE1, HEADFMT);
02970 WRITE (OUTFILE1, "(2X/ 6X, "MARKET PEN MULT.", 4X, 9F10.4, 7X,
02980 5HNORM.)", FM);
02990 ,
03000 COMMENT... CALCULATE THE NORMALIZATION FACTOR CF(J);
03010 FOR J:=1 STEP 1 UNTIL NPERIOD DO
03020 BEGIN
03030 CF(J) := 0; !INITIALIZATION!
03040 FOR K:=1 STEP 1 UNTIL 9 DO
03050 CF(J) := FM(K) * MKTPEN(K,J) + CF(J);
03060 CF(J) := IF CF(J)=0 THEN 1 ELSE 1/CF(J)
03070 END J;
03080 ,
03090 COMMENT... CALCULATE ADJUSTED MKT PEN, EACH CYCLE IN EACH YEAR;

```

Table D-19 (Cont'd)

```

03100   FOR K:=1 STEP 1 UNTIL 9 DO
03110   FOR J:=1 STEP 1 UNTIL T2 DO
03120       BEGIN
03130           INTEGER JJ;    !JJ = PERIOD NUMBER IN WHICH YEAR J OCCURS!
03140           JJ := 0;  FOR JJ := JJ+1 WHILE J>PEREND[JJ] DO;
03150               MP[K,J] := FM[K] * CF[JJ] * MKTPEN[K,JJ];
03160               IF MOD(J,OUTSTEP)=0 OR J=T2 THEN MPOUT[10,
03170                   IF J<T2 THEN J%OUTSTEP ELSE NSTEPS1] := CF[JJ]
03180                   !STORE NORM. FACTOR CC FOR PRINTING!
03190       END;
03200   ,
03210   COMMENT... WRITE ADJUSTED MARKET PENETRATIONS;
03220   FOR K:=0 STEP 1 UNTIL 9 DO
03230   FOR J:=1 STEP 1 UNTIL NSTEPS1 DO
03240       MPOUT[K,J] := IF K=0 THEN 1985 + JYEAR[J,1]
03250           ELSE MP[K, JYEAR[J,1]];
03260   WRITE (OUTFILE1, "(6X, ""ADJUSTED MKT PEN:"", 99X, 6HFACTOR/
03270       (9X, I4, 13X, 9F10.4, F12.4/))", MPOUT)
03280   END;
03290   ,
03300   COMMENT... ADJUST CAPITAL COST FOR TAXES, INSURANCE, AND
03310   RETIREMENT DISPERSION;
03320       BEGIN
03330       ,
03340       PRINTF ("("OCONSIDER TAXES? (T OR F)""");
03350       INPUT (TAXES);
03360       FTAX := IF TAXES THEN FTAX ELSE 0;
03370       ,
03380       IF NONEW THEN WRITE (OUTFILE,
03390           "(2X/ 6X, ""1975 CAPITAL COST ($/KW):""/
03400           9X, ""BASE VALUE"", 7X, 9F10.1)", CCAPO);
03410       FOR K:=1 STEP 1 UNTIL 9 DO
03420           CCAPO[K] := CCAPO[K] * (1+FTAX) * (1+FINSUR) * (1+FRETDISP);
03430       IF NONEW THEN WRITE (OUTFILE,
03440           "(9X, ""WITH TAXES, ETC.""", 1X, 9F10.1)", CCAPO)
03450       END;
03460       ,
03470   COMMENT... WRITE HEAT RATES, IF "NNT" SCENARIO;
03480       IF NONEW THEN WRITE (OUTFILE,
03490           "(2X/ 6X, ""HEAT RATE (BTU/KWHR):"", I9, 8I10)", HR);
03500       ,
03510   COMMENT... ESCALATE ALL QUANTITIES FROM 1975 TO 1985;
03520       BEGIN
03522       REAL GROWTH;
03524       GROWTH := (1+GROWTH1)(T0-10) * (1+GROWTH2)T0;
03530       ENERGY0 := ENERGY0 * GROWTH;
03540       CAPY0 := CAPY0 * GROWTH;
03550       FOR K:=1 STEP 1 UNTIL 9 DO
03560           BEGIN
03570               CCAPO[K] := CCAPO[K] * (1+ECAP[K])10;
03580               CFOM0[K] := CFOM0[K] * (1+EFOM[K])10;
03590               CVOM0[K] := CVOM0[K] * (1+EVOM[K])10;

```

Table D-19 (Cont'd)

```

03600      CFUELO(K) := CFUELO(K) * (1 +
03610          (IF EFUEL(K)>=0 THEN EFUEL(K) ELSE EOIL(1)))^10
03620      END K
03630  END
03640 *
03650 COMMENT... CALCULATE CAPACITY ADDITION RATE DELTAC (MW/YR);
03660 BEGIN
03670 REAL C1, C2;
03680 C1 := CAPY0 * LN(2)/TD2;
03690 C2 := CAPY0 * LN(2)/TD1 * 2^(-LIFE/TD1) / (1 - 2^(-LIFE/TD1));
03700 FOR J:=0 STEP 1 UNTIL LIFE-T0 DO
03710   DELTAC(J) := C1 * 2^(J/TD2) + C2 * 2^(J/TD1);
03720   C1 := C1 * (1 + 2^(-LIFE/TD2));
03730   C2 := C2 * 2^(-LIFE/TD1);
03740   FOR J:=LIFE-T0+1 STEP 1 UNTIL T2 DO
03750     DELTAC(J) := C1 * 2^(J/TD2) + C2 * 2^(J/TD1)
03760   END;
03770 *
03780 COMMENT... CALCULATE INSTALLED CAPACITY FOR EACH CYCLE (ONLY
03790 THOSE UNITS INSTALLED BETWEEN JAN 1986 AND DEC 1986+T2);
03800 BEGIN
03810 REAL ARRAY DELTACOUT(0:10, 1:NSTEPS1), CAPYOUT(0:10, 0:NSTEPS2);
03820 REAL PROCEDURE AVADDEDCAPY(J); VALUE J; INTEGER J;
03830   AVADDEDCAPY := 0.5 * (DELTAC(J-1) + DELTAC(J)) *
03840   (IF K<10 THEN MPI(K,J) ELSE 1);
03850 *
03860 FOR K:=1 STEP 1 UNTIL 10 DO
03870   FOR J:=0 STEP 1 UNTIL T2+LIFE DO
03880     CAPY(K,J) := (IF J=0 THEN 0 ELSE CAPY(K,J-1))
03890     + (IF J>0 & J<=T2 THEN AVADDEDCAPY(J) ELSE 0)
03900     - (IF J>LIFE THEN AVADDEDCAPY(J-LIFE) ELSE 0);
03910 *
03920 COMMENT... WRITE RESULTS;
03930 FOR K:=0 STEP 1 UNTIL 10 DO
03940   FOR J:=0 STEP 1 UNTIL NSTEPS2 DO
03950     BEGIN
03960       IF J>0 AND J<=NSTEPS1 THEN
03970         DELTACOUT(K,J) := IF K=0 THEN 1985 + JYEAR(J,1)
03980         ELSE DELTAC(JYEAR(J,1))*(IF K<10 THEN MPI(K, JYEAR(J,1))
03990         ELSE 1);
04000       CAPYOUT(K,J) := IF K=0 THEN 1985 + JYEAR(J,2)
04010       ELSE CAPY(K, JYEAR(J,2))
04020     END K & J;
04030   IF OUTSTEP<5 THEN WRITEHEAD (OUTFILE1, HEADFMT);
04040   WRITE (OUTFILE1, "(2X/ 6X, ""CAPY ADDN RATE (GW/YR):"", 94X,
04050     5HTOTAL/
04060     9X, 4H1985, -3PF115.1/
04070     (9X, 0PI4, 13X, -3P9F10.1, F12.1/))", DELTAC(0), DELTACOUT);
04080   IF OUTSTEP<5 THEN WRITEHEAD (OUTFILE1, HEADFMT);
04090   WRITE (OUTFILE1, "(2X/ 6X, ""INSTALLED CAPY (GW):"", 97X,
04100     5HTOTAL/
04110     (9X, 0PI4, 13X, -3P9F10.1, F12.1/))", CAPYOUT)

```

Table D-19 (Cont'd)

```

04120     END;
04130
04140 COMMENT... ADJUST CAPACITY FACTOR "CAPFAC" SO THAT PROPER TOTAL
04150 ENERGY IS GENERATED IN EACH YEAR;
04160     BEGIN
04170     REAL ARRAY CFOUT, ENERGYOUT(0:10, 1:NSTEPS2), CC(1:69);
04180     FOR J:=1 STEP 1 UNTIL T2+LIFE DO
04190         BEGIN
04200             REAL ENEWAV, E1, E2, KTO;
04210             REAL ARRAY ENEW(0: 2*(T2+LIFE));
04220             INTEGER J2, JJ;
04230             '
04240             COMMENT... ENEW[J2] = ENERGY GENERATED BY "NEW" UNITS AT
04250                 J2/2 YEARS AFTER END OF 1985;
04260             IF J=1 THEN KTO := 2^(T0/TD1 - T0/TD2);
04270             FOR J2 := (IF J=1 THEN 0 ELSE 2*J-1) STEP 1 UNTIL 2*J DO
04280                 BEGIN
04290                     REAL T;
04300                     T := J2/2;
04310                     ENEW[J2] := ENERGY0 * (
04320                         IF J<=LIFE-T0 THEN
04330                             2^(T/TD2) - 1 + KTO*(2^(T/TD1) - 1)/
04340                             (2^(LIFE/TD1) - 1)
04350                         ELSE IF J<LIFE THEN
04360                             E1 + (2^(T/TD2) - 2^((LIFE-T0)/TD2))
04370                             *(2^(-LIFE/TD2) + 1)
04380                             + KTO*(2^(T/TD1) - 2^((LIFE-T0)/TD1))
04390                             /((2^(LIFE/TD1) - 1)*2^(-LIFE/TD1))
04400                         ELSE IF J<=T2 THEN 2^(T/TD2)
04410                         ELSE IF J<=(2*LIFE - T0) THEN
04420                             2^(T/TD2) - (2^(T/TD2) - 2^(T2/TD2))
04430                             *(2^(-LIFE/TD2) + 1)
04440                             - KTO*(2^(T/TD1) - 2^(T2/TD1))/(1 - 2^(-LIFE/TD1))
04450                             *2^(-2*LIFE/TD1)
04460                         ELSE !J<=T2+LIFE!
04470                             2^(T/TD2) - E2 - (2^(T/TD2) - 2^((2*LIFE-T0)/TD2))
04480                             *(1 + 2^(-LIFE/TD2) + 2^(-2*LIFE/TD2))
04490                             - KTO*(2^(T/TD1) - 2^((2*LIFE-T0)/TD1))
04500                             *2^(-3*LIFE/TD1) / (1 - 2^(-LIFE/TD1)) );
04510                     IF J=LIFE-T0 THEN E1 := ENEW[J2]/ENERGY0;
04520                     IF J=2*LIFE-T0 THEN E2 := 2^(T/TD2) - ENEW[J2]/ENERGY0;
04530                     '
04540                     COMMENT... CORRECT ENEW[J2] FOR DROP IN CAPFAC OF UNITS
04550                         INSTALLED BEFORE 1986;
04560                     IF J<LIFE THEN
04570                         ENEW[J2] := ENEW[J2] + T/600 * CAPY0
04580                         * (2^(T/TD2) - ENEW[J2]/ENERGY0)
04590                     END J2;
04600                     '
04610                     COMMENT... CC = CORRECTION FACTOR FOR YEAR J;
04620                     CC[J] := 0; !INITIALIZATION!
04630                     IF J>T2 THEN JJ := NPERIOD ELSE

```

Table D-19 (Cont'd)

```

04640      BEGIN
04650      JJ := 0; FOR JJ := JJ+1 WHILE J>PEREND[JJ] DO
04660      END;
04670      FOR K:=1 STEP 1 UNTIL 9 DO
04680      CC[J] := CC[J] + CAPFAC[K,JJ]*(CAPY[K,J-1] + CAPY[K,J])/2;
04690      ENEWAV := (ENEW[2*(J-1)] + 4*ENEW[2*J-1] + ENEW[2*J]) / 6;
04700      CC[J] := IF CC[J]=0 THEN 1 ELSE ENEWAV/CC[J];
04710      '
04720      COMMENT... ADJUST CAPACITY FACTOR;
04730      FOR K:=1 STEP 1 UNTIL 9 DO
04740      CF[K,J] := CC[J] * CAPFAC[K,JJ]
04750      END J;
04760      '
04770      COMMENT... WRITE ADJUSTED CAPY FACTORS AND ENERGY GENERATED;
04780      FOR J:=1 STEP 1 UNTIL NSTEPS2 DO
04790      BEGIN
04800      ENERGYOUT[10,J] := 0; !INITIALIZE SUM!
04810      FOR K:=0 STEP 1 UNTIL 10 DO
04820      BEGIN
04830      CFOUT[K,J] := IF K=0 THEN 1985 + JYEAR[J,2]
04840      ELSE IF K<10 THEN CF[K, JYEAR[J,2]]
04850      ELSE CC[JYEAR[J,2]];
04860      ENERGYOUT[K,J] := IF K=0 THEN CFOUT[K,J]
04870      ELSE IF K<10 THEN CFOUT[K,J] * (CAPY[K, JYEAR[J,2]-1]
04880      + CAPY[K, JYEAR[J,2]]) / 2
04890      ELSE ENERGYOUT[10,J];
04900      IF K>0 & K<10 THEN
04910      ENERGYOUT[10,J] := ENERGYOUT[10,J] + ENERGYOUT[K,J]
04920      END K
04930      END J;
04940      WRITEHEAD (OUTFILE1, HEADFMT);
04950      WRITE (OUTFILE1, "(2X/ 123X, ""CORR."" /
04960      6X, ""ADJUSTED CAPY FACTORS:"", 94X, ""FACTOR"" /
04970      (9X, 14, 13X, 9F10.4, F12.4/))", CFOUT);
04980      IF OUTSTEP<5 THEN WRITEHEAD (OUTFILE1, HEADFMT);
04990      WRITE (OUTFILE1,
05000      "(2X/ 6X, ""ENERGY GENERATED"", 101X, 5HTOTAL/
05010      6X, ""(GW-YR PER YEAR):"", 100X, 5H-----/
05020      (9X, 0P14, 13X, -3P9F10.1, F12.1/))", ENERGYOUT)
05030      END;
05040      '
05050      COMMENT... CALCULATE ESCALATED COSTS IN EACH YEAR FOR EACH CYCLE;
05060      BEGIN
05070      REAL ARRAY CFOMOUT, CVOMOUT, CFUELOUT(0:9, 0:NSTEPS2);
05080      '
05090      COMMENT... ESCALATE CAP, FIXED O&M, VAR O&M, AND FUEL COSTS;
05100      FOR K:=1 STEP 1 UNTIL 9 DO
05110      FOR J:=0 STEP 1 UNTIL T2+LIFE DO
05120      BEGIN
05130      IF J<=T2 THEN CCAPI[K,J] := IF J=0 THEN CCAPO[K]
05140      ELSE CCAPI[K,J-1] * (1 + ECAP[K]);
05150      CFOM[K,J] := IF J=0 THEN CFOMO[K]

```

Table D-19 (Cont'd)

```

05160         ELSE CFOM[K,J-1] * (1 + EFOM[K]);
05170     CVOM[K,J] := IF J=0 THEN CVOM0[K]
05180         ELSE CVOM[K,J-1] * (1 + EVOM[K]);
05190     CFUEL[K,J] := IF J=0 THEN CFUEL0[K]
05200         ELSE CFUEL[K,J-1] * (1 +
05210         (IF EFUEL[K]>0 THEN EFUEL[K]
05220         ELSE IF J<=JOIL[1] THEN EOIL[1]
05230         ELSE IF J<=JOIL[2] THEN EOIL[2] ELSE EOIL[3]))
05240     END K AND J;
05250
05260 COMMENT... WRITE FSCALATED FIXED O&M, VAR O&M, AND FUEL COSTS
05270     IF "NNT" SCENARIO;
05280 IF NONEW THEN
05290     BEGIN
05300     FOR K:=0 STEP 1 UNTIL 9 DO
05310     FOR J:=0 STEP 1 UNTIL NSTEPS2 DO
05320         BEGIN
05330             INTEGER JJ;
05340             JJ := IF J=NSTEPS2 THEN T2+LIFE ELSE J*OUTSTEP;
05350             CFOMOUT[K,J] := IF K=0 THEN 1985+JJ ELSE CFOM[K,JJ];
05360             CVOMOUT[K,J] := IF K=0 THEN 1985+JJ ELSE CVOM[K,JJ];
05370             CFUELOUT[K,J] := IF K=0 THEN 1985+JJ ELSE CFUEL[K,JJ]
05380         END;
05390     IF OUTSTEP<5 THEN WRITEHEAD (OUTFILE, HEADFMT0);
05400     WRITE (OUTFILE,
05410         "(2X/ 6X, ""ESCALATED COSTS:""/
05420         8X, ""FIXED O&M"", 4X, I4, 1X, 9F10.2/
05430         8X, ""($/KW-YR)"", 4X, I4, 1X, 9F10.2/
05440         (21X, I4, 1X, 9F10.2/))", CFOMOUT);
05450     WRITEHEAD (OUTFILE, HEADFMT0);
05460     WRITE (OUTFILE,
05470         "(2X/ 6X, ""ESCALATED COSTS:""/
05480         8X, ""VAR. O&M"", 5X, I4, 1X, 9F10.2/
05490         8X, ""(MILLS/KWHR)"", 1X, I4, 1X, 9F10.2/
05500         (21X, I4, 1X, 9F10.2/))", CVOMOUT);
05510     IF OUTSTEP<5 THEN WRITEHEAD (OUTFILE, HEADFMT0);
05520     WRITE (OUTFILE,
05530         "(2X/ 6X, ""ESCALATED COSTS:""/
05540         8X, ""FUEL"", 9X, I4, 1X, 9F10.2/
05550         8X, ""($/MBTU)"", 5X, I4, 1X, 9F10.2/
05560         (21X, I4, 1X, 9F10.2/))", CFUELOUT)
05570     END NONEW=TRUE
05580 END;
05590
05600 COMMENT... IF "NNT" SCENARIO, TRANSFER SCRATCH FILE TO OUTPUT FILE;
05610 IF NONEW THEN
05620     BEGIN
05630     STRING LINE;
05640     REWIND ("SCRFILE");
05650     ''' NEXTLINE: ''' READ ("SCRFILE", "(A)", LASTLINE, LINE);
05660     WRITE (OUTFILE, "(A)", LINE);
05670     GOTO NEXTLINE;

```


Table D-19 (Cont'd)

```

05680      ' ' LASTLINE: ' ' CLOSE ("SCRFIL")
05690      END;
05700      '
05710      COMMENT... CALCULATE 1975 WORTH OF ALL GENERATION COSTS;
05720      BEGIN
05730      REAL ARRAY WCAP, WFOM, WVOM, WFUEL(1:9),
05740      CCAPOUT, FOMFWOUT, VOMFWOUT, FUELFWOUT(0:9, 0:NSTEPS1),
05750      WORTHOUT(0:10, 0:NSTEPS1);
05760      REAL WCAPTOT, WFONTOT, WVOMTOT, WFUELTOT;
05770      '
05780      WCAPTOT := WFONTOT := WVOMTOT := WFUELTOT := WGENTOT := 0;
05790      '
05800      FOR K:=1 STEP 1 UNTIL 9 DO
05810      BEGIN
05820      WCAP[K] := WFOM[K] := WVOM[K] := WFUEL[K] := 0;
05830      FOR J:=0 STEP 1 UNTIL T2 DO
05840      BEGIN
05850      INTEGER JTAU;
05860      REAL FOMFW, VOMFW, FUELFW, JSIMP, FACTOR;
05870      '
05880      FOMFW := VOMFW := FUELFW := 0;
05890      '
05900      COMMENT... INTEGRATE RECURRING COSTS OVER LIFETIME;
05910      FOR JTAU:=0 STEP 1 UNTIL LIFE DO
05920      BEGIN
05930      REAL DISCOUNT, KSIMP, CFAV;
05940      DISCOUNT := (1+R)-JTAU;
05950      KSIMP := IF JTAU=0 OR JTAU=LIFE THEN 1/3
05960      ELSE IF MOD(JTAU,2)=0 THEN 2/3 ELSE 4/3;
05970      CFAV := IF J+JTAU=0 THEN (3*CF[K,1] - CF[K,2]) / 2
05980      ELSE IF J+JTAU=T2+LIFE THEN
05990      (3*CF[K, T2+LIFE] - CF[K, T2+LIFE-1]) / 2
06000      ELSE (CF[K, J+JTAU] + CF[K, J+JTAU+1]) / 2;
06010      !INTERPOLATE OR EXTRAPOLATE FROM MIDYEAR VALUES
06020      TO YEAR-END VALUES!
06030      FOMFW := FOMFW + CFOM[K,J+JTAU]*DISCOUNT*KSIMP;
06040      VOMFW := VOMFW + CVOM[K,J+JTAU] * CFAV
06050      * DISCOUNT * KSIMP;
06060      FUELFW := FUELFW + HR[K] * CFUEL[K,J+JTAU]
06070      * CFAV * DISCOUNT * KSIMP
06080      END JTAU;
06090      '
06100      VOMFW := VOMFW * 8.76; !HR/YR X $/MILL!
06110      FUELFW := FUELFW * 8.76E-3; !HR/YR X MBTU/BTU!
06120      '
06130      COMMENT... STORE OUTPUTS FOR SELECTED YEARS;
06140      IF MOD(J,OUTSTEP)=0 OR J=T2 THEN
06150      BEGIN
06160      INTEGER JOUT;
06170      JOUT := IF J<T2 THEN J%OUTSTEP ELSE NSTEPS1;
06180      CCAPOUT[K,JOUT] := IF CAPY[K,T2]>0 THEN CCAPI[K,J] ELSE 0;
06190      FOMFWOUT[K,JOUT] := IF CAPY[K,T2]>0 THEN FOMFW ELSE 0;

```

Table D-19 (Cont'd)

```

06200      VOMFWOUT[K,JOUT] := VOMFW;
06210      FUELFWOUT[K,JOUT] := FUELFW
06220      END;
06230      .
06240      COMMENT... INTEGRATE OVER YEARS OF INSTALLATION;
06250      JSIMP := IF J=0 OR J=T2 THEN 1/3
06260      ELSE IF MOD(J,2)=0 THEN 2/3 ELSE 4/3;
06270      IF MOD(T2,2)>0 AND J>=T2-2 THEN
06280      JSIMP := IF J=T2 THEN 5/12 ELSE IF J=T2-1 THEN 1
06290      ELSE !J=T2-2! 5/4; !CORRECTION FOR ODD NR STEPS!
06300      FACTOR := (1+R)-(J+10) * 1E-3 !KW/MW X M$/S!
06310      * DELTAC[J] *
06320      (IF J=0 THEN (3*MP[K,1] - MP[K,2]) / 2
06330      ELSE IF J=T2 THEN (3*MP[K,T2] - MP[K,T2-1]) / 2
06340      ELSE (MP[K,J] + MP[K,J+1]) / 2);
06350      !INTERPOLATE OR EXTRAPOLATE FROM MIDYEAR VALUES
06360      OF MKT PEN "MP" TO YEAR-END VALUES!
06370      WCAP[K] := WCAP[K] + JSIMP*FACTOR*CCAP[K,J];
06380      WFOM[K] := WFOM[K] + JSIMP*FACTOR*FOMFW;
06390      WVOM[K] := WVOM[K] + JSIMP*FACTOR*VOMFW;
06400      WFUEL[K] := WFUEL[K] + JSIMP*FACTOR*FUELFW;
06410      .
06420      COMMENT... STORE 1975 WORTHS FOR SUBSEQUENT PRINTING;
06430      IF MOD(J,OUTSTEP)=0 OR J=T2 THEN
06440      WORTHOUT[K,IF J=T2 THEN NSTEPS1 ELSE J%OUTSTEP] :=
06450      FACTOR*(CCAP[K,J] + FOMFW + VOMFW + FUELFW)
06460      END J;
06470      .
06480      COMMENT... GET TOTALS OVER CYCLES;
06490      WCAPTOT := WCAPTOT + WCAP[K];
06500      WFOMTOT := WFOMTOT + WFOM[K];
06510      WVOMTOT := WVOMTOT + WVOM[K];
06520      WFUELTOT := WFUELTOT + WFUEL[K];
06530      WGEN[K] := WCAP[K] + WFOM[K] + WVOM[K] + WFUEL[K];
06540      WGENTOT := WGENTOT + WGEN[K]
06550      END K;
06560      .
06570      COMMENT... WRITE RESULTS FOR GENERATING COSTS;
06580      WRITEHEAD (OUTFILF, HEADFMT);
06590      FOR J:=0 STEP 1 UNTIL NSTEPS1 DO
06600      CCAPOUT[0,J] := FOMFWOUT[0,J] := VOMFWOUT[0,J] :=
06610      FUELFWOUT[0,J] := WORTHOUT[0,J] := 1985 + JYEAR[J,1];
06620      WRITE (OUTFILE,
06630      "(2X/ 6X, ""FUTURE LIFE-CYCLE""/
06640      6X, ""WORTHS ($/KW):""/
06650      8X, ""CAPITAL"", 6X, I4, 1X, 9F10.2/
06660      (21X, I4, 1X, 9F10.2/))", CCAPOUT);
06670      IF OUTSTEP<3 THEN WRITEHEAD (OUTFILE, HEADFMT);
06680      WRITE (OUTFILE,
06690      "(2X/ 6X, ""FUT L-C WORTH ($/KW):""/
06700      8X, ""FIXED O&M"", 4X, I4, 1X, 9F10.2/
06710      (21X, I4, 1X, 9F10.2/))", FOMFWOUT);

```

Table D-19 (Cont'd)

```

06720 IF OUTSTEP<5 THEN WRITEHEAD (OUTFILE, HEADFMT);
06730 WRITE (OUTFILE,
06740     "(2X/ 6X, ""FUT L-C WORTH ($/KW):""/
06750     8X, ""VAR. O&M"", 5X, 14, 1X, 9F10.2/
06760     (21X, 14, 1X, 9F10.2/))", VOMFWOUT);
06770 IF OUTSTEP<3 THEN WRITEHEAD (OUTFILE, HEADFMT);
06780 WRITE (OUTFILE,
06790     "(2X/ 6X, ""FUT L-C WORTH ($/KW):""/
06800     8X, ""FUEL"", 9X, 14, 1X, 9F10.2/
06810     (21X, 14, 1X, 9F10.2/))", FUELFWOUT);
06820 WRITEHEAD (OUTFILE, HEADFMT);
06830 FOR J:=0 STEP 1 UNTIL NSTEPS1 DO
06840     BEGIN
06850         WORTHOUT[10,J] := 0;
06860         FOR K:=1 STEP 1 UNTIL 9 DO WORTHOUT[10,J] :=
06870             WORTHOUT[10,J] + WORTHOUT[K,J]
06880     END J;
06890 WRITE (OUTFILE,
06900     "(2X/ 6X, ""1975 WORTH (B$) OF"", 99X, 5HTOTAL/
06910     6X, ""UNITS INSTALLED IN:"", 98X, 5H-----/
06920     (9X, OPI4, 13X, -3P9F10.3, F12.3/)", WORTHOUT);
06930 IF OUTSTEP<5 THEN WRITEHEAD (OUTFILE, HEADFMT);
06940 WRITE (OUTFILE,
06950     "(2X/ 6X, ""INTEGRATED 1975"", 102X, ""TOTAL""/
06960     6X, ""WORTHS (B$):"", 105X, 5(1H-)/
06970     9X, ""CAPITAL"", 10X, -3P9F10.3, F12.3/
06980     9X, ""FIXED O&M"", 8X, 9F10.3, F12.3/
06990     9X, ""VAR. O&M"", 9X, 9F10.3, F12.3/
07000     9X, ""FUEL"", 13X, 9F10.3, F12.3/
07010     9X, ""TOTAL FOR GEN."", 3X, 9F10.3, F12.3)",
07020     WCAP, WCAPTOT, WFOM, WFOMTOT, WVOM, WVOMTOT,
07030     WFUEL, WFUELTOT, WGEN, WGENTOT)
07040     END;
07050 *
07060 COMMENT... COMPUTE 1985 WORTH OF R&D PROGRAMS;
07070     BEGIN
07080         WRDTOT := 0;
07090         FOR K:=7 STEP 1 UNTIL 9 DO
07100             BEGIN
07110                 REAL RRD;
07120                 RRD := (1+R)/(1+ERD[K]) - 1; !EFFECTIVE DISCOUNT RATE!
07130                 T1[K] := T1[K] + 8; !START IN 1978 INSTEAD OF 1986!
07140                 WRD[K] := CRD[K]/T1[K] * (1 - (1+RRD)-T1[K])
07150                     / LN(1+RRD);
07160                 WRDTOT := WRDTOT + WRD[K]
07170             END K;
07180 *
07190 WRITE (OUTFILE, "(2X/ 9X, ""R&D PROGRAM"", 6X, -3P9F10.3,
07200     F12.3)", WRD, WRDTOT)
07210     END;
07220 *
07230 COMMENT... CALCULATE NET WORTH (GENERATION + R&D), AND COMPARE TO

```

Table D-19 (Cont'd)

```

07240 NO NEW TECHNOLOGY CASE TO OBTAIN SAVINGS;
07250 BEGIN
07260 REAL WNETREF;
07270 FOR K:=1 STEP 1 UNTIL 9 DO
07280     WNET[K] := WGEN[K] + WRD[K];
07290 WNETTOT := WRDTOT + WGENTOT;
07300 WRITE (OUTFILE, "(2X/ 9X, ""TOTAL"", 12X, -3P9F10.3, F12.3/
07310     120X, 8(1H=)/ 2X)", WNET, WNETTOT);
07320 ;
07330 COMMENT... IF THIS IS "NO NEW TECHNOLOGY" SCENARIO THEN WRITE
07340     NET WORTH INTO FILE, OTHERWISE READ THAT FILE;
07350 IF NONNEW THEN
07360     BEGIN
07370         OPENT ("WNETREF", "", "/CYCLES3/OUTPUT/WNETREF");
07380         ENDFILE ("WNETREF");
07390         WRITE ("WNETREF", "(V)", WNETTOT);
07400         CLOSE ("WNETREF");
07410     END
07420 ELSE
07430     BEGIN
07440         OPENSHR ("WNETREF", "", "/CYCLES3/OUTPUT/WNETREF,R");
07450         READ ("WNETREF", "(V)", ERROR, WNETREF);
07460         CLOSE ("WNETREF");
07470         GOTO SAVINGS;
07480     ;
07490     '*** ERROR: ***'
07500     BEGIN
07510         PRINTF ("(""ONO DATA IN FILE "", 9H""WNETREF"",
07520             "" FROM NO-NEW-TECHNOLOGY SCENARIO."" /
07530             "" UNABLE TO COMPUTE SAVINGS...""))");
07540         GOTO LAST
07550     END;
07560 ;
07570     '*** SAVINGS: ***'
07580     WSAV := WNETREF - WNETTOT;
07590     WRITE (OUTFILE, "(1H0, 53X, ""WORTH OF SAVINGS ="",
07600         -3PF9.3, "" B$""", WSAV)
07610     END ELSECLAUSE;
07620 ;
07630 COMMENT... IDENTIFY CONDITIONS;
07640 BEGIN
07650     STRING CONDITIONS;
07660     CONDITIONS := (IF INTANG THEN "WITH" ELSE "WITHOUT") *
07670         " INTANGIBLES, " * (IF TAXES THEN "WITH" ELSE "WITHOUT")
07680         * " TAXES";
07690     WRITE (OUTFILE, "(1H0," * INTSTR(68 - LENGTH(CONDITIONS)%2)
07700         * "X, A)", CONDITIONS)
07710 END
07720 END;
07730 ;
07740 COMMENT... CLOSE SCENARIO AND OUTPUT FILES;
07750 '*** LAST: ***'

```

Table D-19 (Cont'd)

```
07760 CLOSE (SCENFILE); CLOSE (OUTFILE);  
07770 PRINTF ("("O... FINISHED..."");  
07780 END PROGRAM
```

Table D-20 is a listing of the batch program "BWORTH". This was formed from the time-sharing program "WORTH" listed in Table D-19. Calculations of the two programs are identical; BWORTH differs only in having the capability of running a sequence of scenarios instead of only one scenario. In fact, BWORTH was formed by using WORTH as a procedure which is called repeatedly, with a few minor modifications to adapt to the batch environment.

Table D-20

NET PRESENT WORTH PROGRAM — BATCH VERSION

J.J.FLECK1/CYCLES3/BWORTH

09/10/77

12:08 PM

```

00010 OPTION SBUF=4;
00020 BEGIN
00021 COMMENT... "BWORTH"
00022     BATCH VERSION OF TIME-SHARING PROGRAM "WORTH".
00023     THE BATCH VERSION EXAMINES ALL SCENARIOS, INSTEAD OF ONE;
00024 '
00030 COMMENT... "WORTH"
00040     THIS PROGRAM CALCULATES THE 1985 WORTH OF ALL COSTS
00050     ASSOCIATED WITH R&D AND ELECTRICITY GENERATION , BASED
00060     UPON MARKET PENETRATION AND CAPACITY FACTORS FROM "OGP".
00070 '
00080     JOEL J FLECK
00090     8 JUNE 1977     REVISED 7 SEP 1977
00100 ;
00101 '
00102 .....
00103 '
00104 COMMENT... PROCEDURE FOR ONE SCENARIO, FORMED FROM "WORTH";
00105 PROCEDURE SCENARIO;
00106 BEGIN
00110 REAL TD1, TD2, GROWTH1, GROWTH2, ENERGY0, CAPY0,
00120     FTAX, FINSUR, FRETDISP, R,
00130     WGENTOT, WRDTOT, WNETTOT, WSAV;
00140 INTEGER LIFE, T2, TO, I, J, K, NPERIOD, !OUTSTEP, ! NSTEPS1, NSTEPS2;
00150 STRING SCENARIO, !SCENFILE, OUTFILE, ! OUTFILE1, HEADFMT, HEADFMT0,
00160     CYCLESFMT;
00170 BOOLEAN NONEW!, INTANG, TAXES!; !REMOVED VARS. NOW IN MAIN PROGRAM!
00180 REAL ARRAY MKTPEN, CAPFAC[1:9, 1:5], MP[1:9, 1:39], CF[1:9, 1:69],
00190     !MARKET PENETRATION & CAPACITY FACTOR AT <<<MIDYEAR>>>!
00200     CRD, ERD, T1, CCAPO, ECAP, CFOMO, EFOM, CVOMO, EVOM, CFUEL0,
00210     EFUEL, HR[1:9], EOIL[1:3], JOIL[1:2],
00220     !CYCLE DATA ON COSTS, ESC RATES, T1, HEAT RATE!
00230     DELTAC[0:39], CAPY[1:10, 0:69],
00240     !CAPACITY GROWTH RATE & CAPACITY AT <<<YEAREND>>>!
00250     CCAP[1:9, 0:39], CFOM, CVOM, CFUEL[1:9, 0:69],
00260     !COSTS FOR CAP, VAR O&M, FIXED O&M, & FUEL AT <<<YEAREND>>>!
00270     WGEN, WNET, WRD[1:9];
00280     !1975 WORTHS OF GENERATION, R&D, & NET COSTS PER CYCLE!
00290 INTEGER ARRAY PEREND[1:5], JYEAR[0:69, 1:2];
00300 STRING ARRAY CYCLE[1:9], EC[1:9, 1:26];
00310 '
00320 PROCEDURE WRITEHEAD(FILE,FMT); VALUE FILE,FMT; STRING FILE,FMT;
00330 COMMENT... WRITES PAGE HEADINGS;
00340 BEGIN
00350     WRITE (FILE, FMT);
00360     WRITE (FILE, CYCLESFMT, CYCLE);
00365     FILE := FMT := ""
00370     END PROCEDURE WRITEHEAD;
00380 '

```

Table D-20 (Cont'd)

```

00390 COMMENT... SET CONSTANTS;
00400 BEGIN
00410 LIFE := 30; !LIFETIME OF EVERY CYCLE, YEARS!
00420 ENERGY0 := 216000; !1975 ELEC ENERGY GENERATION, MW-YR!
00430 CAPY0 := 480000; !1975 CAPACITY, MW!
00440 T2 := 39; !YEARS FROM 1985 TO LAST INSTALLATION!
00450 T0 := 10; !YRS FROM GROWTH CHANGE (1975) TO 1985!
00460 GROWTH1 := .065; !ELEC ENERGY GROWTH RATE THRU 1975!
00470 GROWTH2 := .056; !ELEC ENERGY GROWTH RATE 1976 & AFTER!
00480 TD1 := LOG(2) / LOG(1 + GROWTH1); !DOUBLING TIME!
00490 TD2 := LOG(2) / LOG(1 + GROWTH2); !DOUBLING TIME!
00500 I:=1; FOR EOIL[I] := .085, .095, .105 DO I:=I+1;
00510 !ESCALATION RATES FOR OIL!
00520 I:=1; FOR JOIL[I] := 5, 15 DO I:=I+1;
00530 !YRS FROM 1985 WHEN OIL ESC CHANGES!
00540 FTAX := 0.69; !0.69 IF TAXES ARE CONSIDERED, 0 IF NOT!
00550 FINSUR := .01; !INSURANCE MULTIPLIER ON CAPITAL COSTS!
00560 FRETDISP := .0056; !RETIRMENT DISPERSION MULT ON CAP COSTS!
00570 R := 0.10; !DISCOUNT RATE!
00580 END;
00590
00600 COMMENT... READ MARKET PENETRATION AND CAPACITY FACTOR FROM OGP
00610 FOR THIS SCENARIO;
00620 BEGIN
00630 !PRINTF ("("OFILNAME CONTAINING OGP OUTPUTS"))");
00640 INPUTF ("(A)", SCENFILE); ... NOW IN MAIN PROGRAM!
00650 OPENSFR (SCENFILE, "", "/CYCLES3/OGP-OUT/"*SCENFILE*".R");
00660 READ (SCENFILE, "(A)", SCENERROR, SCENARIO);
00670 READ (SCENFILE, "(V)", SCENERROR, NPERIOD);
00680 COMMENT... READ YEARS IN WHICH PERIODS END;
00690 BEGIN
00700 INTEGER ARRAY DATA[1:NPERIOD];
00710 READ (SCENFILE, "(9X,*INTSTR(NPERIOD)*"V)", SCENERROR, DATA);
00720 FOR J:=1 STEP 1 UNTIL NPERIOD DO PEREND[J] := DATA[J] - 1985;
00730 END;
00740 COMMENT... READ MARKET PENETRATIONS AND CAPACITY FACTORS;
00750 FOR K:=1 STEP 1 UNTIL 9 DO
00760 BEGIN
00770 REAL ARRAY DATA[1:2*NPERIOD];
00780 READ (SCENFILE, "(8X,*INTSTR(2*NPERIOD)*"V)", SCENERROR, DATA);
00790 FOR J:=1 STEP 1 UNTIL NPERIOD DO
00800 BEGIN
00810 MKTPEN[K,J] := DATA[2*J-1];
00820 CAPFAC[K,J] := DATA[2*J];
00830 END J
00840 END K;
00850 GOTO ENDSCEN;
00860
00870 *** SCENERROR: ***
00880 BEGIN
00890 PRINTF ("("OFILE "", A, "", FATAL ERROR:""/
00900 6X, ""INSUFFICIENT DATA..."")",

```


Table D-20 (Cont'd)

```

00910          SCENFILE);
00920          GOTO LAST
00930          END;
00940      ,
00950      ' ' ' ENDSCEM;; ' ' '
00960      END READING OGP OUTPUT FILE;
00970      ,
00980      COMMENT... READ DATA FILES FOR ALL 9 CYCLES;
00990      BEGIN
01000      BOOLEAN DATAERROR;
01010      DATAERROR := FALSE;
01020      FOR K:=1 STEP 1 UNTIL 9 DO
01030          BEGIN
01040              INTEGER I, LN;
01050              STRING CRITFILE, COSTFILE, DUMMY;
01060              ,
01070              COMMENT... READ CRITERIA FILE FOR CYCLE K;
01080              CRITFILE := "CRIT" * INTSTR(K);
01090              OPENSFR (CRITFILE, "", "/CYCLES3/CRITERIA/"*CRITFILE*",R");
01100              READ (CRITFILE, "(A)", CRITERIOR, DUMMY);
01110              FOR I:=1 STEP 1 UNTIL 26 DO !I = CRITERION NUMBER!
01120                  BEGIN
01130                      READ (CRITFILE, "(I2, IX, A1)", CRITERIOR, LN, EC(K,I));
01140                      IF LN/=I THEN
01150                          BEGIN
01160                              PRINTF ("("OFIE "", A, "", FATAL ERROR:""/
01170                                  6X, ""LINE "", A, "" IS NUMBERED "", A)",
01180                                  CRITFILE, INTSTR(I), LN);
01190                              DATAERROR := TRUE
01200                              END;
01210                              IF EC(K,I)/="G" AND EC(K,I)/="F" AND EC(K,I)/="P" THEN
01220                                  BEGIN
01230                                      PRINTF ("("OFIE "", A, "", FATAL ERROR:""/
01240                                          6X, ""LINE "", A, "" HAS ILLEGAL DATUM "",
01250                                          IH"", A, IH""),
01260                                          CRITFILE, INTSTR(I), EC(K,I));
01270                                      DATAERROR := TRUE
01280                                      END
01290                                  END I;
01300                                  CLOSE (CRITFILE);
01310                                  GOTO READCOST;
01320                                  ,
01330                                  ' ' ' CRITERIOR: ' ' '
01340                                  BEGIN
01350                                      PRINTF ("("OFIE "", A, "", FATAL ERROR:""/
01360                                          6X, ""TOO SHORT; ONLY "", A, "" LINES..."")",
01370                                          CRITFILE, INTSTR(I-1));
01380                                      CLOSE (CRITFILE);
01390                                      DATAERROR := TRUE
01400                                      END;
01410                                  ,
01420                                  ' ' ' READCOST;; ' ' '

```

Table D-20 (Cont'd)

```

01430      COMMENT... READ COST-DATA FILE FOR CYCLE K;
01440      COSTFILE := "COST" * INTSTR(K);
01450      OPENSHR (COSTFILE, "", "/CYCLES3/COSTDATA/"*COSTFILE*".R");
01460      READ (COSTFILE, "(A)", COSTERROR, CYCLE(K));
01470      READ (COSTFILE, "(A3, 3V)", COSTERROR, DUMMY, CRD(K), ERD(K),
01480          T1(K));
01490      READ (COSTFILE, "(A3, 2V)", COSTERROR, DUMMY, CCAPO(K),
01500          ECAPI(K));
01510      READ (COSTFILE, "(A3, 2V)", COSTERROR, DUMMY, CFOMO(K),
01520          EFOM(K));
01530      READ (COSTFILE, "(A3, 2V)", COSTERROR, DUMMY, CVOMO(K),
01540          EVOM(K));
01550      READ (COSTFILE, "(A4, 2V)", COSTERROR, DUMMY, CFUELO(K),
01560          EFUEL(K));
01570      READ (COSTFILE, "(A2, 1V)", COSTERROR, DUMMY, HR(K));
01580      CLOSE (COSTFILE);
01590      GOTO ENDK;
01600      '
01610      '... COSTERROR: ...
01620      BEGIN
01630      PRINTF ("("OFILE ", A, ", FATAL ERROR:""/
01640          6X, "INSUFFICIENT DATA..."")",
01650          COSTFILE);
01660      CLOSE (COSTFILE);
01670      DATAERROR := TRUE
01680      END;
01690      '
01700      '... ENDK: ...
01710      END K;
01720      '
01730      IF DATAERROR THEN
01740      BEGIN
01750      PRINTF ("("OPROGRAM ABORTED DUE TO ERRORS IN DATA..."")");
01760      GOTO LAST
01770      END
01780      END READING DATA FILES FOR CYCLES;
01790      '
01800      COMMENT... OPEN OUTPUT FILE, SET UP OUTPUT PRINTING STEPS, AND
01810      CREATE HEADING FORMATS;
01820      BEGIN
01830      INTEGER LSCEN, INDENT;
01840      INTEGER ARRAY LCYCLE[1:18];
01850      '
01860      !PRINTF ("("OOUTPUT FILENAME"")");
01870      INPUTF ("(A)", OUTFILE);
01880      OPEN (OUTFILE, "", "/CYCLES3/OUTPUT/"*OUTFILE);
01890      ENDFILE (OUTFILE); ... NOW IN MAIN PROGRAM!
01900      '
01910      COMMENT... SETUP FOR OUTPUTS;
01920      !PRINTF ("("OYEARS BETWEEN OUTPUT STEPS"")");
01930      INPUT (OUTSTEP); ... NOW IN MAIN PROGRAM!
01940      NSTEPS1 := T2%OUTSTEP + (IF MOD(T2,OUTSTEP)>0 THEN 1 ELSE 0);

```

Table D-20 (Cont'd)

```

01950      !NR. OUTPUT STEPS FROM TO TO T2!
01960      NSTEPS2 := (T2+LIFE)%OUTSTEP + (IF MOD(T2+LIFE,OUTSTEP)>0
01970      THEN 1 ELSE 0);      !NR. OUTPUT STEPS FROM TO TO T2+LIFE!
01980      FOR J:=0 STEP 1 UNTIL NSTEPS2 DO
01990          JYEAR[J,1] := JYEAR[J,2] := J*OUTSTEP;
02000      JYEAR[NSTEPS1,1] := T2;
02010      JYEAR[NSTEPS2,2] := T2+LIFE;
02020      !JYEAR = YEARS FROM TO TO "J"TH OUTPUT STEP!
02030      ,
02040      COMMENT... CREATE HEADING FORMATS;
02050      HEADFMT0 := "(1H1, 52X, "SCENARIO-INDEPENDENT QUANTITIES"/
02060      53X, 31(1H*))";      !PAGE HEADING FMT FOR SCEN-IND OUTPUTS!
02070      LSCEN := LENGTH (SCENARIO);
02080      INDENT := 67 - LSCEN/2;
02090      FOR K:=1 STEP 1 UNTIL 9 DO
02100          BEGIN
02110              LCYCLE[2*K] := LENGTH (CYCLE[K]);
02120              LCYCLE[2*K - 1] := 10 - LCYCLE[2*K]
02130          END;
02140      ENCODES (HEADFMT, !PAGE HEADING FMT FOR SCEN-DEP OUTPUTS!
02150      "(", "(1H1, "", I2, ""X, "", I2, ""H"", A, ""/",
02160      I2, ""X, "", I2, ""(1H*))""),
02170      INDENT-1, LSCEN, SCENARIO, INDENT, LSCEN);
02180      ENCODES (CYCLESFMT, !COLUMN TITLES FMT (CYCLE ACRONYMS)!
02190      "(", "1H0/ 26X", 9("(", "", I2, ""X, A", I2), ""/",
02200      ""26X", 9("(", "", I2, ""X, "", I2, ""(1H-)""), ""))",
02210      LCYCLE, LCYCLE);
02220      END;
02230      ,
02240      COMMENT... ADJUST R&D COST FOR PROBABILITY OF DEVELOPMENT SUCCESS.
02250      WRITE UNADJUSTED AND ADJUSTED VALUES IF "NNT" SCENARIO;
02260      BEGIN
02270          ,
02280          COMMENT... PRINT HEADING FOR SCENARIO-INDEPENDENT QUANTITIES,
02290          BUT ONLY IF "NO NEW TECHNOLOGY" SCENARIO;
02300          NONEW := SEARCH (SCENARIO, "NO NEW", 1, 1) > 0;
02310          IF NONEW THEN WRITEHEAD (OUTFILE, HEADFMT0);
02320          ,
02330          COMMENT... ADJUST R&D COSTS AND WRITE RESULTS;
02340          IF NONEW THEN WRITE (OUTFILE, "(2X/ 6X, "R&D COST (M$):"/
02350          9X, ""BEFORE ADJUSTMENT", 9F10.1)", CRD);
02360          FOR K:=7 STEP 1 UNTIL 9 DO
02370              CRD[K] := CRD[K] * (2 - (IF EC[K,3]="G" THEN 0.95
02380              ELSE IF EC[K,3]="F" THEN 0.80 ELSE !EC="P"! 0.65));
02390          IF NONEW THEN WRITE (OUTFILE, "(9X, ""AFTER ADJUSTMENT "",
02400          9F10.1)", CRD);
02410          ,
02420          COMMENT... SET R&D COST TO ZERO FOR CYCLES NOT IN SCENARIO;
02430          IF SEARCH(SCENFILE,"NNT",1,1)>0 THEN CRD[7]:=CRD[8]:=CRD[9]:=0;
02440          IF SEARCH(SCENFILE,"AFB",1,1)>0 THEN CRD[8] := CRD[9] := 0;
02450          IF SEARCH(SCENFILE,"CC",1,1)>0 THEN CRD[7] := CRD[9] := 0;
02460          IF SEARCH(SCENFILE,"MHD",1,1)>0 THEN CRD[7] := CRD[8] := 0

```

Table D-20 (Cont'd)

```

02470     END;
02480 *
02490 COMMENT... ADJUST MARKET PENETRATION FOR INTANGIBLES;
02500     BEGIN
02510     REAL ARRAY P[4:26, 1:3], FM[1:9], CF[1:NPERIOD],
02520     MPOUT[0:10, 1:NSTEPS1];
02530     *
02540     !PRINTF ("("OADJUST FOR INTANGIBLES? (T OR F)"))");
02550     INPUT (INTANG); ... NOW IN MAIN PROGRAM!
02560     *
02570     COMMENT... SET VALUES FOR P MULTIPLIERS;
02580     IF INTANG THEN
02590         BEGIN
02600             FOR I:=4 STEP 1 UNTIL 26 DO P[I,1] := 1; !"G"!
02610             I:=4; FOR P[I,2] := .88, .99, .92, .97, .96, .99, .99,
02620             .93, .95, .99, .99, .95, .93, .90, .99, .94, .96,
02630             .97, .95, .99, .96, .92, .98 DO I := I+1; !"F"!
02640             FOR I:=4 STEP 1 UNTIL 26 DO
02650                 P[I,3] := IF I=13 OR I=15 OR I=24 OR I=25 THEN 0.50
02660                 ELSE 1 - 2*(1 - P[I,2]) !"P"!
02670             END;
02680         *
02690     COMMENT... CALCULATE THE MULTIPLIER FOR INTANGIBLES, FM[K];
02700     FOR K:=1 STEP 1 UNTIL 9 DO
02710     IF INTANG THEN
02720         BEGIN
02730             REAL PMIN, PKI;
02740             *
02750             FM[K] := PMIN := 1; !INITIALIZE!
02760             FOR I:=4 STEP 1 UNTIL 26 DO
02770                 BEGIN
02780                     PKI := P[I, IF EC[K,I]="G" THEN 1 ELSE IF EC[K,I]="F"
02790                     THEN 2 ELSE !EC="P"! 3];
02800                     FM[K] := FM[K] * PKI;
02810                     PMIN := IF PKI<PMIN THEN PKI ELSE PMIN
02820                     END I;
02830                     FM[K] := SQRT (PMIN * FM[K])
02840                     END INTANG=TRUE
02850             ELSE
02860                 FM[K] := 1; !INTANG=FALSE!
02870             *
02880     COMMENT... WRITE MARKET PENETRATION MULTIPLIERS.
02890     (IF THIS IS THE "NNT" SCENARIO, WRITE SCENARIO-DEPENDENT
02900     QUANTITIES ON A SCRATCH FILE UNTIL ALL SCENARIO-INDEPENDENT
02910     QUANTITIES HAVE BEEN WRITTEN ON THE OUTPUT FILE. OTHER-
02920     WISE, WRITE ALL SCEN-DEP QUANTITIES ON THE OUTPUT FILE.);
02930     IF NONEW THEN OPENS("SCRFILE");
02940     OUTFILE1 := IF NONEW THEN "SCRFILE" ELSE OUTFILE;
02950     COMMENT... WRITE HEADING FOR SCENARIO-DEPENDENT QUANTITIES;
02960     WRITEHEAD (OUTFILE1, HEADFMT);
02970     WRITE (OUTFILE1, "(2X/ 6X, ""MARKET PEN MULT."" , 4X, 9F10.4, 7X,
02980     5HNORM.)", FM);

```

Table D-20 (Cont'd)

```

02990      *
03000      COMMENT... CALCULATE THE NORMALIZATION FACTOR CF[J];
03010      FOR J:=1 STEP 1 UNTIL NPERIOD DO
03020          BEGIN
03030              CF[J] := 0;  !INITIALIZATION!
03040              FOR K:=1 STEP 1 UNTIL 9 DO
03050                  CF[J] := FM[K] * MKTPEN[K,J] + CF[J];
03060              CF[J] := IF CF[J]=0 THEN 1 ELSE 1/CF[J]
03070          END J;
03080      *
03090      COMMENT... CALCULATE ADJUSTED MKT PEN, EACH CYCLE IN EACH YEAR;
03100      FOR K:=1 STEP 1 UNTIL 9 DO
03110          FOR J:=1 STEP 1 UNTIL T2 DO
03120              BEGIN
03130                  INTEGER JJ;  !JJ = PERIOD NUMBER IN WHICH YEAR J OCCURS!
03140                  JJ := 0;  FOR JJ := JJ+1 WHILE J>PEREND(JJ) DO;
03150                      MP[K,J] := FM[K] * CF[JJ] * MKTPEN[K,JJ];
03160                      IF MOD(J,OUTSTEP)=0 OR J=T2 THEN MPOUT[10,
03170                          IF J<T2 THEN J%OUTSTEP ELSE NSTEPS1] := CF[JJ]
03180                          !STORE NORM. FACTOR CC FOR PRINTING!
03190                      END;
03200              *
03210              COMMENT... WRITE ADJUSTED MARKET PENETRATIONS;
03220              FOR K:=0 STEP 1 UNTIL 9 DO
03230                  FOR J:=1 STEP 1 UNTIL NSTEPS1 DO
03240                      MPOUT[K,J] := IF K=0 THEN 1985 + JYEAR[J,1]
03250                      ELSE MP[K, JYEAR[J,1]];
03260              WRITE (OUTFILE1, "(6X, ""ADJUSTED MKT PEN:"", 99X, 6HFACTOR/
03270                  (9X, 14, 13X, 9F10.4, F12.4/))", MPOUT)
03280              END;
03290      *
03300      COMMENT... ADJUST CAPITAL COST FOR TAXES, INSURANCE, AND
03310      RETIREMENT DISPERSION;
03320          BEGIN
03330              *
03340              !PRINTF ("("OCONSIDER TAXES? (T OR F)""");
03350              INPUT (TAXES);  ... NOW IN MAIN PROGRAM!
03360              FTAX := IF TAXES THEN FTAX ELSE 0;
03370              *
03380              IF NONEW THEN WRITE (OUTFILE,
03390                  "(2X/ 6X, ""1975 CAPITAL COST ($/KW):""/
03400                  9X, ""BASE VALUE"", 7X, 9F10.1)", CCAPO);
03410              FOR K:=1 STEP 1 UNTIL 9 DO
03420                  CCAPO[K] := CCAPO[K] * (1+FTAX) * (1+FINSUR) * (1+FRETDISP);
03430              IF NONEW THEN WRITE (OUTFILE,
03440                  "(9X, ""WITH TAXES, ETC."" , 1X, 9F10.1)", CCAPO)
03450              END;
03460      *
03470      COMMENT... WRITE HEAT RATES, IF "NNT" SCENARIO;
03480          IF NONEW THEN WRITE (OUTFILE,
03490              "(2X/ 6X, ""HEAT RATE (BTU/KWHR):"", 19, 8I10)", HR);
03500      *

```

Table D-20 (Cont'd)

```

03510 COMMENT... ESCALATE ALL QUANTITIES FROM 1975 TO 1985;
03520 BEGIN
03522 REAL GROWTH;
03524 GROWTH := (1+GROWTH1)^(T0-10) * (1+GROWTH2)^T0;
03530 ENERGY0 := ENERGY0 * GROWTH;
03540 CAPY0 := CAPY0 * GROWTH;
03550 FOR K:=1 STEP 1 UNTIL 9 DO
03560 BEGIN
03570 CCAPO[K] := CCAPO[K] * (1+ECAP[K])^10;
03580 CFOMO[K] := CFOMO[K] * (1+EFOM[K])^10;
03590 CVOMO[K] := CVOMO[K] * (1+EVOM[K])^10;
03600 CFUELO[K] := CFUELO[K] * (1 +
03610 (IF EFUEL[K]>=0 THEN EFUEL[K] ELSE EOIL[1]))^10
03620 END K
03630 END
03640 *
03650 COMMENT... CALCULATE CAPACITY ADDITION RATE DELTAC (MW/YR);
03660 BEGIN
03670 REAL C1, C2;
03680 C1 := CAPY0 * LN(2)/TD2;
03690 C2 := CAPY0 * LN(2)/TD1 * 2^(-LIFE/TD1) / (1 - 2^(-LIFE/TD1));
03700 FOR J:=0 STEP 1 UNTIL LIFE-T0 DO
03710 DELTAC[J] := C1 * 2^(J/TD2) + C2 * 2^(J/TD1);
03720 C1 := C1 * (1 + 2^(-LIFE/TD2));
03730 C2 := C2 * 2^(-LIFE/TD1);
03740 FOR J:=LIFE-T0+1 STEP 1 UNTIL T2 DO
03750 DELTAC[J] := C1 * 2^(J/TD2) + C2 * 2^(J/TD1)
03760 END;
03770 *
03780 COMMENT... CALCULATE INSTALLED CAPACITY FOR EACH CYCLE (ONLY
03790 THOSE UNITS INSTALLED BETWEEN JAN 1986 AND DEC 1986+T2);
03800 BEGIN
03810 REAL ARRAY DELTACOUT[0:10, 1:NSTEPS1], CAPYOUT[0:10, 0:NSTEPS2];
03820 REAL PROCEDURE AVADDEDCAPY(J); VALUE J; INTEGER J;
03830 AVADDEDCAPY := 0.5 * (DELTAC[J-1] + DELTAC[J]) *
03840 (IF K<10 THEN MP[K,J] ELSE 1);
03850 *
03860 FOR K:=1 STEP 1 UNTIL 10 DO
03870 FOR J:=0 STEP 1 UNTIL T2+LIFE DO
03880 CAPY[K,J] := (IF J=0 THEN 0 ELSE CAPY[K,J-1])
03890 + (IF J>0 & J<=T2 THEN AVADDEDCAPY(J) ELSE 0)
03900 - (IF J>LIFE THEN AVADDEDCAPY(J-LIFE) ELSE 0);
03910 *
03920 COMMENT... WRITE RESULTS;
03930 FOR K:=0 STEP 1 UNTIL 10 DO
03940 FOR J:=0 STEP 1 UNTIL NSTEPS2 DO
03950 BEGIN
03960 IF J>0 AND J<=NSTEPS1 THEN
03970 DELTACOUT[K,J] := IF K=0 THEN 1985 + JYEAR[J,1]
03980 ELSE DELTAC[JYEAR[J,1]]*(IF K<10 THEN MP[K, JYEAR[J,1]]
03990 ELSE 1);
04000 CAPYOUT[K,J] := IF K=0 THEN 1985 + JYEAR[J,2]

```

Table D-20 (Cont'd)

```

04010         ELSE CAPY(K, JYEAR(J,2))
04020     END K & J;
04030     IF OUTSTEP<5 THEN WRITEHEAD (OUTFILE1, HEADFMT);
04040     WRITE (OUTFILE1, "(2X/ 6X, "CAPY ADDN RATE (GW/YR):", 94X,
04050         5HTOTAL/
04060         9X, 4H1985, -3PF115.1/
04070         (9X, 0PI4, 13X, -3P9F10.1, F12.1/))", DELTAC(0), DELTACOUT);
04080     IF OUTSTEP<5 THEN WRITEHEAD (OUTFILE1, HEADFMT);
04090     WRITE (OUTFILE1, "(2X/ 6X, "INSTALLED CAPY (GW):", 97X,
04100         5HTOTAL/
04110         (9X, 0PI4, 13X, -3P9F10.1, F12.1/))", CAPYOUT)
04120     END;
04130
04140     COMMENT... ADJUST CAPACITY FACTOR "CAPFAC" SO THAT PROPER TOTAL
04150     ENERGY IS GENERATED IN EACH YEAR;
04160     BEGIN
04170     REAL ARRAY CFOUT, ENERGYOUT(0:10, 1:NSTEPS2), CC(1:69);
04180     FOR J:=1 STEP 1 UNTIL T2+LIFE DO
04190     BEGIN
04200     REAL ENEWAV, E1, E2, KTO;
04210     REAL ARRAY ENEW(0: 2*(T2+LIFE));
04220     INTEGER J2, JJ;
04230     ,
04240     COMMENT... ENEW(J2) = ENERGY GENERATED BY "NEW" UNITS AT
04250     J2/2 YEARS AFTER END OF 1985;
04260     IF J=1 THEN KTO := 2^(T0/TD1 - T0/TD2);
04270     FOR J2 := (IF J=1 THEN 0 ELSE 2*J-1) STEP 1 UNTIL 2*J DO
04280     BEGIN
04290     REAL T;
04300     T := J2/2;
04310     ENEW(J2) := ENERGY0 * (
04320     IF J<=LIFE-T0 THEN
04330     2^(T/TD2) - 1 + KTO*(2^(T/TD1) - 1)/
04340     (2^(LIFE/TD1) - 1)
04350     ELSE IF J<LIFE THEN
04360     E1 + (2^(T/TD2) - 2^((LIFE-T0)/TD2))
04370     *(2^(-LIFE/TD2) + 1)
04380     + KTO*(2^(T/TD1) - 2^((LIFE-T0)/TD1))
04390     /(2^(LIFE/TD1) - 1)*2^(-LIFE/TD1)
04400     ELSE IF J<=T2 THEN 2^(T/TD2)
04410     ELSE IF J<=(2*LIFE - T0) THEN
04420     2^(T/TD2) - (2^(T/TD2) - 2^(T2/TD2))
04430     *(2^(-LIFE/TD2) + 1)
04440     - KTO*(2^(T/TD1) - 2^(T2/TD1))/(1 - 2^(-LIFE/TD1))
04450     *2^(-2*LIFE/TD1)
04460     ELSE !J<=T2+LIFE!
04470     2^(T/TD2) - E2 - (2^(T/TD2) - 2^((2*LIFE-T0)/TD2))
04480     *(1 + 2^(-LIFE/TD2) + 2^(-2*LIFE/TD2))
04490     - KTO*(2^(T/TD1) - 2^((2*LIFE-T0)/TD1))
04500     *2^(-3*LIFE/TD1) / (1 - 2^(-LIFE/TD1)) );
04510     IF J=LIFE-T0 THEN E1 := ENEW(J2)/ENERGY0;
04520     IF J=2*LIFE-T0 THEN E2 := 2^(T/TD2) - ENEW(J2)/ENERGY0;

```

Table D-20 (Cont'd)

```

04530      '
04540      COMMENT... CORRECT ENEW[J2] FOR DROP IN CAPFAC OF UNITS
04550          INSTALLED BEFORE 1986;
04560      IF J<LIFE THEN
04570          ENEW[J2] := ENEW[J2] + T/600 * CAPY0
04580          * (2*(T/TD2) - ENEW[J2]/ENERGY0)
04590      END J2;
04600      '
04610      COMMENT... CC = CORRECTION FACTOR FOR YEAR J;
04620      CC[J] := 0; !INITIALIZATION!
04630      IF J>T2 THEN JJ := NPERIOD ELSE
04640          BEGIN
04650              JJ := 0; FOR JJ := JJ+1 WHILE J>PEREND[JJ] DO
04660                  END;
04670          FOR K:=1 STEP 1 UNTIL 9 DO
04680              CC[J] := CC[J] + CAPFAC[K,JJ]*(CAPY[K,J-1] + CAPY[K,J])/2;
04690          ENEWAV := (ENEW[2*(J-1)] + 4*ENEW[2*J-1] + ENEW[2*J]) / 6;
04700          CC[J] := IF CC[J]=0 THEN 1 ELSE ENEWAV/CC[J];
04710      '
04720      COMMENT... ADJUST CAPACITY FACTOR;
04730      FOR K:=1 STEP 1 UNTIL 9 DO
04740          CF[K,J] := CC[J] * CAPFAC[K,JJ]
04750      END J;
04760      '
04770      COMMENT... WRITE ADJUSTED CAPY FACTORS AND ENERGY GENERATED;
04780      FOR J:=1 STEP 1 UNTIL NSTEPS2 DO
04790          BEGIN
04800              ENERGYOUT[10,J] := 0; !INITIALIZE SUM!
04810              FOR K:=0 STEP 1 UNTIL 10 DO
04820                  BEGIN
04830                      CFOUT[K,J] := IF K=0 THEN 1985 + JYEAR[J,2]
04840                          ELSE IF K<10 THEN CF[K, JYEAR[J,2]]
04850                          ELSE CC[JYEAR[J,2]];
04860                      ENERGYOUT[K,J] := IF K=0 THEN CFOUT[K,J]
04870                          ELSE IF K<10 THEN CFOUT[K,J] * (CAPY[K, JYEAR[J,2]-1]
04880                              + CAPY[K, JYEAR[J,2]]) / 2
04890                          ELSE ENERGYOUT[10,J];
04900                      IF K>0 & K<10 THEN
04910                          ENERGYOUT[10,J] := ENERGYOUT[10,J] + ENERGYOUT[K,J]
04920                      END K
04930                  END J;
04940              WRITEHEAD (OUTFILE1, HEADFMT);
04950              WRITE (OUTFILE1, "(2X/ 123X, ""CORR."" /
04960                  6X, ""ADJUSTED CAPY FACTORS:"", 94X, ""FACTOR"" /
04970                  (9X, I4, 13X, 9F10.4, F12.4/))", CFOUT);
04980              IF OUTSTEP<5 THEN WRITEHEAD (OUTFILE1, HEADFMT);
04990              WRITE (OUTFILE1,
05000                  "(2X/ 6X, ""ENERGY GENERATED"", 101X, 5HTOTAL/
05010                  6X, ""(GW-YR PER YEAR):"", 100X, 5H----/
05020                  (9X, 0P14, 13X, -3P9F10.1, F12.1/))", ENERGYOUT)
05030          END;
05040      '

```


Table D-20 (Cont'd)

```

05050 COMMENT... CALCULATE ESCALATED COSTS IN EACH YEAR FOR EACH CYCLE;
05060 BEGIN
05070 REAL ARRAY CFOMOUT, CVOMOUT, CFUELOUT(0:9, 0:NSTEPS2);
05080 '
05090 COMMENT... ESCALATE CAP, FIXED O&M, VAR O&M, AND FUEL COSTS;
05100 FOR K:=1 STEP 1 UNTIL 9 DO
05110 FOR J:=0 STEP 1 UNTIL T2+LIFE DO
05120 BEGIN
05130 IF J<=T2 THEN CCAPI[K,J] := IF J=0 THEN CCAPO[K]
05140 ELSE CCAPI[K,J-1] * (1 + ECAPI[K]);
05150 CFOM[K,J] := IF J=0 THEN CFOMO[K]
05160 ELSE CFOM[K,J-1] * (1 + EFOM[K]);
05170 CVOM[K,J] := IF J=0 THEN CVOMO[K]
05180 ELSE CVOM[K,J-1] * (1 + EVOM[K]);
05190 CFUEL[K,J] := IF J=0 THEN CFUELO[K]
05200 ELSE CFUEL[K,J-1] * (1 +
05210 (IF EFUEL[K]>0 THEN EFUEL[K]
05220 ELSE IF J<=JOIL(1) THEN EOIL(1)
05230 ELSE IF J<=JOIL(2) THEN EOIL(2) ELSE EOIL(3)))
05240 END K AND J;
05250 '
05260 COMMENT... WRITE ESCALATED FIXED O&M, VAR O&M, AND FUEL COSTS
05270 IF "NNT" SCENARIO;
05280 IF NONEW THEN
05290 BEGIN
05300 FOR K:=0 STEP 1 UNTIL 9 DO
05310 FOR J:=0 STEP 1 UNTIL NSTEPS2 DO
05320 BEGIN
05330 INTEGER JJ;
05340 JJ := IF J=NSTEPS2 THEN T2+LIFE ELSE J*OUTSTEP;
05350 CFOMOUT[K,J] := IF K=0 THEN 1985+JJ ELSE CFOM[K,JJ];
05360 CVOMOUT[K,J] := IF K=0 THEN 1985+JJ ELSE CVOM[K,JJ];
05370 CFUELOUT[K,J] := IF K=0 THEN 1985+JJ ELSE CFUEL[K,JJ]
05380 END;
05390 IF OUTSTEP<5 THEN WRITEHEAD (OUTFILE, HEADFMT0);
05400 WRITE (OUTFILE,
05410 "(2X/ 6X, ""ESCALATED COSTS:""/
05420 8X, ""FIXED O&M"", 4X, I4, 1X, 9F10.2/
05430 8X, ""($/KW-YR)"", 4X, I4, 1X, 9F10.2/
05440 (21X, I4, 1X, 9F10.2/))", CFOMOUT);
05450 WRITEHEAD (OUTFILE, HEADFMT0);
05460 WRITE (OUTFILE,
05470 "(2X/ 6X, ""ESCALATED COSTS:""/
05480 8X, ""VAR. O&M"", 5X, I4, 1X, 9F10.2/
05490 8X, ""(MILLS/KWHR)"", 1X, I4, 1X, 9F10.2/
05500 (21X, I4, 1X, 9F10.2/))", CVOMOUT);
05510 IF OUTSTEP<5 THEN WRITEHEAD (OUTFILE, HEADFMT0);
05520 WRITE (OUTFILE,
05530 "(2X/ 6X, ""ESCALATED COSTS:""/
05540 8X, ""FUEL"", 9X, I4, 1X, 9F10.2/
05550 8X, ""($/MBTU)"", 5X, I4, 1X, 9F10.2/
05560 (21X, I4, 1X, 9F10.2/))", CFUELOUT)

```

Table D-20 (Cont'd)

```

05570      END NONEW=TRUE
05580      END;
05590 '
05600 COMMENT... IF "NNT" SCENARIO, TRANSFER SCRATCH FILE TO OUTPUT FILE;
05610 IF NONEW THEN
05620     BEGIN
05630     STRING LINE;
05640     REWIND ("SCRFILE");
05650     ''' NEXTLINE: ''' READ ("SCRFILE", "(A)", LASTLINE, LINE);
05660     WRITE (OUTFILE, "(A)", LINE);
05670     GOTO NEXTLINE;
05680     ''' LASTLINE: ''' CLOSE ("SCRFILE");
05685     LINE := "";
05690     END;
05700 '
05710 COMMENT... CALCULATE 1975 WORTH OF ALL GENERATION COSTS;
05720     BEGIN
05730     REAL ARRAY WCAP, WFOM, WVOM, WFUEL[1:9],
05740     CCAPOUT, FOMFWOUT, VOMFWOUT, FUELFWOUT[0:9, 0:NSTEPS1],
05750     WORTHOUT[0:10, 0:NSTEPS1];
05760     REAL WCAPTOT, WFOMTOT, WVOMTOT, WFUELTOT;
05770     '
05780     WCAPTOT := WFOMTOT := WVOMTOT := WFUELTOT := WGENTOT := 0;
05790     '
05800     FOR K:=1 STEP 1 UNTIL 9 DO
05810         BEGIN
05820             WCAP[K] := WFOM[K] := WVOM[K] := WFUEL[K] := 0;
05830             FOR J:=0 STEP 1 UNTIL T2 DO
05840                 BEGIN
05850                     INTEGER JTAU;
05860                     REAL FOMFW, VOMFW, FUELFW, JSIMP, FACTOR;
05870                     '
05880                     FOMFW := VOMFW := FUELFW := 0;
05890                     '
05900                     COMMENT... INTEGRATE RECURRING COSTS OVER LIFETIME;
05910                     FOR JTAU:=0 STEP 1 UNTIL LIFE DO
05920                         BEGIN
05930                             REAL DISCOUNT, KSIMP, CFAV;
05940                             DISCOUNT := (1+R)^(-JTAU);
05950                             KSIMP := IF JTAU=0 OR JTAU=LIFE THEN 1/3
05960                                 ELSE IF MOD(JTAU,2)=0 THEN 2/3 ELSE 4/3;
05970                             CFAV := IF J+JTAU=0 THEN (3*CF[K,1] - CF[K,2]) / 2
05980                                 ELSE IF J+JTAU=T2+LIFE THEN
05990                                     (3*CF[K, T2+LIFE] - CF[K, T2+LIFE-1]) / 2
06000                                 ELSE (CF[K, J+JTAU] + CF[K, J+JTAU+1]) / 2;
06010                             !INTERPOLATE OR EXTRAPOLATE FROM MIDYEAR VALUES
06020                             TO YEAR-END VALUES!
06030                             FOMFW := FOMFW + CFOM[K,J+JTAU]*DISCOUNT*KSIMP;
06040                             VOMFW := VOMFW + CVOM[K,J+JTAU] * CFAV
06050                             * DISCOUNT * KSIMP;
06060                             FUELFW := FUELFW + HR[K] * CFUEL[K,J+JTAU]
06070                             * CFAV * DISCOUNT * KSIMP

```

Table D-20 (Cont'd)

```

06080      END JTAU;
06090      ,
06100      VOMFW := VOMFW * 8.76;  !HR/YR X $/MILL!
06110      FUELFW := FUELFW * 8.76E-3;  !HR/YR X MBTU/BTU!
06120      ,
06130      COMMENT... STORE OUTPUTS FOR SELECTED YEARS;
06140      IF MOD(J,OUTSTEP)=0 OR J=T2 THEN
06150          BEGIN
06160              INTEGER JOUT;
06170              JOUT := IF J<T2 THEN J%OUTSTEP ELSE NSTEPS1;
06180              CCAPOUT(K,JOUT) := IF CAPY(K,T2)>0 THEN CCAPI(K,J) ELSE 0;
06190              FOMFWOUT(K,JOUT) := IF CAPY(K,T2)>0 THEN FOMFW ELSE 0;
06200              VOMFWOUT(K,JOUT) := VOMFW;
06210              FUELFWOUT(K,JOUT) := FUELFW
06220          END;
06230      ,
06240      COMMENT... INTEGRATE OVER YEARS OF INSTALLATION;
06250      JSIMP := IF J=0 OR J=T2 THEN 1/3
06260          ELSE IF MOD(J,2)=0 THEN 2/3 ELSE 4/3;
06270      IF MOD(T2,2)>0 AND J>=T2-2 THEN
06280          JSIMP := IF J=T2 THEN 5/12 ELSE IF J=T2-1 THEN 1
06290              ELSE !J=T2-2! 5/4;  !CORRECTION FOR ODD NR STEPS!
06300      FACTOR := (1+R)^(-(J+10)) * 1E-3 !KW/MW X MS/$!
06310          * DELTAC(J) *
06320          (IF J=0 THEN (3*MP(K,1) - MP(K,2)) / 2
06330              ELSE IF J=T2 THEN (3*MP(K,T2) - MP(K,T2-1)) / 2
06340              ELSE (MP(K,J) + MP(K,J+1)) / 2);
06350          !INTERPOLATE OR EXTRAPOLATE FROM MIDYEAR VALUES
06360          OF MKT PEN "MP" TO YEAR-END VALUES!
06370      WCAPI(K) := WCAPI(K) + JSIMP*FACTOR*CCAPI(K,J);
06380      WFOM(K) := WFOM(K) + JSIMP*FACTOR*FOMFW;
06390      WVOM(K) := WVOM(K) + JSIMP*FACTOR*VOMFW;
06400      WFUEL(K) := WFUEL(K) + JSIMP*FACTOR*FUELFW;
06410      ,
06420      COMMENT... STORE 1975 WORTHS FOR SUBSEQUENT PRINTING;
06430      IF MOD(J,OUTSTEP)=0 OR J=T2 THEN
06440          WORTHOUT(K,IF J=T2 THEN NSTEPS1 ELSE J%OUTSTEP) :=
06450              FACTOR*(CCAPI(K,J) + FOMFW + VOMFW + FUELFW)
06460      END J;
06470      ,
06480      COMMENT... GET TOTALS OVER CYCLES;
06490      WCAPTOT := WCAPTOT + WCAPI(K);
06500      WFOMTOT := WFOMTOT + WFOM(K);
06510      WVOMTOT := WVOMTOT + WVOM(K);
06520      WFUELTOT := WFUELTOT + WFUEL(K);
06530      WGEN(K) := WCAPI(K) + WFOM(K) + WVOM(K) + WFUEL(K);
06540      WGENTOT := WGENTOT + WGEN(K)
06550      END K;
06560      ,
06570      COMMENT... WRITE RESULTS FOR GENERATING COSTS;
06580      WRITEHEAD (OUTFILE, HEADFMT);
06590      FOR J:=0 STEP 1 UNTIL NSTEPS1 DO

```

Table D-20 (Cont'd)

```

06600      CCAPOUT[0,J] := FOMFWOUT[0,J] := VOMFWOUT[0,J] :=
06610      FUELFWOUT[0,J] := WORTHOUT[0,J] := 1985 + JYEAR[J,1];
06620      WRITE (OUTFILE,
06630      "(2X/ 6X, ""FUTURE LIFE-CYCLE""/
06640      6X, ""WORTHS ($/KW):""/
06650      8X, ""CAPITAL"", 6X, I4, 1X, 9F10.2/
06660      (21X, I4, 1X, 9F10.2/))", CCAPOUT);
06670      IF OUTSTEP<3 THEN WRITEHEAD (OUTFILE, HEADFMT);
06680      WRITE (OUTFILE,
06690      "(2X/ 6X, ""FUT L-C WORTH ($/KW):""/
06700      8X, ""FIXED O&M"", 4X, I4, 1X, 9F10.2/
06710      (21X, I4, 1X, 9F10.2/))", FOMFWOUT);
06720      IF OUTSTEP<5 THEN WRITEHEAD (OUTFILE, HEADFMT);
06730      WRITE (OUTFILE,
06740      "(2X/ 6X, ""FUT L-C WORTH ($/KW):""/
06750      8X, ""VAR. O&M"", 5X, I4, 1X, 9F10.2/
06760      (21X, I4, 1X, 9F10.2/))", VOMFWOUT);
06770      IF OUTSTEP<3 THEN WRITEHEAD (OUTFILE, HEADFMT);
06780      WRITE (OUTFILE,
06790      "(2X/ 6X, ""FUT L-C WORTH ($/KW):""/
06800      8X, ""FUEL"", 9X, I4, 1X, 9F10.2/
06810      (21X, I4, 1X, 9F10.2/))", FUELFWOUT);
06820      WRITEHEAD (OUTFILE, HEADFMT);
06830      FOR J:=0 STEP 1 UNTIL NSTEPS1 DO
06840      BEGIN
06850      WORTHOUT[10,J] := 0;
06860      FOR K:=1 STEP 1 UNTIL 9 DO WORTHOUT[10,J] :=
06870      WORTHOUT[10,J] + WORTHOUT[K,J]
06880      END J;
06890      WRITE (OUTFILE,
06900      "(2X/ 6X, ""1975 WORTH (B$) OF"", 99X, 5HTOTAL/
06910      6X, ""UNITS INSTALLED IN:"", 98X, 5H-----/
06920      (9X, OPI4, 13X, -3P9F10.3, F12.3/))", WORTHOUT);
06930      IF OUTSTEP<5 THEN WRITEHEAD (OUTFILE, HEADFMT);
06940      WRITE (OUTFILE,
06950      "(2X/ 6X, ""INTEGRATED 1975"", 102X, ""TOTAL""/
06960      6X, ""WORTHS (B$):"", 105X, 5(1H-)/
06970      9X, ""CAPITAL"", 10X, -3P9F10.3, F12.3/
06980      9X, ""FIXED O&M"", 8X, 9F10.3, F12.3/
06990      9X, ""VAR. O&M"", 9X, 9F10.3, F12.3/
07000      9X, ""FUEL"", 13X, 9F10.3, F12.3/
07010      9X, ""TOTAL FOR GEN."", 3X, 9F10.3, F12.3)",
07020      WCAP, WCAPTOT, WFOM, WFOMTOT, WVOM, WVOMTOT,
07030      WFUEL, WFUELTOT, WGEN, WGENTOT)
07040      END;
07050
07060      COMMENT... COMPUTE 1985 WORTH OF R&D PROGRAMS;
07070      BEGIN
07080      WRDTOT := 0;
07090      FOR K:=7 STEP 1 UNTIL 9 DO
07100      BEGIN
07110      REAL RRD;

```

Table D-20 (Cont'd)

```

07120      RRD := (1+R)/(1+ERD(K)) - 1; !EFFECTIVE DISCOUNT RATE!
07130      T1(K) := T1(K) + 8; !START IN 1978 INSTEAD OF 1986!
07140      WRD(K) := CERD(K)/T1(K) * (1 - (1+RRD)-T1(K))
07150          / LN(1+RRD);
07160      WRDTOT := WRDTOT + WRD(K)
07170      END K;
07180      *
07190      WRITE (OUTFILE, "(2X/ 9X, ""R&D PROGRAM"", 6X, -3P9F10.3,
07200          F12.3)", WRD, WRDTOT)
07210      END;
07220      *
07230      COMMENT... CALCULATE NET WORTH (GENERATION + R&D), AND COMPARE TO
07240      NO NEW TECHNOLOGY CASE TO OBTAIN SAVINGS;
07250      BEGIN
07260      REAL WNETREF;
07270      FOR K:=1 STEP 1 UNTIL 9 DO
07280          WNET(K) := WGEN(K) + WRD(K);
07290      WNETTOT := WRDTOT + WGENTOT;
07300      WRITE (OUTFILE, "(2X/ 9X, ""TOTAL"", 12X, -3P9F10.3, F12.3/
07310          120X, 8(1H=)/ 2X)", WNET, WNETTOT);
07320      *
07330      COMMENT... IF THIS IS "NO NEW TECHNOLOGY" SCENARIO THEN WRITE
07340      NET WORTH INTO FILE, OTHERWISE READ THAT FILE;
07350      IF NONEW THEN
07360          !BEGIN
07370          OPENT ("WNETREF", "", "/CYCLES3/OUTPUT/WNETREF");
07380          ENDFILE ("WNETREF");
07390          WRITE ("WNETREF", "(V)", WNETTOT);
07400          CLOSE ("WNETREF");
07410          END ... WNETREF NOW VAR. OF MAIN! WNETREF := WNETTOT
07420      ELSE
07430          BEGIN
07440          !OPENSHR ("WNETREF", "", "/CYCLES3/OUTPUT/WNETREF,R");
07450          READ ("WNETREF", "(V)", ERROR, WNETREF);
07460          CLOSE ("WNETREF");
07470          GOTO SAVINGS;
07480          *
07490          *** ERROR: ***
07500          BEGIN
07510          PRINTF ("("NO DATA IN FILE "", 9H"WNETREF"",
07520              "" FROM NO-NEW-TECHNOLOGY SCENARIO."" /
07530              "" UNABLE TO COMPUTE SAVINGS..."");
07540          GOTO LAST
07550          END;
07560          *
07570          *** SAVINGS: *** .....!
07580          WSAV := WNETREF - WNETTOT;
07590          WRITE (OUTFILE, "(1H0, 53X, ""WORTH OF SAVINGS ="",
07600              -3PF9.3, "" B$""", WSAV)
07610          END ELSECLAUSE;
07620          *
07630      COMMENT... IDENTIFY CONDITIONS;

```


Table D-20 (Cont'd)

```

08080      GOTO NEXTSCEN
08090      END;
08100      '
08110      COMMENT... PRINT OUTPUT;
08120      PRINTF ("(3(2X/), "" NUMBER OF COPIES OF OUTPUT""");
08130      INPUT (NCOPIES);
08140      PRINT (" ");
08150      FOR KOPY:=1 STEP 1 UNTIL NCOPIES DO
08160          BEGIN
08170              STRING LINE;
08180              PRINTF ("(1H1/ 28(2X/), 62X, 4HCOPY, I2)", KOPY);
08190              REWIND (OUTFILE);
08200              ''' NEXTLINE: READ (OUTFILE, "(A)", LASTLINE, LINE);
08210              PRINTF ("(A)", LINE);
08220              GOTO NEXTLINE;
08230              ''' LASTLINE:
08240              END KOPY;
08250      '
08260      CLOSE (OUTFILE)
08270      END PROGRAM

```

Table D-21 is a one-page listing of file IT-TF-5, which is a typical set of control card images for running the batch program "BWORDH". The lines of this file are explained as follows:

0010	Information for tabbing and remote station destination (LB); normally not changed.
0020	Identification line. Change all data after the comma on this line, to describe the current run appropriately.
0030-0130	Control card images to compile and execute; normally not changed. Note that 0080 calls in the source program "BWORDH".
0140-0240	Data to answer questions asked by "BWORDH". These lines are described in more detail below; note that the order of the questions asked by BWORDH differs from the order in WORTH:
0150	Answer to question, YEARS BETWEEN OUTPUT STEPS? (See Table D-19)
0160	Answer to question, ADJUST FOR INTANGIBLES (T OR F)?
0170	Answer to question, CONSIDER TAXES (T OR F)?
0180-0230	Answers to repeated question, FILENAME CONTAINING OGP OUTPUTS?. Note that after the last scenario filename has been entered, a null response is required (line 0230).
0240	Answer to question, NUMBER OF COPIES OF OUTPUT?

Table D-22 is a one-page listing of file CRUNALL. This file can be used as a script file under the CRUN system to run BWORDH under all variations considered.

Table D-21
CONTROL CARDS FOR BATCH PROGRAM

```
*****
J.J.FLECK1/CYCLES3/RUN/IT-TF-5          09/10/77    11:37 AM
*****
```

```
0010*#H(2).R(LB)
0020*IDENT#J.J.FLECK1,INTANG T - TAXES F - 5 YR STEP
0030*OPTION#ALGOL,NOFC
0040*USE#.XR./36/.,.000-0/136/
0050*ALGOL#NLRO,NDECK,SC11
0060*LIMITS#2,32K
0070*PRMFL***,R,R,LIBRARY/.00A
0080*SELECTA#/CYCLES3/ WORTH
0090*LIBRARY#AR
0100*USE#.UTLIT
0110*EXECUTE
0120*LIMITS#10,36K,-1K,30K
0130*PRMFL#AR,R,R,LIBRARY/ALG-LIB
0140*DATA#1*
0150*5
0160*T
0170*F
0180*SCEN-JNT
0190*SCEN-ATP
0200*SCEN-CC
0210*SCEN-MHD
0220*SCEN-CH
0230*
0240*3
0250*#ENDJOB
```

Table D-22
SCRIPT FILE FOR SENSITIVITY RUNS

```
*****
J.J.FLECK1/CYCLES3/RUN/CRUALL          09/10/77    11:37 AM
*****
```

```
SYST CARD
H
RUN /CYCLES3/RUN/IT-TT-
RUN /CYCLES3/RUN/IT-TF-
RUN /CYCLES3/RUN/IF-TF-
RUN /CYCLES3/RUN/IF-TT-
RUN /CYCLES3/RUN/T1.1-F*5
RUN /CYCLES3/RUN/T1.2-F*5
RUN /CYCLES3/RUN/T1.1-T*5
RUN /CYCLES3/RUN/T1.2-T*5
RUN /CYCLES3/RUN/IT-TF-1
```

Data Files for OGP Outputs

Table D-23 contains listing of five data files, corresponding to five scenarios for which OGP was run. Each of these data files was prepared by summarizing OGP outputs, as an input file to the Net Present Worth computer program.

Each of these files appears in the following format:

- First line — Scenario name
- Second line — Number of periods into which OGP outputs are summarized
- Third line — Years in which the periods end
- All subsequent lines —
 - Word beginning in Column 1, Cycle name
 - All other words — Two numbers separated by commas. These numbers are the average values of market penetration f_{kj} and capacity factor F_{kj} , respectively, for cycle k in period j .

Table D-23
DATA FILES — OGP INPUTS

J.J.FLECK1/CYCLES3/OGP-OUT/SCEN-NNT

09/10/77

11:36 AM

NO NEW TECHNOLOGY

4 PERIODS

YEAR-ENDS	1994	2004	2014	2024
STLWR	.750,.710	.858,.630	.674,.600	.847,.600
STSCRB	.187,.300	.092,.270	.037,.250	.033,.240
GT/OIL	.063,.066	0,.051	0,.010	0,.001
GT/SCL	0,0	.050,.012	.227,.023	.120,.014
GTCC/OIL	0,0	0,0	0,0	0,0
GTCC/SCL	0,0	0,0	.062,.120	0,.140
STAFB	0,0	0,0	0,0	0,0
GTWCCE	0,0	0,0	0,0	0,0
OCMHD	0,0	0,0	0,0	0,0

J.J.FLECK1/CYCLES3/OGP-OUT/SCEN-AFB

09/10/77

11:36 AM

"STAFB" - MINIMUM COMPETITION

5 PERIODS

YEAR-ENDS	1987	1994	2004	2014	2024
STLWR	1.000,.720	0,.740	.439,.730	.289,.730	.376,.730
STSCRB	0,0	0,0	0,0	0,0	0,0
GT/OIL	0,0	.048,.035	0,.033	0,.009	0,.001
GT/SCL	0,0	0,0	.073,.005	.176,.004	.125,.004
GTCC/OIL	0,0	0,0	0,0	0,0	0,0
GTCC/SCL	0,0	0,0	0,0	.181,.025	0,.025
STAFB	0,0	.952,.480	.488,.490	.354,.440	.499,.440
GTWCCE	0,0	0,0	0,0	0,0	0,0
OCMHD	0,0	0,0	0,0	0,0	0,0

Table D-23 (Cont'd)

J.J.FLECK1/CYCLES3/OGP-OUT/SCEN-CC

09/10/77

11:36 AM

"GTWCCE" - MINIMUM COMPETITION

4 PERIODS

YEAR-ENDS	1995	2004	2014	2024
STLWR	.769,.700	0,.710	0,.720	0,.720
STSCR	.172,.300	0,.160	0,.110	0,.160
GT/OIL	.059,.067	0,.020	0,.004	0,.000
GT/SCL	0,0	.019,.005	.304,.007	.160,.010
GTCC/OIL	0,0	0,0	0,0	0,0
GTCC/SCL	0,0	0,0	.073,.055	0,.055
STAFB	0,0	0,0	0,0	0,0
GTWCCE	0,0	.981,.520	.623,.570	.840,.620
OCMHD	0,0	0,0	0,0	0,0

J.J.FLECK1/CYCLES3/OGP-OUT/SCEN-MHD

09/10/77

11:36 AM

"OCMHD" - MINIMUM COMPETITION (1932 MW)

5 PERIODS

YEAR-ENDS	1994	2004	2008	2014	2024
STLWR	.750,.710	.858,.630	.506,.590	0,.570	0,.510
STSCR	.187,.300	.092,.270	0,.170	0,.240	0,.160
GT/OIL	.063,.066	0,.051	0,.026	0,.005	0,.006
GT/SCL	0,0	.050,.012	.253,.012	.052,.031	.076,.027
GTCC/OIL	0,0	0,0	0,0	0,0	0,0
GTCC/SCL	0,0	0,0	.241,.054	0,.100	0,.082
STAFB	0,0	0,0	0,0	0,0	0,0
GTWCCE	0,0	0,0	0,0	0,0	0,0
OCMHD	0,0	0,0	0,0	.948,.680	.924,.630

Table D-23 (Cont'd)

J.J.FLECK1/CYCLES3/OGP-OUT/SCEN-CM

09/10/77

11:36 AM

CROWDED MARKET

5 PERIODS

YEAR-ENDS	1987	1995	2005	2014	2024
STLWR	1.000,.720	0,.740	0,.730	0,.720	0,.720
STSCR	0,0	0,0	0,0	0,0	0,0
GT/OIL	0,0	.042,.044	0,.023	0,.010	0,.001
GT/SCL	0,0	.069,.004	.057,.004	.254,.012	.129,.012
GTCC/OIL	0,0	0,0	0,0	0,0	0,0
GTCC/SCL	0,0	0,0	0,0	0,0	0,0
STAFB	0,0	.889,.490	.123,.360	0,.280	0,.210
GTWCCE	0,0	0,0	.820,.760	.225,.660	.519,.600
OCMHD	0,0	0,0	0,0	.521,.680	.352,.680

Table D-24 lists twelve data files. These are similar to the OGP output data files of Table D-23, except that the years in which a cycle is introduced are varied. All are for Minimum Competition Scenarios: four variations of T_1 for each of the three cycles considered in minimum competition. Format for these data files is the same as for the OGP output data files in Table D-23.

The names of these 12 data files and the corresponding variations in T_1 are as follows:

<u>File Name</u>	<u>T_1 Variation</u>
SC-AFB-2	STAFB introduced 2 years early (Jan 1986)
SC-AFB-1	STAFB introduced 1 year early (Jan 1987)
SC-AFB.1	STAFB introduced 1 year late (Jan 1989)
SC-AFB.2	STAFB introduced 2 years late (Jan 1990)
SC-CC-2	GTWCCE introduced 2 years early (Jan 1994)
SC-CC-1	GTWCCE introduced 1 year early (Jan 1995)
SC-CC.1	GTWCCE introduced 1 year late (Jan 1997)
SC-CC.2	GTWCCE introduced 2 years late (Jan 1998)
SC-MHD-2	OCMHD introduced 2 years early (Jan 2007)
SC-MHD-1	OCMHD introduced 1 year early (Jan 2008)
SC-MHD.1	OCMHD introduced 1 year late (Jan 2010)
SC-MHD.2	OCMHD introduced 2 years late (Jan 2011)

Table D-24

DATA FILES — VARIATIONS OF T₁

J.J.FLECK1/CYCLES3/OGP-OUT/SC-AFB-2

09/10/77

11:36 AM

"STAFB" - MINIMUM COMPETITION (T1 HASTENED 2 YEARS)

4 PERIODS

YEAR-ENDS	1994	2004	2014	2024
STLWR	0,.740	.439,.730	.289,.730	.376,.730
STSCRB	0,0	0,0	0,0	0,0
GT/OIL	.048,.035	0,.033	0,.009	0,.001
GT/SCL	0,0	.073,.005	.176,.004	.125,.004
GTCC/OIL	0,0	0,0	0,0	0,0
GTCC/SCL	0,0	0,0	.181,.025	0,.025
STAFB	.952,.480	.488,.490	.354,.440	.499,.440
GTWCCE	0,0	0,0	0,0	0,0
OCMHD	0,0	0,0	0,0	0,0

J.J.FLECK1/CYCLES3/OGP-OUT/SC-AFB-1

09/10/77

11:36 AM

"STAFB" - MINIMUM COMPETITION

5 PERIODS

YEAR-ENDS	1986	1994	2004	2014	2024
STLWR	1.000,.720	0,.740	.439,.730	.289,.730	.376,.730
STSCRB	0,0	0,0	0,0	0,0	0,0
GT/OIL	0,0	.048,.035	0,.033	0,.009	0,.001
GT/SCL	0,0	0,0	.073,.005	.176,.004	.125,.004
GTCC/OIL	0,0	0,0	0,0	0,0	0,0
GTCC/SCL	0,0	0,0	0,0	.181,.025	0,.025
STAFB	0,0	.952,.480	.488,.490	.354,.440	.499,.440
GTWCCE	0,0	0,0	0,0	0,0	0,0
OCMHD	0,0	0,0	0,0	0,0	0,0

Table D-24 (Cont'd)

J.J.FLECK1/CYCLES3/OGP-OUT/SC-AFB.1

09/10/77

11:36 AM

"STAFB" - MINIMUM COMPETITION

5 PERIODS

YEAR-ENDS	1988	1994	2004	2014	2024
STLWR	1.000,.720	0,.740	.439,.730	.289,.730	.376,.730
STSCRB	0,0	0,0	0,0	0,0	0,0
GT/OIL	0,0	.048,.035	0,.033	0,.009	0,.001
GT/SCL	0,0	0,0	.073,.005	.176,.004	.125,.004
GTCC/OIL	0,0	0,0	0,0	0,0	0,0
GTCC/SCL	0,0	0,0	0,0	.181,.025	0,.025
STAFB	0,0	.952,.480	.488,.490	.354,.440	.499,.440
GTWCCE	0,0	0,0	0,0	0,0	0,0
OCMHD	0,0	0,0	0,0	0,0	0,0

J.J.FLECK1/CYCLES3/OGP-OUT/SC-AFB.2

09/10/77

11:36 AM

"STAFB" - MINIMUM COMPETITION

5 PERIODS

YEAR-ENDS	1989	1994	2004	2014	2024
STLWR	1.000,.720	0,.740	.439,.730	.289,.730	.376,.730
STSCRB	0,0	0,0	0,0	0,0	0,0
GT/OIL	0,0	.048,.035	0,.033	0,.009	0,.001
GT/SCL	0,0	0,0	.073,.005	.176,.004	.125,.004
GTCC/OIL	0,0	0,0	0,0	0,0	0,0
GTCC/SCL	0,0	0,0	0,0	.181,.025	0,.025
STAFB	0,0	.952,.480	.488,.490	.354,.440	.499,.440
GTWCCE	0,0	0,0	0,0	0,0	0,0
OCMHD	0,0	0,0	0,0	0,0	0,0

Table D-24 (Cont'd)

J.J.FLECK1/CYCLES3/OGP-OUT/SC-CC-2

09/10/77

11:36 AM

"GTWCCE" - MINIMUM COMPETITION

4 PERIODS

YEAR-ENDS	1993	2004	2014	2024
STLWR	.769,.700	0,.710	0,.720	0,.720
STSCR8	.172,.300	0,.160	0,.110	0,.160
GT/OIL	.059,.067	0,.020	0,.004	0,.000
GT/SCL	0,0	.019,.005	.304,.007	.160,.010
GTCC/OIL	0,0	0,0	0,0	0,0
GTCC/SCL	0,0	0,0	.073,.055	0,.055
STAFB	0,0	0,0	0,0	0,0
GTWCCE	0,0	.981,.520	.623,.570	.840,.620
OCMHD	0,0	0,0	0,0	0,0

J.J.FLECK1/CYCLES3/OGP-OUT/SC-CC-1

09/10/77

11:36 AM

"GTWCCE" - MINIMUM COMPETITION

4 PERIODS

YEAR-ENDS	1994	2004	2014	2024
STLWR	.769,.700	0,.710	0,.720	0,.720
STSCR8	.172,.300	0,.160	0,.110	0,.160
GT/OIL	.059,.067	0,.020	0,.004	0,.000
GT/SCL	0,0	.019,.005	.304,.007	.160,.010
GTCC/OIL	0,0	0,0	0,0	0,0
GTCC/SCL	0,0	0,0	.073,.055	0,.055
STAFB	0,0	0,0	0,0	0,0
GTWCCE	0,0	.981,.520	.623,.570	.840,.620
OCMHD	0,0	0,0	0,0	0,0

Table D-24 (Cont'd)

J.J.FLECK1/CYCLES3/OGP-OUT/SC-CC.1

09/10/77

11:36 AM

"GTWCCE" - MINIMUM COMPETITION

4 PERIODS

YEAR-ENDS	1996	2004	2014	2024
STLWR	.769,.700	0,.710	0,.720	0,.720
STSCR	.172,.300	0,.160	0,.110	0,.160
GT/OIL	.059,.067	0,.020	0,.004	0,.000
GT/SCL	0,0	.019,.005	.304,.007	.160,.010
GTCC/OIL	0,0	0,0	0,0	0,0
GTCC/SCL	0,0	0,0	.073,.055	0,.055
STAFB	0,0	0,0	0,0	0,0
GTWCCE	0,0	.981,.520	.623,.570	.840,.620
OCMHD	0,0	0,0	0,0	0,0

J.J.FLECK1/CYCLES3/OGP-OUT/SC-CC.2

09/10/77

11:36 AM

"GTWCCE" - MINIMUM COMPETITION

4 PERIODS

YEAR-ENDS	1997	2004	2014	2024
STLWR	.769,.700	0,.710	0,.720	0,.720
STSCR	.172,.300	0,.160	0,.110	0,.160
GT/OIL	.059,.067	0,.020	0,.004	0,.000
GT/SCL	0,0	.019,.005	.304,.007	.160,.010
GTCC/OIL	0,0	0,0	0,0	0,0
GTCC/SCL	0,0	0,0	.073,.055	0,.055
STAFB	0,0	0,0	0,0	0,0
GTWCCE	0,0	.981,.520	.623,.570	.840,.620
OCMHD	0,0	0,0	0,0	0,0

Table D-24 (Cont'd)

J.J.FLECK1/CYCLES3/OGP-OUT/SC-MHD-2

09/10/77

11:36 AM

"OCMHD" - MINIMUM COMPETITION (1932 MW)

5 PERIODS

YEAR-ENDS	1994	2004	2006	2014	2024
STLWR	.750,.710	.858,.630	.506,.590	0,.570	0,.510
STSCRB	.187,.300	.092,.270	0,.170	0,.240	0,.160
GT/OIL	.063,.066	0,.051	0,.026	0,.005	0,.006
GT/SCL	0,0	.050,.012	.253,.012	.052,.031	.076,.027
GTCC/OIL	0,0	0,0	0,0	0,0	0,0
GTCC/SCL	0,0	0,0	.241,.054	0,.100	0,.082
STAFB	0,0	0,0	0,0	0,0	0,0
GTWCCE	0,0	0,0	0,0	0,0	0,0
OCMHD	0,0	0,0	0,0	.948,.680	.924,.630

J.J.FLECK1/CYCLES3/OGP-OUT/SC-MHD-1

09/10/77

11:36 AM

"OCMHD" - MINIMUM COMPETITION (1932 MW)

5 PERIODS

YEAR-ENDS	1994	2004	2007	2014	2024
STLWR	.750,.710	.858,.630	.506,.590	0,.570	0,.510
STSCRB	.187,.300	.092,.270	0,.170	0,.240	0,.160
GT/OIL	.063,.066	0,.051	0,.026	0,.005	0,.006
GT/SCL	0,0	.050,.012	.253,.012	.052,.031	.076,.027
GTCC/OIL	0,0	0,0	0,0	0,0	0,0
GTCC/SCL	0,0	0,0	.241,.054	0,.100	0,.082
STAFB	0,0	0,0	0,0	0,0	0,0
GTWCCE	0,0	0,0	0,0	0,0	0,0
OCMHD	0,0	0,0	0,0	.948,.680	.924,.630

Table D-24 (Cont'd)

J.J.FLECK1/CYCLES3/OGP-OUT/SC-MHD.1

09/10/77

11:36 AM

"OCMHD" - MINIMUM COMPETITION (1932 MW)

5 PERIODS

YEAR-ENDS	1994	2004	2009	2014	2024
STLWR	.750,.710	.858,.630	.506,.590	0,.570	0,.510
STSCR	.187,.300	.092,.270	0,.170	0,.240	0,.160
GT/OIL	.063,.066	0,.051	0,.026	0,.005	0,.006
GT/SCL	0,0	.050,.012	.253,.012	.052,.031	.076,.027
GTCC/OIL	0,0	0,0	0,0	0,0	0,0
GTCC/SCL	0,0	0,0	.241,.054	0,.100	0,.082
STAFB	0,0	0,0	0,0	0,0	0,0
GTWCCE	0,0	0,0	0,0	0,0	0,0
OCMHD	0,0	0,0	0,0	.948,.680	.924,.630

J.J.FLECK1/CYCLES3/OGP-OUT/SC-MHD.2

09/10/77

11:36 AM

"OCMHD" - MINIMUM COMPETITION (1932 MW)

5 PERIODS

YEAR-ENDS	1994	2004	2010	2014	2024
STLWR	.750,.710	.858,.630	.506,.590	0,.570	0,.510
STSCR	.187,.300	.092,.270	0,.170	0,.240	0,.160
GT/OIL	.063,.066	0,.051	0,.026	0,.005	0,.006
GT/SCL	0,0	.050,.012	.253,.012	.052,.031	.076,.027
GTCC/OIL	0,0	0,0	0,0	0,0	0,0
GTCC/SCL	0,0	0,0	.241,.054	0,.100	0,.082
STAFB	0,0	0,0	0,0	0,0	0,0
GTWCCE	0,0	0,0	0,0	0,0	0,0
OCMHD	0,0	0,0	0,0	.948,.680	.924,.630

Data Files for Cycle Costs

Table D-25 lists nine data files, which are the data pertaining to costs for the nine cycles considered in this study. Format for each of these files is as follows:

<u>Line No.</u>	<u>Data</u>
1	Cycle acronym
2	"R&D" R&D Cost (M\$), R&D escalation rate, T_1 (yrs from 1985 to first introduction)
3	"CAP" Capital cost (\$/kW), Capital escalation rate
4	"FOM" Fixed O&M cost (\$/kW-yr), Fixed-O&M escalation rate
5	"VOM" Variable O&M cost (mills/kW-hr), Variable-O&M escalation rate
6	"FUEL" Input fuel cost (\$/MBtu), Fuel escalation rate (-1 if fuel is oil, which has special escalation)
7	"HR" Heat rate (Btu/kW-hr elec)

Table D-25
DATA FILES FOR CYCLE COSTS

J.J.FLECK1/CYCLES3/COSTDATA/COST1 09/10/77 11:37 AM

STLWR
R&D 0. .065 0
CAP 776. .065
FOM 2.67 .065
VOM 0.68 .065
FUEL 0.52 .074
HR 10400

J.J.FLECK1/CYCLES3/COSTDATA/COST2 09/10/77 11:37 AM

STSCR
R&D 0. .065 0
CAP 591. .065
FOM 2.44 .065
VOM 2.18 .065
FUEL 0.94 .072
HR 10736

J.J.FLECK1/CYCLES3/COSTDATA/COST3 09/10/77 11:37 AM

GT/OIL
R&D 0. .065 0
CAP 116. .065
FOM 0.53 .065
VOM 1.37 .065
FUEL 1.85 -1
HR 11013

Table D-25 (Cont'd)

J.J.FLECK1/CYCLES3/COSTDATA/COST4

09/10/77

11:37 AM

GT/SCL

R&D 0. .065 0

CAP 116. .065

FOM 0.53 .065

VOM 1.37 .065

FUEL 3.50 .072

HR 11013

J.J.FLECK1/CYCLES3/COSTDATA/COST5

09/10/77

11:37 AM

GTCC/OIL

R&D 0. .065 0

CAP 282. .065

FOM 1.44 .065

VOM 1.29 .065

FUEL 1.85 -1

HR 8014

J.J.FLECK1/CYCLES3/COSTDATA/COST6

09/10/77

11:37 AM

GTCC/SCL

R&D 0. .065 0

CAP 282. .065

FOM 1.44 .065

VOM 1.29 .065

FUEL 3.50 .072

HR 8014

Table D-25 (Cont'd)

J.J.FLECK1/CYCLES3/COSTDATA/COST7

09/10/77

11:37 AM

STAFB

R&D 228. .065 3
CAP 447. .065
FOM 2.68 .065
VOM 1.75 .065
FUEL 0.94 .072
HR 9536

J.J.FLECK1/CYCLES3/COSTDATA/COST8

09/10/77

11:37 AM

GTWCCE

R&D 418. .065 11
CAP 474. .065
FOM 1.25 .065
VOM 1.83 .065
FUEL 0.94 .072
HR 7759

J.J.FLECK1/CYCLES3/COSTDATA/COST9

09/10/77

11:37 AM

OCMHD

R&D 1444. .065 18
CAP 477. .065
FOM 1.37 .065
VOM 1.50 .065
FUEL 0.97 .072
HR 7068

Data Files for Evaluation Criteria Ratings

Table D-26 lists nine data files, which are the Evaluation Criteria ratings for the nine cycles considered in this study. Format for each of these files is as follows:

- First line — Cycle acronym and description
- All subsequent lines — Evaluation Criterion number, Evaluation Criterion rating (G, F, or P)

Table D-26

DATA FILES FOR EVALUATION CRITERIA RATINGS

J.J.FLECK1/CYCLES3/CRITERIA/CRIT1

09/10/77

11:37 AM

STLWR (STEAM - LIGHT WATER REACTOR)

01 G

02 G

03 G

04 F

05 P

06 G

07 P

08 P

09 G

10 F

11 P

12 F

13 G

14 G

15 G

16 G

17 F

18 G

19 P

20 P

21 P

22 P

23 P

24 G

25 G

26 G

Table D-26 (Cont'd)

J.J.FLECK1/CYCLES3/CRITERIA/CRIT2

09/10/77

11:37 AM

STSCR8 (STEAM - WET GAS SCRUBBERS - COAL)

01 G
02 G
03 G
04 F
05 F
06 G
07 P
08 P
09 G
10 G
11 P
12 G
13 G
14 G
15 G
16 G
17 F
18 G
19 P
20 F
21 P
22 F
23 P
24 F
25 G
26 G

Table D-26 (Cont'd)

J.J.FLECK1/CYCLES3/CRITERIA/CRIT3

09/10/77

11:37 AM

GT/OIL (CONVENTIONAL OPEN CYCLE GAS TURBINE - OIL)

01 G
02 G
03 G
04 G
05 G
06 G
07 P
08 G
09 F
10 F
11 P
12 G
13 G
14 G
15 G
16 G
17 G
18 G
19 G
20 G
21 G
22 G
23 P
24 F
25 F
26 G

Table D-26 (Cont'd)

J.J.FLECK1/CYCLES3/CRITERIA/CRIT4

09/10/77 11:37 AM

GT/SCL (CONVENTIONAL OPEN CYCLE GAS TURBINE - SCL)

01 G
02 G
03 G
04 G
05 G
06 G
07 P
08 G
09 F
10 F
11 P
12 G
13 G
14 G
15 G
16 G
17 G
18 G
19 G
20 G
21 G
22 G
23 P
24 P
25 G
26 G

Table D-26 (Cont'd)

J.J.FLECK1/CYCLES3/CRITERIA/CRIT5

09/10/77

11:37 AM

GTCC/OIL (CONVENTIONAL OPEN CYCLE GAS TURBINE COMBINED - OIL)

01 G
02 G
03 G
04 G
05 F
06 G
07 F
08 F
09 G
10 G
11 F
12 G
13 G
14 G
15 G
16 G
17 G
18 G
19 F
20 G
21 F
22 F
23 P
24 F
25 F
26 G

Table D-26 (Cont'd)

J.J.FLECK1/CYCLES3/CRITERIA/CRIT6

09/10/77

11:37 AM

GTCC/SCL (CONVENTIONAL OPEN CYCLE GAS TURBINE COMBINED - SCL)

01 G
02 G
03 G
04 G
05 F
06 G
07 F
08 F
09 G
10 G
11 F
12 G
13 G
14 G
15 G
16 G
17 G
18 G
19 F
20 G
21 F
22 F
23 P
24 P
25 G
26 G

Table D-26 (Cont'd)

J.J.FLECK1/CYCLES3/CRITERIA/CRIT7

09/10/77

11:37 AM

STAFB (ADVANCED STEAM, AFB FURNACE, COAL)

01 F
02 G
03 G
04 F
05 F
06 G
07 F
08 P
09 G
10 G
11 F
12 G
13 G
14 G
15 G
16 G
17 G
18 G
19 F
20 F
21 P
22 F
23 F
24 F
25 G
26 G

Table D-26 (Cont'd)

J.J.FLECK1/CYCLES3/CRITERIA/CRIT8

09/10/77

11:37 AM

GTWCCE (ADV OPEN CYCLE GAS TURBINE, WATER COOLED, COMB CYCLE, LBTU - COAL)

01 F
02 F
03 F
04 F
05 F
06 G
07 F
08 F
09 G
10 G
11 P
12 G
13 G
14 G
15 G
16 G
17 G
18 G
19 F
20 G
21 F
22 F
23 F
24 G
25 G
26 G

Table D-26 (Cont'd)

J.J.FLECK1/CYCLES3/CRITERIA/CRIT9

09/10/77

11:37 AM

OCMHD (OPEN CYCLE MHD - COAL)

01 P
02 P
03 P
04 F
05 F
06 G
07 G
08 P
09 F
10 P
11 P
12 F
13 G
14 F
15 G
16 F
17 F
18 G
19 F
20 G
21 P
22 P
23 F
24 G
25 G
26 G

Nomenclature for Variables Used in Net Present Worth Computations

<u>Symbol in Text</u>	<u>Symbol in Programs</u>	<u>Definition</u>
$C(t)$	CAPY[k,j]	Capacity installed for cycle-k units in year j, mw (if k is omitted, this refers to total installed capacity in year j or at time t)
$C_{\emptyset}$	CAPY $\emptyset$	Total installed capacity at t=0, mw
$C_{pre}(t)$	---	Total installed capacity for pre-scenario units in a given year, mw
$\Delta C(t)$	DELTA C[j]	Capacity addition rate in year j, mw/yr
$C_{cap,k}(t)$	CCAP[k,j]	Capital cost of cycle-k units installed in year j (at time t), \$/kw
---	CCAP $\emptyset$ [k]	Capital cost of cycle-k units installed at t=0, \$/kw
$C_{FOM,k}(t)$	CFOM[k,j]	Fixed component of operating & maintenance cost of cycle-k units installed in year j (at time t), \$/kw-yr
---	CFOM $\emptyset$ [k]	Fixed O&M cost of cycle-k units installed at t=0, \$/kw-yr
$C_{fuel,k}(t)$	CFUEL[k,j]	Input fuel cost for cycle-k units installed in year j (at time t), \$/MBTU
---	CFUEL $\emptyset$ [k]	Input fuel cost for cycle-k units installed at t=0, \$/MBTU
$C_{O\&M}(t)$	---	Total operating & maintenance cost of units installed at time t, mills/kwhr
$C_{R\&D}$	CRD[k]	Cost of research & development program for cycle k, M\$
$C_{VOM,k}(t)$	CVOM[k,j]	Variable component of operating & maintenance cost of cycle-k units installed in year j (at time t), mills/kwhr
---	CVOM $\emptyset$ [k]	Variable O&M cost of cycle-k units installed at t=0, mills/kwhr

<u>Symbol in Text</u>	<u>Symbol in Programs</u>	<u>Definition</u>
C_f	---	Future worth (in year of installation) of life-cycle costs of electricity for cycle-k units installed in a given year, M\$
$C_{f(cap)}$	---	Capital-cost component of C_f , M\$
$C_{f(O\&M)}$	---	Operating & maintenance component of C_f , M\$
$C_{f(fuel)}$	---	Fuel-cost component of C_f , M\$
$c_f(t)$	CF[j]	Correction factor (normalization) for market penetration f in year j (at time t)
$c_F(t)$	CC[j]	Correction factor for capacity factor F in year j (at time t)
---	CAPFAC [k,j]	see F symbol in text
---	CF [k,j]	see $\widehat{F}$ symbol in text
---	CYCLE [k]	String variable for cycle-k acronym
---	DELTAC [j]	see ΔC symbol in text
$E(t)$	---	Electric energy to be generated in year t, mw-yr
$E_\emptyset$	ENERGY $\emptyset$	Electric energy generated at t=0, mw-yr
$E_{post}(t)$	---	Electric energy generated by post-scenario units (those installed in 2025 or after) in year t, mw-yr
$E_{pre}(t)$	---	Electric energy generated by pre-scenario units (those installed in 1985 or before) in year t, mw-yr
$E_s(t)$	ENEW[j]	Electric energy generated by "scenario" units (those installed between 1986 and 2024 inclusive) in year j or t, mw-yr

<u>Symbol in Text</u>	<u>Symbol in Programs</u>	<u>Definition</u>
---	ECAP[k]	Escalation rate for capital cost of cycle k, per annum
---	EFOM[k]	Escalation rate for fixed O&M cost of cycle k, per annum
---	EFUEL[k]	Escalation rate for fuel cost of cycle k, per annum
---	EOIL[j]	Escalation rate for oil, in 3 periods, per annum. See JOIL [j].
---	ERD[k]	Escalation rate for raw cost of cycle k, per annum
---	EVOM[k]	Escalation rate for variable O&M cost of cycle k, per annum
$F_k(t)$	CAPFAC[k, j]	Capacity factor for cycle-k units in year j or at time t. Capacity factor is defined as this ratio: $\frac{\text{Energy generated by a plant in one year}}{\text{En. gen. if plant runs at full capy all yr}}$
$F_{pre}(t)$	---	Capacity factor for aggregated pre-scenario units at time t
$\widehat{F}_k(t)$	CF[k, j]	Corrected capacity factor for cycle-k units in year j (at time t)
---	FOMFW	Future worth (in year of installation) of fixed O&M costs for units installed in that year, M\$
---	FUELFW	Future worth (in year of installation) of fuel costs for units installed in that year, M\$
---	FINSUR, FRETDISP, FTAX	see k_{insur} , $k_{retdisp}$, k_{tax} symbols in text
$f_k(t)$	MP[k, j]	Market penetration of cycle k in year j (at time t), after correcting for effect of intangibles
$f_{O,k}(t)$	MKTPEN[k, j]	Market penetration of cycle k in year j (at time t), as given by OGP (no intangibles)
$f_{M,k}$	FM[k]	Market penetration multiplier for cycle k, to factor in intangibles

<u>Symbol in Text</u>	<u>Symbol in Programs</u>	<u>Definition</u>
g	GROWTH1, GROWTH2	Growth rate of demand for electric energy, per annum (1 and 2 refer to rates before and after doubling time increase at t_0 , respectively)
HR(k)	HR[k]	Heat rate for cycle k, BTU/kwhr elec
h	HSTEP	Increment for numerical integration, years
i	I	Index for Evaluation Criteria
j	J, JJ	Index for years or periods
k	K	Index for cycles
---	JOIL[j]	Years in which oil escalation rate EOIL changes
---	JSIMP	Multiplier used in integration by Simpson's rule
k_{insur}	FINSUR	Adder to capital costs for insurance
k_{retdisp}	FRETDISP	Adder to capital costs for retirement dispersion
k_{tax}	FTAX	Adder to capital costs for income and property taxes
k_p	---	Proportionality constant relating importance weighting (Direct Weighting Method) to market penetration (Net Present Worth Method)
L	LIFE	Plant lifetime, installation to replacement (years)
---	MP, MKTPEN	see f and f_0 symbols in text
n	NSTEPS	Number of integration steps
---	NPERIOD	Number of periods into which OGP output is divided when smoothed
---	NSTEPS1	Number of output steps from $t=0$ (1985) until last installation under scenario (T_2 , 2024)
---	NSTEPS2	Number of output steps from $t=0$ (1985) until retirement of last scenario unit (T_2+L , 2054)

<u>Symbol in Text</u>	<u>Symbol in Programs</u>	<u>Description</u>
---	OUTSTEP	Step between output data, years
P_{DS}	---	Probability of development success for cycle k
---	PEREND[j]	Years in which periods of smoothed OGP output end
P_{ik}	$P[i,ii]$	Probability that a random site is acceptable for cycle k, as determined by Evaluation Criterion i (ii is an index for Good, Fair, Poor)
r	R	Discount rate, per annum
---	SCENARIO	String variable for description of scenario
T_1	$T1[k]$	Time from 1975 until first commercial installation of cycle k, years
T_2	T2	Time from 1975 until end of scenario installations, years
t	T	Time, years t=0 at 1985 in the programs. t=0 at 1975 thru eq D-23 of text; t=0 at 1985 in eqs D-24 and after in text.
t_D	---	Doubling time for electric energy demand, years
t_{D1}	TD1	Doubling time in and prior to $(1985 - t_0)$, years
t_{D2}	TD2	Doubling time after $(1985 - t_0)$, years
t_0	$T0$	Time (years prior to end of 1985) when doubling time changes
---	VOMFW	Future worth (in year of installation) of variable O&M costs for units installed in that year, M\$

<u>Symbol in Text</u>	<u>Symbol in Programs</u>	<u>Definition</u>
W_{COE}	WGENTOT	Present worth (at $t=0$) of costs of electricity generated in a scenario, M\$
---	WGEN[k]	Contribution of cycle k to WNEIGEN
$W_{R\&D}$	WRDTOT	Present worth (at $t=0$) of the R&D costs for the cycles in a scenario, M\$
---	WRD[k]	Present worth (at $t=0$) of the R&D cost for cycle k, M\$
---	WCAPTOT	Present worth (at $t=0$) of all capital costs in a scenario, M\$
---	WCAP[k]	Contribution of cycle k to WCAPTOT
---	WFOMTOT	Present worth (at $t=0$) of all fixed O&M costs in a scenario, M\$
---	WFOM[k]	Contribution of cycle k to WFOMTOT
---	WFUELTOT	Present worth (at $t=0$) of all fuel costs in a scenario, M\$
---	WFUEL[k]	Contribution of cycle k to WFUELTOT
---	WVOMTOT	Present worth (at $t=0$) of all variable O&M costs in a scenario, M\$
---	WVOM[k]	Contribution of cycle k to WVOMTOT
W_{net}	WNETTOT	Present worth (at $t=0$) of undertaking R&D and subsequently installing the cycles in a scenario, M\$
---	WNET[k]	Contribution of cycle k to WNETTOT
W_{sav}	WSAV	Present worth (at $t=0$) of going to a given scenario instead of the reference scenario (No New Technology)
w	---	Importance weighting for an Evaluation Criterion, from the Direct Weighting Method
ρ	---	Pairwise correlation coefficient between effects of two Evaluation Criteria upon market penetration

REFERENCE

D-1. E.J. Mishan, Economics for Social Decisions, Praeger Publishers, New York, 1973 .

Appendix E

NET PRESENT WORTH WITH DISCRETE ANNUAL PAYMENTS

In the "Net Present Worth Method" described in Section 6 and Appendix D, integration of differential expressions was used to derive the present-worth equations. The use of integration implies continuous compounding of interest and escalation. Continuous compounding is probably a more accurate reflection of the real financial situation than the more common practice of compounding with discrete annual payments. However, because utilities normally use discrete annual compounding, equations for present-worth using annual compounding are derived in this Appendix. The basis for compounding here is that money is borrowed at the beginning of each year, and interest is paid at the end of each year. The results of using these equations are very close to the results of the equations derived in Section 6 and Appendix D.

It is also assumed here that total system capacity is not a continuous function but increases in discrete steps as new generation is added.

A net discount rate (r) is used to move money in time. The net rate is the interest rate when there is no inflation; it can be expressed as:

$$r = (1+i)/(1+a) - 1 \quad (E-1)$$

where i and a are the interest and inflation rates respectively. The discount rate has a value of 3.3% when $i=10\%$ and $a=6.5\%$.

ASSUMPTIONS

The same types of assumptions are made here as were used in Section 6 and Appendix D:

- The new cycle is not ready for commercial application until T_1 years from the present.
- R&D costs are paid for in equal annual payments at the end of each year from now until the end of year T_1 .
- The first addition of new cycle capacity is added at the beginning of year $T_1 + 1$.

- The new cycle will displace a fraction f of all generating capacity additions in each year until T_2 .
- At T_2 the new cycle is superseded by some future technology, and no further installations of the new cycle will be made.
- For each addition of the new cycle there is a saving of S mills/kWh (in constant dollars of year zero) during all of its operating life, L . These savings are represented by a discrete amount at the end of each year of the unit's life.

Figure E-1 shows the relation in time of the R&D costs and the savings benefits of the new cycle.

Figure E-1. Cash Flow and Present Worth of R&D Savings

R&D costs are paid at the end of each year. Each payment is the total R&D cost ($C_{R\&D}$ divided by the number of years T_1).

The following series is used to express the present-worth of the R&D costs in year zero using the net discount rate, r .

$$W_{R\&D} = \frac{C_{R\&D}}{T_1} \sum_{n=1}^{T_1} (1+r)^{-n}$$

$$W_{R\&D} = \frac{C_{R\&D}}{T_1} \left[(1+r)^{-1} + (1+r)^{-2} + \dots + (1+r)^{-T_1} \right]$$

$$(1+r) W_{R\&D} = \frac{C_{R\&D}}{T_1} \left[1 + (1+r)^{-1} + \dots + (1+r)^{-(T_1-1)} \right]$$

Subtracting the last equation from the second will reduce the series to

$$W_{R\&D} = \frac{C_{R\&D}}{T_1} \left[\frac{1 - (1+r)^{-T_1}}{r} \right] = \frac{C_{R\&D}}{T_1} \left[\frac{(1+r)^{T_1} - 1}{r (1+r)^{T_1}} \right] \quad (E-2)$$

The expression in brackets is the conventional expression for the present worth of an annuity, sometimes called the "series present-worth factor."

The total capacity at year zero is C_0 . The capacity will grow at some percentage rate, g . In any year, n , the total capacity is

$$C = C_0 (1+g)^n$$

The amount added any year, n , is g times the total capacity in the previous year.

$$CA = C_0 (1+g)^{n-1} g$$

Assuming replacement of retiring generation of life, L , the capacity added any year is

$$\begin{aligned} CA &= \left[C_0 (1+g)^{(n-1)} \right] g + \left[C_0 (1+g)^{(n-1-L)} \right] g \\ &= C_0 (1+g)^{n-1} g \left[1 + (1+g)^{-L} \right] \end{aligned}$$

New cycle generation is not available until T_1 years of R&D have elapsed. The first new cycle unit will be added at the beginning of year $T_1 + 1$. The amount of new cycle capacity added is

$$C_n = \left[f C_0 (1+g)^{T_1} \right] g \left[1 + (1+g)^{-L} \right] \quad (E-3)$$

where f is the fraction of capacity added which uses the new cycle.

The savings, in dollars, of the new cycle over the old is represented by an amount at the end of each year of the unit's life which is the product of the savings in mills/kWh (= \$/MWh), the MW capacity, the capacity factor, F , and 8760 hours per year. These savings are discounted

at a net rate r to the beginning of each unit's life. The present worth of these savings for each unit over the life, L , is:

$$C = 8760 F S C_n \left[\frac{(1+r)^L - 1}{r(1+r)^L} \right] \quad (E-4)$$

where the expression in brackets is the series present-worth factor as in Equation E-1.

The saving of new cycle generation will grow as the new capacity grows and the present-worth will be computed at a net rate, r . The following series represents the yearly growth and worth of the savings at time T_1 .

$$P = C \sum_{n=0}^{T_2 - T_1 - 1} \left(\frac{1+g}{1+r} \right)^n = C \left[1 + \left(\frac{1+g}{1+r} \right) + \left(\frac{1+g}{1+r} \right)^2 + \dots + \left(\frac{1+g}{1+r} \right)^{(T_2 - T_1 - 1)} \right]$$

This series can also be reduced to a single equation.

$$(1+r)P = C \left[(1+r) + (1+g) + \frac{(1+g)^2}{(1+r)} + \dots + \frac{(1+g)^{T_2 - T_1 - 1}}{(1+r)^{T_2 - T_1 - 2}} \right]$$

$$(1+g)P = C \left[(1+g) + \frac{(1+g)^2}{(1+r)} + \frac{(1+g)^3}{(1+r)^2} + \dots + \frac{(1+g)^{T_2 - T_1}}{(1+r)^{T_2 - T_1 - 1}} \right]$$

Subtracting

$$P(r-g) = C \left[(1+r) - \frac{(1+g)^{T_2 - T_1}}{(1+r)^{T_2 - T_1 - 1}} \right]$$

$$P = C \left(\frac{1}{r-g} \right) \left[(1+r) - \frac{(1+g)^{T_2 - T_1}}{(1+r)^{T_2 - T_1 - 1}} \right]$$

The total worth of the savings for all units for all years, as of year zero, is:

$$W_S = \frac{P}{(1+r)^{T_1}}$$

The complete expression for W_S is:

$$W_S = \frac{8760 F S C_o g (1+g)^{T_1}}{(r-g)(1+r)^{T_1}} \left[1 + \frac{1}{(1+g)^L} \right] \times \left[\frac{(1+r)^L - 1}{r(1+r)^L} \right] \times \left[(1+r) - \frac{(1+g)^{T_2 - T_1}}{(1+r)^{T_2 - T_1 - 1}} \right]$$

and the net present-worth is:

$$W = W_S - W_{R\&D}$$

Appendix F

OUTPUT OF NET PRESENT WORTH PROGRAMS

The results presented in this appendix are intended to exemplify an application of this method rather than a definitive study. Only three advanced cycles were analyzed in Phase 3 with one set of economic and growth conditions. This is considered sufficient to demonstrate the major features of this methodology and form a basis for later studies which include more candidate cycles and consider several alternative futures.

Generation phase diagrams were used to screen the Phase 3 cycles prior to running the Generation Expansion program, and these results are presented in Appendix F.2 below. Phase diagrams were then computed for these cycles using different assumptions about the fuel price inflation rate to check the sensitivity of results to this variable. (Appendix F.3). The Phase 1 cycles were also compared in phase diagrams using the Phase 1 fuel cost assumptions; these results are presented in Appendix F.1 below.

Generation Expansion results are presented for the five Phase 3 competition scenarios in Appendix F.4, and the impact of intangibles on the market penetration and capacity factors is presented in Appendix F.5.

The Net Present Worth of Savings for each Phase 3 scenario is presented in Appendix F.6 along with sensitivity runs showing the effects of impact of intangibles and taxes on the conclusions. Sensitivity of savings to the date of first commercial service are discussed in Appendix F.7.

F.1 GENERATION PHASE DIAGRAMS - PHASE 1 CYCLES

Figures F-1 and F-2 show screening curves for the most competitive Phase 1 cycles in the year 2000. The lowest cost of electricity is given by the following combination:

<u>Cycle Name*</u>	<u>Capacity Factors</u>
21. GTP1-HBTUP1	0-413 h/yr
6. GTARO-OILP1	413-568 h/yr
9. GTWCCS-SCLP1	568-2601 h/yr
8. GTWCCG-COALP1	2601-8760 h/yr

Figure F-1. Screening Curves (Year 2000) — Phase 1 Cycles

Table F-1 summarizes this conclusion and similar results for each year from 1975 to 2010. In each year, only commercially available cycles were allowed to compete; thus, cycles above the diagonal line in Table F-1 are excluded from consideration. These results are plotted in Figure F-3.

*See Appendix D, Table D-5 for identification

Figure F-2. Screening Curves (Year 2000) — Phase 1 Cycles

Table F-1

GENERATION PHASE DIAGRAM RESULTS - PHASE 1 CYCLES

	Cycle Identification Number and Date of First Commercial Service																				
Year	20 1975	21 1975	6 1980	7 1984	5 1985	3 1985	1 1987	2 1987	8 1987	11 1987	9 1988	12 1990	15 1991	16 1992	18 1992	19 1992	10 1995	13 1997	17 1997	4 2000	14 2000
1975	8760	1642	Maximum Economical Capacity Factors - Hours/Year																		
76	8760	1642																			
77	8760	1642																			
78	8760	1642																			
79	8760	1642																			
1980	8760	413	2768	Advanced Cycles Are Not Commercially Available in These Years																	
81	8760	413	2768																		
82	8760	413	2768																		
83	8760	413	2768																		
84	*	413	1572	8760																	
1985	*	413	1572	8760	*	*															
86	*	413	1572	8760	*	*															
87	*	413	1335	*	*	*	*	*	8760	*											
88	*	413	568	*	*	*	*	*	8760	*	2601										
89	*	413	568	*	*	*	*	*	8760	*	2601										
1990	*	413	568	*	*	*	*	*	8760	*	2601	*									
91	*	413	568	*	*	*	*	*	8760	*	2601	*	*								
92	*	413	568	*	*	*	*	*	8760	*	2601	*	*	*		*					
93	*	413	568	*	*	*	*	*	8760	*	2601	*	*	*	*	*					
94	*	413	568	*	*	*	*	*	8760	*	2601	*	*	*	*	*	*				
1995	*	413	568	*	*	*	*	*	8760	*	2601	*	*	*	*	*	*	*			
96	*	413	568	*	*	*	*	*	8760	*	2601	*	*	*	*	*	*	*			
97	*	413	568	*	*	*	*	*	8760	*	2601	*	*	*	*	*	*	*	*	*	
98	*	413	568	*	*	*	*	*	8760	*	2601	*	*	*	*	*	*	*	*	*	*
99	*	413	568	*	*	*	*	*	8760	*	2601	*	*	*	*	*	*	*	*	*	*
2000	*	413	568	*	*	*	*	*	8760	*	2601	*	*	*	*	*	*	*	*	*	*
1	*	413	568	*	*	*	*	*	8760	*	2601	*	*	*	*	*	*	*	*	*	*
2	*	413	568	*	*	*	*	*	8760	*	2601	*	*	*	*	*	*	*	*	*	*
3	*	413	568	*	*	*	*	*	8760	*	2601	*	*	*	*	*	*	*	*	*	*
4	*	413	568	*	*	*	*	*	8760	*	2601	*	*	*	*	*	*	*	*	*	*
2005	*	413	568	*	*	*	*	*	8760	*	2601	*	*	*	*	*	*	*	*	*	*
6	*	413	568	*	*	*	*	*	8760	*	2601	*	*	*	*	*	*	*	*	*	*
7	*	413	568	*	*	*	*	*	8760	*	2601	*	*	*	*	*	*	*	*	*	*
8	*	413	568	*	*	*	*	*	8760	*	2601	*	*	*	*	*	*	*	*	*	*
9	*	413	568	*	*	*	*	*	8760	*	2601	*	*	*	*	*	*	*	*	*	*
2010	*	413	568	*	*	*	*	*	8760	*	2601	*	*	*	*	*	*	*	*	*	*

Legend:

No.	Cycle Name	Fuel File
1	STAFBP1	COALP1
2	STCONV	OILP1
3	STHTGR	NUCHP1
4	LMFBR	NUCLP1
5	GTARG	HBTUP1
6	GTARO	OILP1
7	GTACC	COALP1
8	GTWCCG	COALP1
9	GTWCCS	SCLP1
10	CO2AFB	COALP1
11	HEAFB	COALP1
12	HEHTGR	NUCHP1
13	OCMHDP1	COALP1
14	PLSMHD	COALP1
15	LMMHD	COALP1
16	MVTAFF	COALP1
17	TRMION	COALP1
18	FCLOTH	H2P1
19	FCLOTO	OILP1
20	STSCRBP1	COALP1
21	GTP1	HBTUP1

(See Appendix D, Tables D-5 through D-8 for cycle and fuel data)

*Cycle is not competitive on cost of electricity basis

* See Appendix D, Tables D-5 through D-8
for cycle name and fuel data file name

Figure F-3. Generation Phase Diagram —
Phase 1 Cycles

F.2 GENERATION PHASE DIAGRAMS - PHASE 3 CYCLES

Tables F-2 through F-4 summarize results for the five Phase 3 scenarios; these results are plotted in Section 8. The input data for these runs are described in Appendix D, Tables D-1 through D-3.

Table F-2

GENERATION PHASE DIAGRAM RESULTS - PHASE 3 CYCLES NO NEW TECHNOLOGY SCENARIO (BASE CASE)

Cycle Name ⁽¹⁾ Fuel File Name ⁽¹⁾ Year	Maximum Economical Capacity Factors (h/yr)			
	STSCRB COAL	GTCC OIL/SCL ⁽²⁾	GT OIL/SCL ⁽²⁾	STLWR NUC
1975	*	3458	2286	8760
1980	*	2956	2015	8760
1985	2694	2370	1747	8760
1990	2651	1806	1491	8760
1995	2609	1434	1286	8760
2000	2568	1386	1245	8760
2005	2528	1340	1205	8760
2010	2489	1295	1166	8760
2015	2451	1252	1129	8760
2020	2414	1210	1093	8760
2025	2378	1169	1058	8760
2030	2343	1131	1024	8760

⁽¹⁾ See Appendix D, Tables D-1 through D-3 for input data.

⁽²⁾ Fuel is oil 1975-1994, semiclean liquid 1995-2060.

*Cycle is not economically competitive.

Table F-3

GENERATION PHASE DIAGRAM RESULTS - PHASE 3 CYCLES
MINIMUM COMPETITION SCENARIOS (BASE CASE)

Cycle Name ⁽¹⁾ Fuel File Name ⁽¹⁾	Maximum Economical Capacity Factors (h/yr)						
	STAFB COAL	GTWCCE COAL	OCMHD MHD CO	STSCRB COAL	GTCC ⁽²⁾ OIL/SCL	GT ⁽²⁾ OIL/SCL	STLWR NUC
Year	STAFB Case						
1988	6348	--	--	*	*	1230	8760
1993	6266	--	--	*	*	989	8760
1998	6187	--	--	*	*	916	8760
2003	6111	--	--	*	*	886	8760
2008	6038	--	--	*	*	857	8760
2013	5968	--	--	*	*	829	8760
2018	5901	--	--	*	*	802	8760
2023	5837	--	--	*	*	776	8760
2028	5776	--	--	*	*	751	8760
	GTWCCE Case						
1996	--	8760	--	*	*	910	*
2001	--	8760	--	*	*	880	*
2006	--	8760	--	*	*	852	*
2011	--	8760	--	*	*	824	*
2016	--	8760	--	*	*	797	*
2021	--	8760	--	*	*	771	*
2026	--	8760	--	*	*	746	*
	OCMHD Case						
2003	--	--	8760	*	*	860	*
2008	--	--	8760	*	*	832	*
2013	--	--	8760	*	*	805	*
2018	--	--	8760	*	*	779	*
2023	--	--	8760	*	*	754	*
2028	--	--	8760	*	*	729	*

(1) See Appendix D, Tables D-1 through D-3 for input data.

(2) Fuel is oil 1975-1994, Semiclean liquid 1995-2060.

*Cycle is not economically competitive.

Table F-4

GENERATION PHASE DIAGRAM RESULTS - PHASE 3 CYCLES
CROWDED MARKET SCENARIO (BASE CASE)

Cycle Name ⁽¹⁾ Fuel File Name ⁽¹⁾	Maximum Economical Capacity Factors (h/yr)						
	STAFB COAL	GTWCCE COAL	OCMHD MHD CO	STSCRB COAL	GTCC ⁽²⁾ OIL/SCL	GT ⁽²⁾ OIL/SCL	STLWR NUC
Year							
1975 } 1980 } 1985 }	Identical to No New Technology Scenario			*	3459	2286	8760
				*	2956	2015	8760
				2694	2370	1747	8760
1988 } 1993 }	6348 } 6266 }	Same as Minimum Competition Scenario - STAFB Case			*	1230	8760
					*	989	8760
1996 } 2001 }	* } * }	8760 } 8760 }	Same as GTWCCE Case		*	910	*
					*	880	*
2003 } 2008 } 2013 } 2018 } 2023 } 2028 }	* } * } * } * } * }	* } * } Same as OCMHD Case	8760 } 8760 } 8760 } 8760 } 8760 }	* } * } * } * }	* } * } * } * }	860 } 832 } 805 } 779 } 754 }	* } * } * } * }
			8760	*	*	729	*

(1) See Appendix D, Tables D-1 through D-3 for input data.

(2) Fuel is oil 1975-1994, semiclean liquid 1995-2060.

*Cycle is not economically competitive.

F.3 GENERATION PHASE DIAGRAMS - SENSITIVITY TO FUEL PRICE ESCALATION RATE

Table F-5 gives results obtained using the input data for coal price inflation perturbation; these results are plotted in Figures F-4 through F-8. Comparison with the base case (Section 6.2) shows that a 1% increase in coal price inflation rate greatly decreases the competitive range of the steam-scrubber plant (STSCRB). It also delays by 14 years the changeover date from oil to semiclean liquid for the gas turbine and the combined cycle. The advanced cycles (STAFB, GTWCCE, and OCMHD) also become less competitive with respect to the light water reactor (STLWR), but the effect is less pronounced than with the STSCRB because of the higher efficiencies of the advanced cycles.

Table F-6 and Figure F-9 show the effect of increasing the oil inflation rate by 1%. In this case, only the gas turbine and combined cycle are affected. The changeover from oil to semiclean liquid occurs nine years earlier than in the base case. During the early years when GT and GTCC burn oil, the competitive range of capacity factors for these cycles is smaller than in the base case; after the change to semiclean liquid, results are identical to the base case.

Table F-7 and Figures F-10 and F-11 describe a future in which uranium inflates 1% faster than the base case. This yields a dramatic improvement in the competitive position of the scrubber plant (STSCRB) in the No New Technology Scenario, and the AFB steam plant (STAFB) in the Minimum Competition and Crowded Market Scenarios. The other cycles are unaffected.

Semiclean liquid fuel derived from coal may follow the price escalation pattern of coal as assumed in the base case. However, a significant portion of the SCL cost is attributable to capital investment in the processing plant, so the fuel price might also be expected to inflate at a rate which is a weighted average of the coal and capital inflation rates. In this study, coal inflates at 7.2% while capital inflates at 6.5%; Table F-8 and Figure F-12 describe a future in which SCL inflates at 6.8% while all other fuels inflate at the base case values. This improves the competitive position of the combined cycle slightly with respect to the base case, and causes a small increase in the capacity factor range. The changeover from oil to SCL occurs four years earlier than in the base case.

Table F-5

GENERATION PHASE DIAGRAM RESULTS - PHASE 3 CYCLES
SENSITIVITY TO COAL PRICE INFLATION RATE

Cycle Name ⁽¹⁾ Fuel File Name ⁽¹⁾	Maximum Economical Capacity Factors (h/yr)						
	STAFB COAL1	GTWCCE COAL1	OCMHD MHDCO1	STSCRB COAL1	GTCC OIL/SCL1 ⁽²⁾	GT OIL/SCL1 ⁽²⁾	STLWR NUC
No New Technology Scenario							
1975	--	--	--	*	3459	2286	8760
1980	--	--	--	*	2956	2015	8760
1985	--	--	--	*	2480	1747	8760
1990	--	--	--	*	2047	1491	8760
1995	--	--	--	*	1671	1256	8760
2000	--	--	--	1443	1312	1050	8760
2005	--	--	--	1317	1006	874	8760
2010	--	--	--	1202	819	749	8760
2015	--	--	--	1097	755	692	8760
2020	--	--	--	1002	696	640	8760
2025	--	--	--	915	642	591	8760
2030	--	--	--	836	593	546	8760
Minimum Competition - STAFB							
1988	4014	--	--	*	*	1374	8760
1993	3633	--	--	*	*	1107	8760
1998	3291	--	--	*	*	886	8760
2003	2983	--	--	*	*	707	8760
2008	2706	--	--	*	*	567	8760
2013	2456	--	--	*	*	515	8760
2018	2231	--	--	*	*	476	8760
2023	2028	--	--	*	*	439	8760
2028	1844	--	--	*	*	406	8760
Minimum Competition - GTWCCE							
1996	--	4720	--	*	*	928	8760
2001	--	4246	--	*	*	749	8760
2006	--	3824	--	*	*	604	8760
2011	--	3447	--	*	*	521	8760
2016	--	3111	--	*	*	481	8760
2021	--	2810	--	*	*	444	8760
2026	--	2541	--	*	*	410	8760
Minimum Competition - OCMHD							
2003	--	--	4761	*	*	679	8760
2008	--	--	4253	*	*	551	8760
2013	--	--	3807	*	*	501	8760
2018	--	--	3413	*	*	463	8760
2023	--	--	3065	*	*	428	8760
2028	--	--	2757	*	*	395	8760
Crowded Market Scenario							
1975-1987	Same as No New Technology Scenario						
1988-1995	Same as STAFB						
1996-2002	Same as GTWCCE						
2003-2030	Same as OCMHD						
	Minimum Competition Scenario						

⁽¹⁾ See Appendix D, Tables D-1 through D-4 for input data.

⁽²⁾ Fuel is oil 1975-2008, semiclean liquid 2009-2060.

* Cycle is not economically competitive.

Note:

STAFB - Steam (3500 P/1000 F/1000 F), AFB, Coal
 GTWCCE - Gas Turbine (Water Cooled) Combined, Low Btu Gasifier, Coal
 OCMHD - Open Cycle MHD, Coal
 STSCRB - Steam, Scrubbers, Coal
 GTCC - Conventional Gas Turbine, Combined, Oil/SCL
 GT - Conventional Gas Turbine, Oil/SCL
 STLWR - Steam, Light Water Reactor, Uranium

Figure F-4. Generation Phase Diagram — Phase 3 Cycles, No New Technology Scenario — Sensitivity to Coal Price Inflation Rate

Figure F-5. Generation Phase Diagram — Phase 3 Cycles, Minimum Competition Scenario, STAFB — Sensitivity to Coal Price Inflation Rate

Figure F-6. Generation Phase Diagram — Phase 3 Cycles, Minimum Competition Scenario, GTWCCE — Sensitivity to Coal Price Inflation Rate

Figure F-7. Generation Phase Diagram — Phase 3 Cycles, Minimum Competition Scenario, OCMHD — Sensitivity to Coal Price Inflation Rate

Figure F-8. Generation Phase Diagram — Phase 3 Cycles, Crowded Market Scenario — Sensitivity to Coal Price Inflation Rate

Table F-6

**GENERATION PHASE DIAGRAM RESULTS - PHASE 3 CYCLES
SENSITIVITY TO OIL PRICE INFLATION RATE**

Cycle Name ⁽¹⁾ Fuel File Name ⁽¹⁾	Maximum Economical Capacity Factors (h/yr)						
	STAFB COAL	GTWCCE COAL	OCMHD MHDCO	STSCRB COAL	GTCC ⁽²⁾ OIL1/SCL	GT ⁽²⁾ OIL1/SCL	STLWR NUC
Year	No New Technology Scenario						
1975	--	--	--	*	2902	2011	8760
1980	--	--	--	2739	2159	1689	8760
1985	--	--	--	2694	1579	1396	8760
1990	--	--	--	2651	1484	1328	8760
1995	--	--	--	2609	1434	1286	8760
2000	--	--	--	2568	1386	1245	8760
2005	--	--	--	2528	1340	1205	8760
2010	--	--	--	2489	1295	1166	8760
2015	--	--	--	2451	1252	1129	8760
2020	--	--	--	2414	1210	1093	8760
2025	--	--	--	2378	1169	1058	8760
2030	--	--	--	2343	1131	1024	8760
	Minimum Competition - STAFB						
1988	--	--	--	*	6348	979	8760
1993	--	--	--	*	6266	947	8760
1998	--	--	--	*	6187	916	8760
2003	--	--	--	*	6111	886	8760
2008	--	--	--	*	6038	857	8760
2013	--	--	--	*	5968	829	8760
2018	--	--	--	*	5901	802	8760
2023	--	--	--	*	5837	776	8760
2028	--	--	--	*	5776	751	8760
	Minimum Competition - GTWCCE						
1996	--	8760	--	*	*	910	*
2001	--	8760	--	*	*	880	*
2006	--	8760	--	*	*	852	*
2011	--	8760	--	*	*	824	*
2016	--	8760	--	*	*	797	*
2021	--	8760	--	*	*	771	*
2026	--	8760	--	*	*	746	*
	Minimum Competition - OCMHD						
2003	--	--	8760	*	*	860	*
2008	--	--	8760	*	*	832	*
2013	--	--	8760	*	*	805	*
2018	--	--	8760	*	*	779	*
2023	--	--	8760	*	*	754	*
2028	--	--	8760	*	*	729	*
	Crowded Market Scenario						
1975-1987	Same as No New Technology Scenario						
1988-1995	Same as STAFB						
1996-2002	Same as GTWCCE						
2003-2030	Same as OCMHD						

(1) See Appendix D, Tables D-1 through D-4 for input data.

(2) Fuel is oil 1975-1985, semiclean liquid 1986-2060.

*Cycle is not economically competitive.

Note:

STAFB - Steam (3500 P/1000 F/1000 F), AFB, Coal
 GTWCCE - Gas Turbine (Water Cooled) Combined, Low Btu Gasifier, Coal
 OCMHD - Open Cycle MHD, Coal
 STSCRB - Steam, Scrubbers, Coal
 GTCC - Conventional Gas Turbine, Combined, Oil/SCL
 GT - Conventional Gas Turbine, Oil/SCL
 STLWR - Steam, Light Water Reactor, Uranium

Figure F-9. Generation Phase Diagram — Phase 3 Cycles, Sensitivity to Oil Price Inflation Rate

Table F-7

**GENERATION PHASE DIAGRAM RESULTS - PHASE 3 CYCLES
SENSITIVITY TO URANIUM PRICE INFLATION RATE**

Cycle Name ⁽¹⁾ Fuel File Name ⁽¹⁾	Maximum Economical Capacity Factors (h/yr)						STLWR NUC1
	STAFB COAL	GTWCCE COAL	OCMHD MHD CO	STSCRB COAL	GTCC ⁽²⁾ OIL/SCL	GT ⁽²⁾ OIL/SCL	
Year	No New Technology Scenario						
1975	--	--	--	*	3661	2286	8760
1980	--	--	--	3317	3100	2015	8760
1985	--	--	--	3517	2370	1747	8760
1990	--	--	--	2784	1806	1491	8760
1995	--	--	--	4147	1434	1286	8760
2000	--	--	--	4661	1386	1245	8760
2005	--	--	--	5431	1340	1205	8760
2010	--	--	--	6690	1295	1166	8760
2015	--	--	--	-8760	1252	1129	*
2020	--	--	--	8760	1210	1093	*
2025	--	--	--	8760	1169	1058	*
2030	--	--	--	8760	1131	1024	*
	Minimum Competition - STAFB						
1988	8760	--	--	*	*	1230	*
1993	8760	--	--	*	*	989	*
1998	8760	--	--	*	*	916	*
2003	8760	--	--	*	*	886	*
2008	8760	--	--	*	*	857	*
2013	8760	--	--	*	*	829	*
2018	8760	--	--	*	*	802	*
2023	8760	--	--	*	*	776	*
2028	8760	--	--	*	*	751	*
	Minimum Competition - GTWCCE						
1996	--	8760	--	*	*	910	*
2001	--	8760	--	*	*	880	*
2006	--	8760	--	*	*	852	*
2011	--	8760	--	*	*	824	*
2016	--	8760	--	*	*	797	*
2021	--	8760	--	*	*	771	*
2026	--	8760	--	*	*	746	*
	Minimum Competition - OCMHD						
2003	--	--	8760	*	*	860	*
2008	--	--	8760	*	*	832	*
2013	--	--	8760	*	*	805	*
2018	--	--	8760	*	*	779	*
2023	--	--	8760	*	*	754	*
2028	--	--	8760	*	*	729	*
	Crowded Market Scenario						
1975-1987	Same as No New Technology Scenario						
1988-1995	Same as STAFB						
1996-2002	Same as GTWCCE						
2003-2030	Same as OCMHD						

(1) See Appendix D, Tables D-1 through D-4 for input data.

(2) Fuel is oil 1975-1994, semiclean liquid 1995-2060.

*Cycle is not economically competitive.

Note:

STAFB - Steam (3500 P/1000 F/1000 F), AFB, Coal
 GTWCCE - Gas Turbine (Water Cooled) Combined, Low Btu Gasifier, Coal
 OCMHD - Open Cycle MHD, Coal
 STSCRB - Steam, Scrubbers, Coal
 GTCC - Conventional Gas Turbine, Combined, Oil/SCL
 GT - Conventional Gas Turbine, Oil/SCL
 STLWR - Steam, Light Water Reactor, Uranium

Figure F-10. Generation Phase Diagram — Phase 3 Cycles, No New Technology Scenario — Sensitivity to Uranium Price Inflation Rate

Figure F-11. Generation Phase Diagram — Phase 3 Cycles, Crowded Market Scenario — Sensitivity to Uranium Price Inflation Rate

Table F-8

GENERATION PHASE DIAGRAM RESULTS - PHASE 3 CYCLES
SENSITIVITY TO SCL PRICE INFLATION RATE

Cycle Name ⁽¹⁾ Fuel File Name ⁽¹⁾	Maximum Economical Capacity Factors (h/yr)						
	STAFB COAL	GTWCCE COAL	OCMHD MHD CO	STSCRB COAL	GTCC ⁽²⁾ SCL2	GT ⁽²⁾ SCL2	STLWR NUC
Year	No New Technology						
1975	--	--	--	*	3459	2286	8760
1980	--	--	--	*	2956	2015	8760
1985	--	--	--	2694	2370	1747	8760
1990	--	--	--	2651	1806	1491	8760
1995	--	--	--	2609	1762	1451	8760
2000	--	--	--	2568	1760	1431	8760
2005	--	--	--	2528	1758	1411	8760
2010	--	--	--	2489	1758	1391	8760
2015	--	--	--	2451	1760	1372	8760
2020	--	--	--	2414	1760	1353	8760
2025	--	--	--	2378	1762	1334	8760
2030	--	--	--	2343	1765	1315	8760
	Minimum Competition - STAFB						
1988	6348	--	--	*	*	1230	8760
1993	6266	--	--	*	*	1103	8760
1998	6187	--	--	*	*	1095	8760
2003	6111	--	--	*	*	1087	8760
2008	6038	--	--	*	*	1079	8760
2013	5968	--	--	*	*	1072	8760
2018	5901	--	--	*	*	1064	8760
2023	5837	--	--	*	*	1058	8760
2028	5776	--	--	*	*	1051	8760
	Minimum Competition - GTWCCE						
1996	--	8760	--	*	*	1066	*
2001	--	8760	--	*	*	1057	*
2006	--	8760	--	*	*	1047	*
2011	--	8760	--	*	*	1038	*
2016	--	8760	--	*	*	1029	*
2021	--	8760	--	*	*	1021	*
2026	--	8760	--	*	*	1012	*
	Minimum Competition - OCMHD						
2003	--	--	8760	*	*	1037	*
2008	--	--	8760	*	*	1028	*
2013	--	--	8760	*	*	1018	*
2018	--	--	8760	*	*	1009	*
2023	--	--	8760	*	*	1001	*
2028	--	--	8760	*	*	992	*
	Crowded Market Scenario						
1975-1987	Same as No New Technology Scenario						
1988-1995	Same as STAFB						
1996-2002	Same as GTWCCE Minimum Competition Scenario						
2003-2030	Same as OCMHD						

(1) See Appendix D, Tables D-1 through D-4 for input data.

(2) Fuel is oil 1975-1990, semiclean liquid 1991-2060.

*Cycle is not economically competitive.

Note:

STAFB - (3500 P/1000 F/1000 F), AFB, Coal
 GTWCCE - Gas Turbine (Water Cooled) Combined, Low Btu Gasifier, Coal
 OCMHD - Open Cycle MHD, Coal
 STSCRB - Steam, Scrubbers, Coal
 GTCC - Conventional Gas Turbine, Combined, Oil/SCL
 GT - Conventional Gas Turbine, Oil/SCL
 STLWR - Steam, Light Water Reactor, Uranium

Figure F-12. Generation Phase Diagram — Phase 3 Cycles — Sensitivity to SCL Price Inflation Rate

F.4 GENERATION EXPANSION RESULTS

The Optimized Generation Planning (OGP) program has been run with the split utility system and other data presented in Appendix D (Tables D-9 through D-16); the results are summarized for the Phase 3 scenarios in Tables F-9 through F-16 below.

Table F-9

NO NEW TECHNOLOGY SCENARIO MARKET PENETRATION

Year	MW Added Each Year				Year	MW Added Each Year			
	STLWR	STSCRB	GT	GTCC		STLWR	STSCRB	GT	GTCC
1986	1x1000				2006	3x1000			2x417
87	1x1000				7	2x1000	1x747		2x417
88	1x1000				8			34x76	2x417
89		2x747			9	2x1000		40x76	
1990	1x1000				2010	2x1000		18x76	
91	1x1000				11	3x1000		6x76	
92	2x1000				12	5x1000			
93			10x76		13	3x1000	1x747	20x76	
94	2x1000	1x747		*	14	4x1000		2x76	
1995	1x1000				2015	3x1000		16x76	
96	3x1000				16	6x1000			
97			10x76		17	4x1000		18x76	
98	2x1000	2x747			18	6x1000			
99	1x1000		6x76		19	6x1000		10x76	
2000	4x1000				2020	5x1000	1x747	12x76	
1	1x1000	1x747			21	6x1000		12x76	
2	3x1000				22	7x1000	1x747	8x76	
3	3x1000				23	6x1000		18x76	
4	3x1000				24	8x1000	1x747	12x76	
2005	3x1000								

*GT and GTCC units added before 1995 are fired with oil; units installed in 1995 and thereafter burn semiclean liquid

Tables F-9, F-11, F-12, F-13, F-14, and F-15 present the market penetration results. These tables identify the number, type, and rating of plants added in each year. For instance, Table F-9 shows that in 1998 OGP added two nuclear plants at 1000 MW and two steam-scrubber plants at 747 MW. As in the Generation Phase Diagrams, GT and GTCC units added after 1994 were specified to burn semiclean liquid fuel derived from coal. Oil burning units installed before 1994 continue to burn oil until they are retired after a 30 year lifetime.

Table F-10

**NO NEW TECHNOLOGY SCENARIO
CAPACITY FACTORS**

Capacity Factors ⁽¹⁾ - %							Capacity Factors ⁽¹⁾ - %						
Year	STLWR	STSCRB	GT		GTCC		Year	STLWR	STSCRB	GT		GTCC	
			OIL	SCL	OIL	SCL				OIL	SCL	OIL	SCL
1986	70.6						2006	58.0	11.6	1.6	0.9	3.4	
87	73.5						7	58.2	11.9	1.2	0.7	2.6	
88	71.4						8	60.0	22.2	3.6	1.3	6.3	
89	72.2	30.3					9	61.5	31.3	0.4	3.6	14.2	
1990	71.1	30.4					2010	63.2	32.7	0.3	4.2	16.7	42.6
91	70.2	30.2					11	61.5	32.0	0.2	4.0	16.2	
92	68.7	30.2					12	61.0	29.0	0.2	3.3	13.9	56.9
93	69.7	31.2	8.1				13	61.2	31.5	0.2	2.0	16.2	0.3
94	67.6	30.4	5.0				14	60.9	29.1	0.1	1.9	14.8	(3)
1995	67.3	30.7	7.1				2015	61.1	30.3	0.1	2.0	16.3	
96	64.4	27.8	4.0				16	60.8	25.9	0.1	1.5	13.0	
97	65.8	31.4	9.1	0.9			17	60.8	28.4	0.1	1.6	16.0	
98	64.7	30.5	5.6	0.5			18	60.6	25.6	0.1	1.4	14.2	
99	64.9	30.9	8.4	1.0			19	60.1	22.3	0.1	1.6	11.0	
2000	62.3	26.8	4.2	0.5			2020	60.2	22.9	0.1	1.5	14.7	
1	62.9	27.6	4.3	2.3			21	59.8	22.3	0.1	1.5	14.6	
2	61.4	23.2	2.9	1.6			22	58.7	21.6	0.1	1.3	13.7	
3	60.2	20.5	2.3	1.3			23	57.3	20.4	0	0.9	13.2	
4	59.3	20.3	2.6	1.4			24	56.9	20.2	0	1.1	13.0	
2005	58.5	15.6	2.3	1.3									

(1) Averaged over all units within type category installed after 1985

(2) Averaged over all units installed before 1985

(3) Last old unit retired

The runs for the No New Technology and Crowded Market scenarios were 39 years in duration; those for the Minimum Competition scenarios were 19 years each, starting at the date of first commercial service. In each Minimum Competition case, the years between 1986 and the date of first commercial service are filled by attaching the No New Technology results. Thus, in Table F-12 years 1986-1995 are identical to the No New Technology case (Table F-9).

Capacity factors for each scenario are presented in Tables F-10, F-11, F-12, F-13, F-14, and F-16. These factors are averaged over all units of each type in the system for every year, and they are listed as a percentage of 8760 h/yr rather than as h/yr. Average capacity factors are also given for the units remaining from among those in place before 1985 (old units). This average includes nuclear, coal fired steam and oil fired steam, and gas turbine units.

Table F-11

MINIMUM COMPETITION SCENARIO (STAFB)
MARKET PENETRATION AND CAPACITY FACTORS

Year	MW Added Each Year					Year	Capacity Factors ⁽¹⁾ - %							Old Units ⁽²⁾
	STLWR	STSCRB	GT	GTCC	STAFB		STLWR	STSCRB	GT		GTCC		STAFB	
									OIL	SCL	OIL	SCL		
1986	1x1000					1986	70.6							
87	1x1000					87	73.5							45.0
88					1x814	88	74.0						47.9	45.0
89					2x814	89	74.3						46.9	
1990					1x814	1990	74.3						48.1	46.0
91					2x814	91	74.3						47.8	
92					1x814	92	74.3						49.5	
93					2x814	93	74.3						49.8	
94			6x76		2x814	94	74.3		3.5				50.1	
1995			10x76		1x814	1995	74.3		5.3	0.4			52.2	47.0
96			8x76		2x814	96	74.3		6.0	0.4			52.4	
97					2x814	97	74.3		4.8	0.3			53.0	
98	2x1000				1x814	98	72.7		4.3	0.4			51.7	
99			6x76		2x814	99	72.7		4.3	0.4			52.3	
2000	2x1000				2x814	2000	72.0		2.3	0.2			48.9	45.0
1	2x1000					1	72.2		2.1	1.0			46.5	
2	3x1000					2	72.2		1.5	0.7			42.3	
3					3x814	3	72.6		1.5	0.7			44.5	
4	2x1000				2x814	4	72.5		1.0	0.5			43.5	
2005			2x76	1x417	3x814	2005	72.6		0.8	0.4	2.6		44.1	43.0
6	2x1000		14x76	2x417		6	72.5		1.1	0.4	2.5		43.5	

(1) Averaged over all units within type category installed after 1985

(2) Averaged over all units installed before 1985

(3) These years are identical to the No New Technology Scenario.

*GT and GTCC units added before 1995 are fired with oil; units installed in 1995 and thereafter burn semiclean liquid.

These market penetration and capacity factor data describe the interaction of advanced cycles in one utility system. The Net Present Worth program describes the economics of this interaction for the entire United States. To get a truly representative picture of the national effect, it would be necessary to run OGP for each of the six synthetic utility regions* and average the results. This is an expensive task beyond the scope of the present work. For the purpose of demonstrating the Net Present Worth (NPW) method, it is judged to be sufficient to use a single region as a guide for specifying market penetration and capacity factors to the NPW program.

*Synthetic Electric Utility Systems for Evaluating Advanced Technologies, Power Technologies Inc., Schenectady, N.Y., EPRI Report # EM-285, February 1977.

Table F-12

**MINIMUM COMPETITION SCENARIO (GTWCCE)
MARKET PENETRATION AND CAPACITY FACTORS**

Year	MW Added Each Year						Year	Capacity Factors ⁽¹⁾ - %								Old Units ⁽²⁾				
	STLWR	STSCRB	GT	GTCC	GTWCCE			STLWR	STSCRB	GT		GTCC		GTWCCE						
										OIL	SCL	OIL	SCL							
1986	1x1000	2x747				(3)	1986	70.6								45.0				
87	1x1000						87	73.5												
88	1x1000						88	71.4												
89							89	72.2									30.3			
1990	1x1000	1x747	10x76			(3)	1990	71.1	30.4	8.1	5.0					44.0				
91	1x1000						91	70.2	30.2											
92	2x1000						92	68.7	30.2											
93							93	69.7	31.2											
94	2x1000						94	67.6	30.4											
1995	1x1000						1995	67.3	30.7								7.1	51.7	38.5	
96							96	68.4	28.6								4.3			
97							97	70.0	27.5								4.3			
98							98	71.0	22.0								2.5			51.0
99							99	71.7	22.2								3.3			0.4
2000		2000	72.0	16.2	2.1	0.2	53.8													
1		1	72.3	13.3	1.8	1.2	54.4													
2		2	72.4	8.0	0.9	0.5	53.4													
3		3	72.4	5.2	0.6	0.3	52.1													
4		4	72.4	4.2	0.6	0.3	50.8													
2005		2005	72.4	3.4	0.6	0.3	50.6	37.0												
6		6	72.4	5.1	0.8	0.4	1.9		52.8											
7		7	72.4	4.7	1.0	0.4	1.8		52.9											
8		8	72.4	4.3	1.2	0.4	1.7		53.2											
9		9	72.2	14.5	0.1	0.9	6.0	58.4	61.6											
2010		2010	72.2	16.7	0.1	1.0	7.5	59.4												
11		11	72.2	16.7	0.1	1.0	7.9	59.8												
12		12	72.6	14.8	0.1	0.9	6.8	60.0												
13		13	72.4	15.3	0	0.9	7.2	60.9												
14		14	72.4	16.9	0	1.0	8.7	61.6		(4)										

(1) Averaged over all units within type category installed after 1985

(2) Averaged over all units installed before 1985

(3) These years are identical to the No New Technology Scenario

(4) Last old unit retired

*GT and GTCC units added after 1994 burn semiclean liquid.

Tables F-17 through F-22 describe the input data for the NPW calculation which have been derived from the OGP output. Market penetration is expressed as a percentage of the total capacity added, and it is a true average of the OGP results in each period. Capacity factors are averaged over the number of years that a unit type is active in each period. For example, Table F-10 shows that the first STSCRB was not added until 1989 in the No New Technology scenario; the average for capacity factors was taken from 1989 to 1994 and is presented as 30% in Table F-12 for the first period (1986-1994).

Table F-13

MINIMUM COMPETITION SCENARIO (OCMHD-1932 MW)⁽¹⁾
MARKET PENETRATION AND CAPACITY FACTORS

Year	MW Added Each Year					Year	Capacity Factors ⁽²⁾ - %							Old Units ⁽³⁾
	STLWR	STSCRB	GT	GTCC	OCMHD		STLWR	STSCRB	GT		GTCC		OCMHD	
									OIL	SCL	OIL	SCL		
1986	1x1000					1986	70.6							45.0
87	1x1000					87	73.5							
88	1x1000					88	71.4							
89		2x747				89	72.2	30.3						
1990	1x1000					1990	71.1	30.4						44.0
91	1x1000					91	70.2	30.2						
92	2x1000					92	68.7	30.2						
93			10x76			93	69.7	31.2	8.1					
94	2x1000	1x747				94	67.6	30.4	5.0					
1995	1x1000					1995	67.3	30.7	7.1					41.4
96	3x1000					96	64.4	27.8	4.0					
97			10x76			97	65.8	31.4	9.1	0.9				
98	2x1000	2x747				98	64.7	30.5	5.6	0.5				
99	1x1000		6x76			99	64.9	30.9	8.4	1.0				
2000	4x1000					2000	62.3	26.8	4.2	0.5				40.1
1	1x1000	1x747				1	62.9	27.6	4.3	2.3				
2	3x1000					2	61.4	23.2	2.9	1.6				
3	3x1000					3	60.2	20.5	2.3	1.2				
4	3x1000					4	59.4	20.3	2.6	1.4				
2005	3x1000					2005	58.4	15.6	2.3	1.3				40.9
6	4x1000					6	57.1	8.3	1.5	0.8				
7				8x417		7	58.9	17.4	1.3	0.7		4.0		
8			46x76			8	60.8	28.2	5.1	2.0		10.3		
9			16x76		2x1932	9	59.9	31.0	0.6	4.0		14.1	68.0	
2010					2x1932	2010	59.6	27.4	0.5	3.4		11.2	68.0	41.1
11					2x1932	11	56.3	23.7	0.4	2.6		9.1	68.0	
12			2x76		2x1932	12	56.4	25.1	0.6	3.4		10.9	68.0	
13					3x1932	13	54.4	20.1	0.5	2.7		8.6	67.6	
14					2x1932	14	53.4	19.1	0.6	2.7		8.4	67.0	(5)
2015			2x76		2x1932	2015	52.8	18.1	0.6	2.9		8.4	66.5	
16					3x1932	16	52.1	16.3	0.6	2.5		7.2	64.6	
17					3x1932	17	51.5	15.1	0.6	2.4		6.7	63.3	
18			26x76		2x1932	18	51.6	18.8	0.5	3.1		9.6	63.6	
19					4x1932	19	50.9	14.2	0.4	2.3		7.7	61.0	
2020					3x1932	2020	50.5	15.0	0.6	2.7		8.5	60.7	
21			14x76		3x1932	21	50.6	15.7	0.6	2.9		9.6	60.3	

(1) Unit Rating = 1932 MW; forced outage rate = 20%

(2) Averaged over all units within type category installed after 1985

(3) Averaged over all units installed before 1985

(4) These years are identical to No New Technology Scenario.

(5) Last old unit retired

*GT and GTCC units added after 1994 burn semiclean liquid.

Although the capacity factors for the old units varied somewhat among the scenarios the effect on energy generated by the old units was relatively small. For simplicity, all of the scenarios in Tables F-17 through F-22 have been assigned the same capacity factors for the old units.

Table F-14

MINIMUM COMPETITION SCENARIO (OCMHD-1000 MW)⁽¹⁾
MARKET PENETRATION AND CAPACITY FACTORS

Year	MW Added Each Year					Year	Capacity Factors ⁽²⁾ - %						
	STLWR	STSCRB	GT	GTCC	OCMHD		STLWR	STSCRB	GT		GTCC		OCMHD
									OIL	SCL	OIL	SCL	
1986	1x1000					1986	70.6						
87	1x1000					87	73.5						
88	1x1000					88	71.4						
89		2x747				89	72.2	30.3					
1990	1x1000					1990	71.1	30.4					
91	1x1000					91	70.2	30.2					
92	2x1000					92	68.7	30.2					
93			10x76			93	69.7	31.2	8.1				
94	2x1000	1x747				94	67.6	30.4	5.0				
1995	1x1000					1995	67.3	30.7	7.1				
96	3x1000					96	64.4	27.8	4.0				
97			10x76			97	65.8	31.4	9.1	0.9			
98	2x1000	2x747				98	64.7	30.5	5.6	0.5			
99	1x1000		6x76			99	64.9	30.9	8.4	1.0			
2000	4x1000					2000	62.3	25.8	4.2	0.5			
1	1x1000	1x747				1	62.9	27.6	4.3	2.3			
2	3x1000					2	61.4	23.2	2.9	1.6			
3					3x1000	3	58.8	20.4	2.3	1.3			72.4
4					3x1000	4	56.5	20.4	2.6	1.4			72.2
2005					3x1000	2005	54.3	15.5	2.3	1.3			72.1
6					4x1000	6	52.1	8.4	1.5	0.8			69.8
7					4x1000	7	51.1	4.6	0.9	0.5			64.8
8			26x76	2x417		8	51.9	11.1	2.4	1.1	3.6		70.0
9			40x76		2x1000	9	52.8	21.4	0.4	2.5	9.7		70.1
2010			4x76		3x1000	2010	53.4	19.9	0.4	2.4	9.1		69.4
11			8x76		3x1000	11	51.5	19.0	0.3	2.0	8.8		68.8
12					5x1000	12	51.2	16.0	0.2	1.8	7.4		67.1
13			16x76		4x1000	13	50.8	17.1	0.2	1.8	8.4		66.8
14			14x76		3x1000	14	50.8	18.2	0.2	1.8	9.7		66.5
2015			4x76		4x1000	2015	50.4	16.9	0.1	1.6	9.1		65.6
16			20x76		4x1000	16	50.1	18.9	0.1	1.7	11.4		65.7
17					6x1000	17	49.7	16.2	0.1	1.4	9.0		64.3
18					6x1000	18	49.4	14.5	0.1	1.2	7.7		63.2
19			8x76		6x1000	19	49.2	13.1	0.1	1.2	8.3		61.8
2020			8x76		6x1000	2020	49.0	12.6	0.1	1.2	8.0		61.4
21			14x76		6x1000	21	48.8	12.8	0.1	1.2	8.1		61.1

(1) Unit rating: 1000 MW; forced outage rate: 15%

(2) Averaged over all units within type category installed after 1985

(3) These years are identical to No New Technology Scenario.

*GT and GTCC units added after 1994 burn semiclean liquid.

The OGP runs for the STAFB and GTWCCE Minimum Competition scenarios did not extend into the final time period of the study (2015-2024). Tables F-18 and F-19 describe the logic used to extrapolate the results into this period for use in the NPW program.

Table F-15

CROWDED MARKET SCENARIO
MARKET PENETRATION

Year	MW Added Each Year						
	STLWR	STSCRB	GT	GTCC	STAFB	GTWCCE	OCMHD
1986	1x1000	(2)					
87	1x1000						
88					1x814		
89					2x814		
1990					1x814		
91					2x814		
92					1x814		
93					2x814		
94			6x76		2x814		
1995			10x76		1x814		
96						4x640	
97						2x640	
98			4x76			4x640	
99			10x76			2x640	
2000						5x640	
1					3x814		
2						4x640	
3						5x640	
4					1x814	4x640	
2005			6x76			4x640	
6							2x1932
7			18x76				1x1932
8			46x76				
9			26x76			2x640	1x1932
2010			2x76			5x640	
11			20x76				1x1932
12			6x76			4x640	1x1932
13			2x76			2x640	2x1932
14			4x76				2x1932
2015						7x640	
16			18x76			3x640	1x1932
17							3x1932
18			18x76			4x640	1x1932
19						8x640	1x1932
2020			24x76			4x640	1x1932
21						12x640	
22			24x76			2x640	2x1932

(1) These years are identical to No New Technology Scenario.

(2) Only STLWR, GT, GTCC, STAFB, GTWCCE and OCMHD were active candidates for selection in these computer runs. The STSCRB was eliminated prior to making the runs on the basis of the Minimum Competition Scenario results.

*GT and GTCC units added before 1995 are fired with oil; units installed in 1995 and thereafter burn semiclean liquid.

Table F-16

**CROWDED MARKET SCENARIO
CAPACITY FACTORS**

Year	Capacity Factors ⁽¹⁾ - %									
	STLWR	STSCR	GT		GTCC		STAFB	GTWCCE	OCMHD	Old Units ⁽²⁾
			OIL	SCL	OIL	SCL				
1986	70.6									45.0
87	73.5									45.0
88	74.0						47.9			
89	74.3						46.9			
1990	74.3						48.1			46.0
91	74.3						47.8			
92	74.3						49.5			
93	74.3						49.8			
94	74.3		3.5				50.1			
1995	74.3		5.3	0.4			52.2			47.0
96	74.3		3.3	0.3			44.8	79.9		
97	74.3		3.5	0.3			43.5	79.6		
98	74.3		3.4	0.3			41.2	77.9		
99	74.3		4.3	0.4			40.6	77.4		
2000	70.8		2.8	0.3			35.9	75.6		40.1
1	72.9		1.7	0.9			35.8	77.0		
2	72.9		1.4	0.7			33.1	75.0		
3	72.9		0.9	0.4			29.1	72.5		
4	72.9		0.7	0.4			28.0	71.0		
2005	72.9		0.7	0.4			25.5	69.9		40.8
6	72.9		0.8	0.5			21.4	66.4	66.6	
7	72.9		1.8	0.6			22.7	65.6	69.0	
8	72.9		5.4	1.0			29.0	67.9	69.0	
9	71.3		0.1	1.6			32.2	68.2	68.0	
2010	71.3		0.1	1.3			29.8	67.4	68.0	61.8
11	71.4		0.1	1.6			31.9	67.4	68.0	
12	73.8		0.1	1.5			30.6	66.8	68.0	57.0
13	72.2		0.1	1.4			28.8	65.3	68.0	
14	72.4		0.1	1.3			27.8	63.6	68.0	(4)
2015	72.4		0.1	1.0			24.5	62.8	68.1	
16	72.1		0.1	1.2			25.9	63.3	68.1	
17	--		0.1	1.2			24.5	61.5	68.1	
18	--		0.1	1.2			24.3	60.8	68.1	
19	--		0.1	1.3			18.7	59.1	68.1	
2020	--		0.1	1.3			19.3	59.0	68.0	
21	--		0.1	1.1			14.1	57.5	68.0	
22	--		0.1	1.2			15.2	56.9	68.1	

(1) Averaged over all units within type category installed after 1985

(2) Averaged over all units installed before 1985

(3) These years are identical to the No New Technology Scenario.

(4) Last old unit retired

Table F-17

**INTERPRETATION OF OGP RESULTS
NO NEW TECHNOLOGY SCENARIO**

Power Plant Type	Time							
	1986-1994		1995-2004		2005-2014		2015-2024	
	f %	F %	f %	F %	f %	F %	f %	F %
STLWR	75.0	71.0	85.8	63.0	67.4	60.0	84.7	60.0
STSCRB	18.7	30.0	9.2	27.0	3.7	25.0	3.3	24.0
GT/OIL	6.3	6.6	0	5.1	0	1.0	0	0.1
GT/SCL	--	--	5.0	1.2	22.7	2.3	12.0	1.4
GTCC/SCL	--	--	--	--	6.2	12.0	0	14.0
Old Units	--	*	--	*	--	*	--	--

$$*F_{OLD} = 0.45 - 0.05(t - 1985)/20, \text{ where } t = \text{year}$$

f = market penetration = MW of unit type installed in period / total MW installed in period

F = capacity factor = MWh generated in period / MWh generated if operated at 100% rating throughout period

Table F-18

**INTERPRETATION OF OGP RESULTS
MINIMUM COMPETITION SCENARIO (STAFB)**

Power Plant Type	Time									
	1986-1987		1988-1994		1995-2004		2005-2014		2015-2024	
	f %	F %	f %	F %	f %	F %	f %	F %	f %	F %
STLWR	100	72	0	74.0	43.9	73.0	28.9	73.0	37.6 ⁽¹⁾	73.0 ⁽¹⁾
GT/OIL	0	--	4.8	3.5	0	3.3	0	0.9	0	0.1 ⁽³⁾
GT/SCL	0	--	0	--	7.3	0.5	17.6	0.4	12.5 ⁽⁴⁾	0.4 ⁽²⁾
GTCC/SCL	0	--	0	--	0	--	18.1	2.5	0 ⁽³⁾	2.5 ⁽²⁾
STAFB	0	--	95.2	48.0	48.8	49.0	35.4	44.0	49.9 ⁽¹⁾	44.0 ⁽²⁾
Old Units	--	*	--	*	--	*	--	*	--	--

(1) If GT/SCL takes 12.5% of market, then STLWR and STAFB divide 87.5% between them. Proportion of capacity between STLWR and STAFB showed increasing trend in previous two periods: (1995-2004): 48.8/43.9 = 1.11, (2005-2014): 35.4/28.9 = 1.22. Assuming that this trend continues, then (2015-2024): $f_{STAFB}/f_{STLWR} = 1.33$. Combining this with the total market share relation, $f_{STAFB} + f_{STLWR} = 0.875$ yields the extrapolations quoted.

(2) Extrapolation, same as value in previous time period

(3) Extrapolation, same as value in final period of No New Technology Scenario

(4) Extrapolation, average of two periods, similar to value in final period of No New Technology Scenario

$$*F_{OLD} = 0.45 - .05(t-1985)/20, \text{ where } t = \text{year}$$

Note:

f = market penetration = MW of unit type installed in period / total MW installed in period
F = capacity factor = MWh generated in period / MWh generated if operated at 100% rating throughout period

Table F-19

INTERPRETATION OF OGP RESULTS
MINIMUM COMPETITION SCENARIO (GTWCCE)

Power Plant Type	Time							
	1986-1995		1996-2004		2005-2014		2015-2024	
	f %	F %	f %	F %	f %	F %	f %	F %
STLWR	76.9	70.0	0	71.0	0	72.0	0	72.0 ⁽¹⁾
STSCRB	17.2	30.0	0	16.0	0	11.0	0	16.0 ⁽²⁾
GT/OIL	5.9	6.7	0	2.0	0	0.4	0	0 ⁽³⁾
GT/SCL	--	--	1.9	0.5	30.4	0.7	16.0 ⁽⁴⁾	1.0 ⁽²⁾
GTCC/SCL	--	--	0	--	7.3	5.5	0	5.5 ⁽¹⁾
GTWCCE	--	--	98.1	52.0	62.3	57.0	84.0 ⁽⁵⁾	62.0 ⁽⁶⁾
Old Units	--	*	--	*	--	*	--	--

(1) Extrapolation, same value as previous period

(2) Extrapolation, value is an average from the years 2009-2014

(3) Extrapolation, same value as final period in No New Technology Scenario

(4) Extrapolation, average of previous two periods; similar to value in final period of No New Technology Scenario, $(1.9+30.4)/2 = 16.2$

(5) Extrapolation, assume that GT/SCL and GTWCCE exclude all other competitors as in the period 1996-2004. If GT/SCL takes 16% of the market, then GTWCCE takes the remainder, 84%

(6) Extrapolation, continue upward trend seen in previous periods

* $F_{OLD} = 0.45 - 0.05(t-1985)/20$, where t = year

Note:

f = market penetration = MW of unit type installed in period ÷ total MW installed in period

F = capacity factor = MWh generated in period ÷ MWh generated if operated at 100% rating throughout period

Table F-20
INTERPRETATION OF OGP RESULTS
MINIMUM COMPETITION SCENARIO (OCMHD-1932 MW)

Power Plant Type	Time									
	1986-1994		1995-2004		2005-2008		2009-2014		2015-2024	
	f %	F %	f %	F %	f %	F %	f %	F %	f %	F %
STLWR	75.0	71.0	85.8	63.0	50.6	59.0	0	57.0	0	51.0
STSCRB	18.7	30.0	9.2	27.0	0	17.0	0	24.0	0	16.0
GT/OIL	6.3	6.6	0	5.1	0	2.6	0	0.5	0	0.6
GT/SCL	--	--	5.0	1.2	25.3	1.2	5.2	3.1	7.6	2.7
GTCC/SCL	--	--	--	--	24.1	5.4	0	10.0	0	8.2
OCMHD	--	--	--	--	0	--	94.8	68.0	92.4	63.0
Old Units	--	*	--	*	--	*	--	*	--	--

*F_{OLD} = 0.45 - 0.05(t-1985)/20, where t = year

Note:

f = market penetration = MW of unit type installed in period / total MW installed in period

F = capacity factor = MWh generated in period / MWh generated if operated at 100% rating throughout period

Table B-21
INTERPRETATION OF OGP RESULTS
MINIMUM COMPETITION SCENARIO (OCMHD-1000 MW)

Power Plant Type	Time									
	1986-1994		1995-2002		2003-2004		2005-2014		2015-2024	
	f %	F %	f %	F %	f %	F %	f %	F %	f %	F %
STLWR	75.0	71.0	81.4	64.0	0	58.0	0	52.0	0	50.0
STSCRB	18.7	30.0	12.1	29.0	0	20.0	0	15.0	0	15.0
GT/OIL	6.3	6.6	0	5.7	0	2.4	0	0.9	0	0.1
GT/SCL	--	--	6.5	1.1	0	1.3	20.5	1.6	9.7	1.4
GTCC/SCL	--	--	0	--	0	--	2.1	8.1	0	8.8
OCMHD	--	--	--	--	100	72.0	77.4	68.0	90.3	63.0

Note:

f = market penetration = MW of unit type installed in period / total MW installed in period

F = capacity factor = MWh generated in period / MWh generated if operated at 100% rating throughout period

Table F-22

INTERPRETATION OGP RESULTS
CROWDED MARKET SCENARIO

Power Plant Type	Time									
	1986-1987		1988-1995		1996-2005		2006-2014		2015-2024	
	f %	F %	f %	F %	f %	F %	f %	F %	f %	F %
STLWR	100.0	72	0	74.0	0	73.0	0	72.0	0	72.0
GT/OIL	0	--	4.2	4.4	0	2.3	0	1.0	0	0.1
GT/SCL	0	--	6.9	0.4	5.7	0.4	25.4	1.2	12.9	1.2
STAFB	--	--	88.9	49.0	12.3	36.0	0	28.0	0	21.0
GTWCCE	--	--	--	--	82.0	76.0	22.5	66.0	51.9	60.0
OCMHD	--	--	--	--	--	--	52.1	68.0	35.2	68.0
Old Units	--	*	--	*	--	*	--	*	--	--

$$*F_{OLD} = 0.45 - 0.05(t-1985)/20, \text{ where } t = \text{year}$$

Note:

f = market penetration = $\frac{\text{MW of unit type installed in period}}{\text{total MW installed in period}}$

F = capacity factor = $\frac{\text{MWh generated in period}}{\text{MWh generated if operated at 100\% rating throughout period}}$

F.5 IMPACT OF INTANGIBLES

The procedure developed for considering the Impact of Intangibles in the Net Present Worth method has been explained in Appendix D.3. In particular, Equation D-5 expresses the market penetration multiplier f_{Mk} for Cycle k as

$$f_{Mk} = \sqrt{\text{MIN}(p_{ik}) \prod_i p_{ik}}$$

where p_{ik} is the market penetration effect of Evaluation Criterion i upon Cycle k. Also, Appendix D.3 explains how a value is assigned to p_{ik} when the "i"th evaluation criterion is good, fair, or poor, respectively, for Cycle k.

Table F-23 lists the resulting values for f_{Mk} for each Cycle k. This is based upon evaluation criteria ratings as listed in Appendix G. Note that two cycles have especially low market penetration multipliers: 0.43 for the GTCC/SCL cycle, and 0.44 for the GT/SCL cycle. These are low because semiclean liquid (SCL) is rated poor in regard to Evaluation Criterion 24, Environmental Intrusion, and this evaluation criterion is one of the hard criteria (for which $p_{ik} = 0.50$ when poor). In no case other than these two is a hard evaluation criterion rated poor.

Table F-23
MARKET PENETRATION MULTIPLIERS FOR INTANGIBLES

Cycle	Mkt Pen Mult
STLWR	0.56
STSCR	0.60
GT/OIL	0.77
GT/SCL	0.44
GTCC/OIL	0.77
GTCC/SCL	0.43
STAFB	0.70
GTWCCE	0.72
OCMHD	0.60

Note that, in contrast, two cycles are tied for the highest market penetration multiplier: 0.77 for both GT/OIL and GTCC/OIL. This implies that the gas turbine and the gas-turbine combined cycle are dramatically changed in regard to intangibles when they must switch from oil to SCL. Because all market penetrations are normalized by Equation D-2 of Appendix D.3 so as to fill the market after market penetrations are decreased for intangibles, the cycles with higher values of f_{Mk} will actually increase their market penetrations above OGP values.

The effect of this is shown by an example in Table F-24. This table is selected for the STAFB Minimum Competition Scenario for installations in the year 2000. Note that the STAFB, which has the highest market penetration multiplier of the three cycles in competition at that time, increases its market penetration from the OGP estimate of 0.49 up to 0.55. The other two cycles have lower market penetration multipliers and thus lose market share: STLWR drops from 0.44 to 0.40, and GT/SCL from 0.07 to 0.05. While the GT/SCL loses only 2% of the market, its relative loss is greatest (from 7% down to 5%), corresponding to its low value of f_{Mk} .

Table F-24
EXAMPLE EFFECT OF MARKET PENETRATION MULTIPLIERS

Cycle	Mkt Pen Multiplier f_{Mk}	—Market Penetration f_{kj} —	
		From OGP	After Adjustment
STAFB	0.70	0.49	0.55
STLWR	0.56	0.44	0.40
GT/SCL	0.44	0.07	0.05
		<u>1.00</u>	<u>1.00</u>
Normalizing factor: $c_f = 1.62$			
Example: STAFB Minimum Competition scenario, year j=2000			

F.6 NET PRESENT WORTH OF SAVINGS, BASE CASE

The base case is defined as having these attributes: intangibles are considered (as they impact market penetration) but taxes are not considered.

Also, all four combinations of intangibles (with/without) and taxes (with/without) have been run. The case with intangibles, without taxes is the base case, of course. The case without intangibles, with taxes is the OGP case, as these are the conditions under which the OGP program runs.

Figures F-13 through F-18 portray the market impact of the various cycles in the various scenarios considered, all for the base case. Figure F-13 plots installed capacity vs. time for the No New Technology Scenario. Note that pre-scenario units are those installed prior to the end of 1985; the last of them can be seen to be retired in 2015. Post-scenario units are those installed after the end of 2024. Scenario units are those installed between 1986 and 2024 inclusive; the last of them can be seen to be retired in 2054. This figure breaks down the scenario units by type of cycle: STLWR, STSCR, GT, and GTCC (because of crowding, no distinction is made between GT and GTCC units which burn oil and those which burn semiclean liquid). It is evident that STLWR units make up the overwhelming majority of scenario capacity.

Figure F-13. Installed Capacity, No New Technology Scenario (Adjusted for Intangibles)

Figure F-14. Electric Energy Generated, No New Technology Scenario (Adjusted for Intangibles)

Figure F-15. Installed Capacity, STAFB Minimum Competition Scenario (Adjusted for Intangibles)

Figure F-16. Installed Capacity, GTWCCE Minimum Competition Scenario (Adjusted for Intangibles)

Figure F-17. Installed Capacity, OCMHD Minimum Competition Scenario (Adjusted for Intangibles)

Figure F-18. Installed Capacity, Crowded Market Scenario
(Adjusted for Intangibles)

Figure F-14 plots electric energy generated vs. time for the No New Technology Scenario. Compare it to Figure F-13, which plots capacity versus time for the same scenario. It is clear that the STLWR scenario units generate nearly all the electrical energy.

Figure F-15 plots installed capacity vs. time for the STAFB Minimum Competition Scenario. It is evident that STAFB units rapidly acquire the dominant market share, though never fully displacing STLWR units. Figure F-16 plots installed capacity vs. time for the GTWCCE Minimum Competition Scenario. Unlike the STAFB Minimum Competition scenario, the new cycle (in this case GTWCCE) does completely displace STLWR. Figure F-17 plots installed capacity vs. time for the OCMHD Minimum Competition Scenario. The OCMHD units never completely displace STLWR. Finally, Figure F-18 plots installed capacity vs. time for the Crowded Market Scenario. Here STAFB units initially displace STLWR, but in turn are displaced by GTWCCE and OCMHD units.

Figure F-19 displays the present worth of savings for the four scenarios with new cycles (STAFB Minimum Competition, GTWCCE Minimum Competition, OCMHD Minimum Competition, and Crowded Market). These savings are displayed under the four combinations with/without intangibles and with/without taxes. In all four combinations, the Crowded

Figure F-19. Present Worth of Savings

Market Scenario has the greatest savings. Also, in all four combinations, the GTWCCE Minimum Competition Scenario has the greatest savings of the three Minimum Competition Scenarios. Note that savings are appreciably smaller when taxes are omitted than when taxes are present; this reflects the capital-intensive nature of new cycles. It is also evident that, comparing the two cases with intangibles to the two cases without intangibles, the impact of intangibles upon savings is minor for the group of cycles considered in this study.

In one instance, the STAFB Minimum Competition Scenario with the base case, the savings are actually negative. This comes about because OGP would have made other decisions if it were to consider intangibles and omit taxes, as the base case does.

Table F-25 tabulates the savings shown graphically in Figure F-19. Also, it lists the net present worth values which underlie the savings. Note that savings are generally much smaller than the net present worth values being compared. This may give the appearance that the savings values are highly uncertain, but that may not be the case, because many of the factors which determine the net present worth values are the same between scenarios.

Table F-25
RESULTS FROM NET PRESENT WORTH METHOD

CASE → INTANGIBLES → TAXES →	"BASE" Included Excluded	With Taxes Included Included	W/O Intangibles Excluded Excluded	"OGP" W/O Intangibles W Taxes Excluded Included
Present Worth of Costs* (B\$)				
No New Technology	3594.3	4787.9	3570.0	4742.5
Minimum Competition - STAFB	3602.6	4503.9	3550.0	4444.4
Minimum Competition - GTWCCE	3422.7	4251.2	3392.1	4195.3
Minimum Competition - OCMHD	3457.7	4438.2	3450.1	4420.4
Crowded Market	3396.7	4172.2	3365.3	4117.8
Net Present Worth of Savings (B\$)				
Minimum Competition - STAFB	-8.3	284.0	20.1	298.1
Minimum Competition - GTWCCE	171.6	536.8	177.9	547.2
Minimum Competition - OCMHD	136.5	349.7	119.9	322.1
Crowded Market	197.5	615.7	204.7	624.8

*1975 Present Worth Expressed in 1975 Dollars

Finally, it should be noted that the present worth of R&D costs are trivial compared to present worths of savings. For the OGP case, the comparisons are as follows:

<u>Scenario</u>	<u>NPW of Savings</u>	<u>NPW of R&D Program</u>
STAFB Minimum Competition	298.1 B\$	0.2 B\$
GTWCCE Minimum Competition	547.2 B\$	0.4 B\$
OCMHD Minimum Competition	322.1 B\$	1.3 B\$
Crowded Market	624.8 B\$	1.9 B\$

One concludes that R&D pays for itself many times over. The problem is not to justify spending R&D dollars, but rather selecting the most productive place to spend limited R&D funds.

Tables F-26 through F-31 list the output from BWORDH for the base case. This case is defined as having:

- Adjustment for intangibles TRUE
- Consideration of taxes FALSE

This listing appears in five year steps, rather than one year steps, to conserve space in this report.

The output is organized as follows:

- Scenario-independent quantities, Table F-26. These include R&D costs, capital costs before and after adjustment, heat rates, and escalated costs vs. time for the three quantities of Fixed O&M, Variable O&M, and Fuel.
- No New Technology scenario, Table F-27. Outputs include market penetration multipliers, adjusted market penetrations vs. time, capacity addition rates vs. time, installed capacities vs. time, adjusted capacity factors vs. time, energy generated by cycles vs. time, future life-cycle worths vs. time for four quantities (capital, fixed O&M, variable O&M, fuel), 1975 worths of units installed in various years, and integrated 1975 worths of units installed in various years, and integrated 1975 worths (broken down by cycles and type of cost).
- STAFB Minimum Competition Scenario, Table F-28. Same outputs as for No New Technology Scenario, plus savings over No New Technology Scenario.
- GTWCCE Minimum Competition Scenario, Table F-29. Similar.
- OCMHD Minimum Competition Scenario, Table F-30. Similar
- Crowded Market Scenario, Table F-31. Similar

Table F-26
BASE CASE
SCENARIO - INDEPENDENT QUANTITIES

	STLWR	STSCR	GT/OIL	GT/SCL	GTCC/OIL	GTCC/SCL	STAFB	GTWCCE	OCMHD
	-----	-----	-----	-----	-----	-----	-----	-----	-----
R&D COST (M\$):									
BEFORE ADJUSTMENT	0.	0.	0.	0.	0.	0.	228.0	418.0	1444.0
AFTER ADJUSTMENT	0.	0.	0.	0.	0.	0.	239.4	501.6	1949.4
1975 CAPITAL COST (\$/KW):									
BASE VALUE	776.0	591.0	116.0	116.0	282.0	282.0	447.0	474.0	477.0
WITH TAXES, ETC.	788.1	600.3	117.8	117.8	286.4	286.4	454.0	481.4	484.5
HEAT RATE (BTU/KWHR):	10400	10736	11013	11013	8014	8014	9536	7759	7068
ESCALATED COSTS:									
FIXED O&M									
(\$/KW-YR)									
1985	5.01	4.58	0.99	0.99	2.70	2.70	5.03	2.35	2.57
1990	6.87	6.28	1.36	1.36	3.70	3.70	6.89	3.21	3.52
1995	9.41	8.60	1.87	1.87	5.07	5.07	9.44	4.40	4.83
2000	12.89	11.78	2.56	2.56	6.95	6.95	12.94	6.03	6.61
2005	17.66	16.14	3.51	3.51	9.52	9.52	17.73	8.27	9.06
2010	24.20	22.11	4.80	4.80	13.05	13.05	24.29	11.33	12.42
2015	33.15	30.30	6.58	6.58	17.88	17.88	33.28	15.52	17.01
2020	45.42	41.51	9.02	9.02	24.50	24.50	45.59	21.26	23.31
2025	62.23	56.87	12.35	12.35	33.56	33.56	62.46	29.13	31.93
2030	85.26	77.91	16.92	16.92	45.98	45.98	85.58	39.92	43.75
2035	116.81	106.75	23.19	23.19	63.00	63.00	117.25	54.69	59.94
2040	160.04	146.26	31.77	31.77	86.32	86.32	160.64	74.93	82.12
2045	219.27	200.38	43.53	43.53	118.26	118.26	220.09	102.66	112.51
2050	300.42	274.54	59.63	59.63	162.03	162.03	301.55	140.65	154.15
2054	386.48	353.19	76.72	76.72	208.44	208.44	387.93	180.94	198.31

Table F-26 (Cont'd)

		STLWR	STSCRB	GT/OIL	GT/SCL	GTCC/OIL	GTCC/SCL	STAFB	GTWCCE	OCMHD
		-----	-----	-----	-----	-----	-----	-----	-----	-----
ESCALATED COSTS:										
VAR. O&M	1985	1.28	4.09	2.57	2.57	2.42	2.42	3.28	3.44	2.82
(MILLS/KWHR)	1990	1.75	5.61	3.52	3.52	3.32	3.32	4.50	4.71	3.86
	1995	2.40	7.68	4.83	4.83	4.55	4.55	6.17	6.45	5.29
	2000	3.28	10.52	6.61	6.61	6.23	6.23	8.45	8.83	7.24
	2005	4.50	14.42	9.06	9.06	8.53	8.53	11.58	12.10	9.92
	2010	6.16	19.76	12.42	12.42	11.69	11.69	15.86	16.58	13.59
	2015	8.44	27.07	17.01	17.01	16.02	16.02	21.73	22.72	18.62
	2020	11.57	37.08	23.31	23.31	21.94	21.94	29.77	31.13	25.52
	2025	15.85	50.81	31.93	31.93	30.07	30.07	40.79	42.65	34.96
	2030	21.71	69.61	43.75	43.75	41.19	41.19	55.88	58.44	47.90
	2035	29.75	95.37	59.94	59.94	56.44	56.44	76.56	80.06	65.62
	2040	40.76	130.67	82.12	82.12	77.32	77.32	104.90	109.69	89.91
	2045	55.84	179.03	112.51	112.51	105.94	105.94	143.72	150.29	123.19
	2050	76.51	245.29	154.15	154.15	145.15	145.15	196.91	205.91	168.78
	2054	98.43	315.56	198.31	198.31	186.73	186.73	253.31	264.89	217.13
ESCALATED COSTS:										
FUEL	1985	1.06	1.88	4.18	7.01	4.18	7.01	1.88	1.88	1.94
(\$/MBTU)	1990	1.52	2.67	6.29	9.93	6.29	9.93	2.67	2.67	2.75
	1995	2.17	3.78	9.90	14.06	9.90	14.06	3.78	3.78	3.90
	2000	3.10	5.35	15.59	19.90	15.59	19.90	5.35	5.35	5.52
	2005	4.43	7.57	25.68	28.18	25.68	28.18	7.57	7.57	7.81
	2010	6.33	10.71	42.30	39.89	42.30	39.89	10.71	10.71	11.06
	2015	9.04	15.17	69.69	56.48	69.69	56.48	15.17	15.17	15.65
	2020	12.92	21.47	114.82	79.95	114.82	79.95	21.47	21.47	22.16
	2025	18.46	30.40	189.15	113.19	189.15	113.19	30.40	30.40	31.37
	2030	26.38	43.04	311.62	160.24	311.62	160.24	43.04	43.04	44.41
	2035	37.69	60.93	513.38	226.86	513.38	226.86	60.93	60.93	62.87
	2040	53.86	86.26	845.77	321.17	845.77	321.17	86.26	86.26	89.01
	2045	76.97	122.11	1393.35	454.68	1393.35	454.68	122.11	122.11	126.01
	2050	109.98	172.88	2295.48	643.69	2295.48	643.69	172.88	172.88	178.39
	2054	146.33	228.31	3422.33	850.07	3422.33	850.07	228.31	228.31	235.59

Table F-27
BASE CASE
NO NEW TECHNOLOGY

	STLWR	STSCRB	GT/OIL	GT/SCL	GTCC/OIL	GTCC/SCL	STAFB	GTWCCE	OCMHD	
	-----	-----	-----	-----	-----	-----	-----	-----	-----	
MARKET PEN MULT.	0.5598	0.5966	0.7680	0.4406	0.7690	0.4266	0.6981	0.7173	0.5970	NORM.
ADJUSTED MKT PEN:										FACTOR
1990	0.7241	0.1924	0.0834	0.	0.	0.	0.	0.	0.	1.7247
1995	0.8620	0.0985	0.	0.0395	0.	0.	0.	0.	0.	1.7946
2000	0.8620	0.0985	0.	0.0395	0.	0.	0.	0.	0.	1.7946
2005	0.7175	0.0420	0.	0.1902	0.	0.0503	0.	0.	0.	1.9017
2010	0.7175	0.0420	0.	0.1902	0.	0.0503	0.	0.	0.	1.9017
2015	0.8673	0.0360	0.	0.0967	0.	0.	0.	0.	0.	1.8291
2020	0.8673	0.0360	0.	0.0967	0.	0.	0.	0.	0.	1.8291
2024	0.8673	0.0360	0.	0.0967	0.	0.	0.	0.	0.	1.8291
CAPY ADDN RATE (GW/YR):										TOTAL
1985										54.4
1990	52.1	13.8	6.0	0.	0.	0.	0.	0.	0.	71.9
1995	82.1	9.4	0.	3.8	0.	0.	0.	0.	0.	95.2
2000	108.6	12.4	0.	5.0	0.	0.	0.	0.	0.	126.0
2005	119.7	7.0	0.	31.7	0.	8.4	0.	0.	0.	166.8
2010	155.9	9.1	0.	41.3	0.	10.9	0.	0.	0.	217.2
2015	247.7	10.3	0.	27.6	0.	0.	0.	0.	0.	285.6
2020	325.8	13.5	0.	36.3	0.	0.	0.	0.	0.	375.6
2024	405.6	16.8	0.	45.2	0.	0.	0.	0.	0.	467.6
INSTALLED CAPY (GW):										TOTAL
1985	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
1990	227.3	60.4	26.2	0.	0.	0.	0.	0.	0.	313.9
1995	540.7	131.6	53.1	3.7	0.	0.	0.	0.	0.	729.1
2000	1014.4	185.7	53.1	25.4	0.	0.	0.	0.	0.	1278.7
2005	1618.1	248.2	53.1	78.6	0.	8.2	0.	0.	0.	2006.1
2010	2300.6	288.1	53.1	259.5	0.	56.0	0.	0.	0.	2957.4
2015	3238.9	338.9	53.1	471.2	0.	104.9	0.	0.	0.	4207.0
2020	4436.9	337.7	26.9	630.1	0.	104.9	0.	0.	0.	5536.5
2025	5580.7	327.0	0.0	788.9	0.	104.9	0.	0.	0.	6801.5
2030	5107.0	272.9	0.0	767.2	0.	104.9	0.	0.	0.	6252.0
2035	4503.4	210.4	0.0	714.0	0.	96.7	0.	0.	0.	5524.5
2040	3820.8	170.5	0.0	533.1	0.	48.9	0.	0.	0.	4573.3
2045	2882.5	119.7	0.0	321.4	0.	0.0	0.	0.	0.	3323.6
2050	1457.3	60.5	0.0	162.5	0.	0.0	0.	0.	0.	1680.3
2054	-0.0	0.0	0.0	0.0	0.	0.0	0.	0.	0.	0.0

Table F-27 (Cont'd)

	STLWR	STSCRB	GT/OIL	GT/SCL	GTCC/OIL	GTCC/SCL	STAFB	GTWCCE	OCMHD	
	-----	-----	-----	-----	-----	-----	-----	-----	-----	
ADJUSTED CAPY FACTORS:										CORR. FACTOR
1990	0.5867	0.2479	0.0545	0.	0.	0.	0.	0.	0.	0.8263
1995	0.5769	0.2472	0.0467	0.0110	0.	0.	0.	0.	0.	0.9157
2000	0.5467	0.2343	0.0443	0.0104	0.	0.	0.	0.	0.	0.8678
2005	0.5367	0.2236	0.0089	0.0206	0.	0.1073	0.	0.	0.	0.8945
2010	0.5538	0.2307	0.0092	0.0212	0.	0.1108	0.	0.	0.	0.9229
2015	0.5644	0.2258	0.0009	0.0132	0.	0.1317	0.	0.	0.	0.9406
2020	0.5451	0.2181	0.0009	0.0127	0.	0.1272	0.	0.	0.	0.9086
2025	0.5345	0.2138	0.0009	0.0125	0.	0.1247	0.	0.	0.	0.8908
2030	0.5370	0.2148	0.0009	0.0125	0.	0.1253	0.	0.	0.	0.8950
2035	0.5397	0.2159	0.0009	0.0126	0.	0.1259	0.	0.	0.	0.8994
2040	0.5289	0.2116	0.0009	0.0123	0.	0.1234	0.	0.	0.	0.8816
2045	0.5107	0.2043	0.0009	0.0119	0.	0.1192	0.	0.	0.	0.8511
2050	0.5110	0.2044	0.0009	0.0119	0.	0.1192	0.	0.	0.	0.8516
2054	0.5152	0.2061	0.0009	0.0120	0.	0.1202	0.	0.	0.	0.8586
ENERGY GENERATED (GW-YR PER YEAR):										TOTAL
1990	118.5	13.3	1.3	0.	0.	0.	0.	0.	0.	133.0
1995	288.9	31.4	2.5	0.0	0.	0.	0.	0.	0.	322.8
2000	525.7	42.1	2.4	0.2	0.	0.	0.	0.	0.	570.4
2005	837.2	54.7	0.5	1.3	0.	0.4	0.	0.	0.	894.2
2010	1232.0	65.5	0.5	5.1	0.	5.6	0.	0.	0.	1308.6
2015	1759.9	75.4	0.0	6.0	0.	13.8	0.	0.	0.	1855.2
2020	2346.1	73.7	0.0	7.8	0.	13.3	0.	0.	0.	2440.9
2025	3004.0	70.9	0.0	9.9	0.	13.1	0.	0.	0.	3097.8
2030	2770.7	59.9	0.0	9.6	0.	13.1	0.	0.	0.	2853.4
2035	2461.7	46.2	0.0	9.2	0.	12.7	0.	0.	0.	2529.7
2040	2061.1	37.0	0.0	6.8	0.	6.7	0.	0.	0.	2111.7
2045	1533.6	25.5	0.0	4.0	0.	0.0	0.	0.	0.	1563.0
2050	825.6	13.7	0.0	2.1	0.	0.0	0.	0.	0.	841.5
2054	101.7	1.7	0.0	0.3	0.	0.0	0.	0.	0.	103.6

Table F-27 (Cont'd)

		STLWR	STSCRB	GT/OIL	GT/SCL	GTCC/OIL	GTCC/SCL	STAFB	GTWCCE	OCMHD
		-----	-----	-----	-----	-----	-----	-----	-----	-----
FUTURE LIFE-CYCLE										
WORTHS (\$/KW):										
CAPITAL										
	1985	1479.46	1126.76	221.16	221.16	0.	537.64	0.	0.	0.
	1990	2026.99	1543.75	303.00	303.00	0.	736.61	0.	0.	0.
	1995	2777.16	2115.08	415.14	415.14	0.	1009.22	0.	0.	0.
	2000	3804.95	2897.84	568.78	568.78	0.	1382.73	0.	0.	0.
	2005	5213.11	3970.29	779.28	779.28	0.	1894.45	0.	0.	0.
	2010	7142.41	5439.64	1067.68	1067.68	0.	2595.57	0.	0.	0.
	2015	9785.72	7452.78	1462.81	1462.81	0.	3556.15	0.	0.	0.
	2020	13407.28	10210.96	2004.18	2004.18	0.	4872.23	0.	0.	0.
	2024	17248.02	13136.05	2578.31	2578.31	0.	6267.96	0.	0.	0.
FUT L-C WORTH (\$/KW):										
FIXED O&M										
	1985	96.25	87.95	19.10	19.10	0.	51.91	0.	0.	0.
	1990	131.86	120.51	26.18	26.18	0.	71.12	0.	0.	0.
	1995	180.67	165.10	35.86	35.86	0.	97.44	0.	0.	0.
	2000	247.53	226.20	49.13	49.13	0.	133.50	0.	0.	0.
	2005	339.13	309.92	67.32	67.32	0.	182.90	0.	0.	0.
	2010	464.64	424.62	92.23	92.23	0.	250.59	0.	0.	0.
	2015	636.60	581.76	126.37	126.37	0.	343.34	0.	0.	0.
	2020	872.20	797.07	173.13	173.13	0.	470.40	0.	0.	0.
	2024	1122.05	1025.40	222.73	222.73	0.	605.15	0.	0.	0.
FUT L-C WORTH (\$/KW):										
VAR. O&M										
	1985	121.52	164.67	16.98	3.83	0.	11.88	0.	0.	0.
	1990	164.25	221.32	18.26	6.98	0.	26.81	0.	0.	0.
	1995	221.41	296.11	17.36	11.86	0.	53.49	0.	0.	0.
	2000	301.30	398.05	13.88	17.25	0.	100.14	0.	0.	0.
	2005	413.85	539.77	6.52	24.59	0.	172.45	0.	0.	0.
	2010	565.40	731.09	5.32	30.00	0.	243.11	0.	0.	0.
	2015	764.75	980.67	2.57	35.95	0.	338.51	0.	0.	0.
	2020	1034.71	1326.86	3.47	48.64	0.	458.01	0.	0.	0.
	2024	1323.08	1696.66	4.44	62.20	0.	585.66	0.	0.	0.
FUT L-C WORTH (\$/KW):										
FUEL										
	1985	1169.86	883.80	384.96	131.10	0.	323.32	0.	0.	0.
	1990	1650.31	1227.33	451.42	241.45	0.	741.43	0.	0.	0.
	1995	2322.17	1697.12	476.70	415.75	0.	1499.60	0.	0.	0.
	2000	3296.49	2357.86	432.48	619.88	0.	2844.63	0.	0.	0.
	2005	4719.38	3303.62	261.06	905.15	0.	4978.48	0.	0.	0.
	2010	6721.80	4623.58	256.80	1144.86	0.	7240.00	0.	0.	0.
	2015	9482.76	6412.28	192.91	1428.67	0.	10396.24	0.	0.	0.
	2020	13381.67	8964.83	313.76	1997.39	0.	14534.69	0.	0.	0.
	2024	17693.87	11766.10	464.67	2621.52	0.	19076.40	0.	0.	0.

Table F-27 (Cont'd)

	STLWR	STSCRB	GT/OIL	GT/SCL	GTCC/OIL	GTCC/SCL	STAFB	GTWCCE	OCMHD	
	-----	-----	-----	-----	-----	-----	-----	-----	-----	
1975 WORTH (B\$) OF UNITS INSTALLED IN:										TOTAL
1985	43.533	9.131	1.124	0.	0.	0.	0.	0.	0.	53.787
1990	49.556	10.316	1.148	0.	0.	0.	0.	0.	0.	61.020
1995	67.104	5.956	0.	0.492	0.	0.	0.	0.	0.	73.552
2000	76.690	6.736	0.	0.577	0.	0.	0.	0.	0.	84.002
2005	73.302	3.260	0.	3.230	0.	3.476	0.	0.	0.	83.268
2010	82.611	3.640	0.	3.433	0.	4.016	0.	0.	0.	93.700
2015	113.140	3.506	0.	1.864	0.	0.	0.	0.	0.	118.510
2020	128.263	3.953	0.	2.105	0.	0.	0.	0.	0.	134.310
2024	142.089	4.359	0.	2.324	0.	0.	0.	0.	0.	148.773
INTEGRATED 1975 WORTHS (B\$):										TOTAL
CAPITAL	1574.402	113.988	3.882	27.743	0.	9.899	0.	0.	0.	1729.914
FIXED O&M	102.421	8.898	0.335	2.397	0.	0.956	0.	0.	0.	115.007
VAR. O&M	124.072	15.774	0.237	0.755	0.	0.922	0.	0.	0.	141.760
FUEL	1451.774	93.529	5.802	29.158	0.	27.333	0.	0.	0.	1607.596
TOTAL FOR GEN.	3252.669	232.188	10.257	60.052	0.	39.110	0.	0.	0.	3594.277
R&D PROGRAM	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
TOTAL	3252.669	232.188	10.257	60.052	0.	39.110	0.	0.	0.	3594.277
										=====

WITH INTANGIBLES, WITHOUT TAXES

Table F-28
BASE CASE
STAFB — MINIMUM COMPETITION

	STLWR	STSCRB	GT/OIL	GT/SCL	GTCC/OIL	GTCC/SCL	STAFB	GTWCCE	OCMHD	
	-----	-----	-----	-----	-----	-----	-----	-----	-----	
MARKET PEN MULT.	0.5598	0.5966	0.7680	0.4406	0.7690	0.4266	0.6981	0.7173	0.5970	NORM.
ADJUSTED MKT PEN:										FACTOR
1990	0.	0.	0.0526	0.	0.	0.	0.9474	0.	0.	1.4257
1995	0.3973	0.	0.	0.0520	0.	0.	0.5507	0.	0.	1.6166
2000	0.3973	0.	0.	0.0520	0.	0.	0.5507	0.	0.	1.6166
2005	0.2870	0.	0.	0.1376	0.	0.1370	0.4384	0.	0.	1.7741
2010	0.2870	0.	0.	0.1376	0.	0.1370	0.4384	0.	0.	1.7741
2015	0.3429	0.	0.	0.0897	0.	0.	0.5674	0.	0.	1.6289
2020	0.3429	0.	0.	0.0897	0.	0.	0.5674	0.	0.	1.6289
2024	0.3429	0.	0.	0.0897	0.	0.	0.5674	0.	0.	1.6289
CAPY ADDN RATL (GW/YR):										TOTAL
1985										54.4
1990	0.	0.	3.8	0.	0.	0.	68.2	0.	0.	71.9
1995	37.8	0.	0.	4.9	0.	0.	52.4	0.	0.	95.2
2000	90.1	0.	0.	6.6	0.	0.	69.4	0.	0.	126.0
2005	47.9	0.	0.	23.0	0.	22.9	73.1	0.	0.	166.8
2010	62.4	0.	0.	29.9	0.	29.8	95.2	0.	0.	217.2
2015	97.9	0.	0.	25.6	0.	0.	162.1	0.	0.	285.6
2020	128.8	0.	0.	33.7	0.	0.	213.1	0.	0.	375.6
2024	160.3	0.	0.	42.0	0.	0.	265.4	0.	0.	467.6
INSTALLED CAPY (GW):										TOTAL
1985	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
1990	119.1	0.	10.4	0.	0.	0.	188.3	0.	0.	313.9
1995	151.9	0.	27.4	4.8	0.	0.	545.0	0.	0.	729.1
2000	370.2	0.	27.4	33.4	0.	0.	847.6	0.	0.	1278.7
2005	641.4	0.	27.4	85.1	0.	22.2	1230.0	0.	0.	2006.1
2010	914.4	0.	27.4	216.0	0.	152.5	1647.1	0.	0.	2957.4
2015	1288.6	0.	27.4	374.6	0.	285.6	2230.8	0.	0.	4207.0
2020	1737.0	0.	17.0	522.0	0.	285.6	2975.0	0.	0.	5536.5
2025	2276.3	0.	0.0	667.9	0.	285.6	3571.7	0.	0.	6801.5
2030	2058.0	0.	0.0	639.3	0.	285.6	3269.1	0.	0.	6252.0
2035	1786.8	0.	0.0	587.6	0.	263.4	2886.6	0.	0.	5524.5
2040	1513.8	0.	0.0	456.8	0.	133.1	2469.6	0.	0.	4573.3
2045	1139.6	0.	0.0	298.2	0.	0.0	1885.9	0.	0.	3323.6
2050	576.1	0.	0.0	150.7	0.	0.0	953.4	0.	0.	1680.3
2054	0.0	0.	0.0	0.0	0.	0.0	0.0	0.	0.	0.0

Table F-28 (Cont'd)

"STAFB" - MINIMUM COMPETITION

	STLWR	STSCRB	GT/OIL	GT/SCL	GTCC/OIL	GTCC/SCL	STAFB	GTWCCE	OCMHD	
	-----	-----	-----	-----	-----	-----	-----	-----	-----	
ADJUSTED CAPY FACTORS:										CORR. FACTOR
1990	0.6155	0.	0.0291	0.	0.	0.	0.3992	0.	0.	0.8318
1995	0.6677	0.	0.0302	0.0046	0.	0.	0.4482	0.	0.	0.9147
2000	0.6383	0.	0.0289	0.0044	0.	0.	0.4284	0.	0.	0.8744
2005	0.6677	0.	0.0082	0.0037	0.	0.0229	0.4025	0.	0.	0.9147
2010	0.7054	0.	0.0087	0.0039	0.	0.0242	0.4252	0.	0.	0.9664
2015	0.7276	0.	0.0010	0.0040	0.	0.0249	0.4385	0.	0.	0.9967
2020	0.7101	0.	0.0010	0.0039	0.	0.0243	0.4280	0.	0.	0.9727
2025	0.6920	0.	0.0009	0.0038	0.	0.0237	0.4171	0.	0.	0.9480
2030	0.6983	0.	0.0010	0.0038	0.	0.0239	0.4209	0.	0.	0.9566
2035	0.7058	0.	0.0010	0.0039	0.	0.0242	0.4254	0.	0.	0.9669
2040	0.6882	0.	0.0009	0.0038	0.	0.0236	0.4148	0.	0.	0.9428
2045	0.6586	0.	0.0009	0.0036	0.	0.0226	0.3970	0.	0.	0.9022
2050	0.6590	0.	0.0009	0.0036	0.	0.0226	0.3972	0.	0.	0.9027
2054	0.6645	0.	0.0009	0.0036	0.	0.0228	0.4005	0.	0.	0.9102
ENERGY GENERATED (GW-YR PER YEAR):										TOTAL
1990	70.9	0.	0.3	0.	0.	0.	61.9	0.	0.	133.0
1995	89.2	0.	0.8	0.0	0.	0.	232.8	0.	0.	322.8
2000	220.8	0.	0.8	0.1	0.	0.	348.7	0.	0.	570.4
2005	412.7	0.	0.2	0.3	0.	0.3	480.7	0.	0.	894.2
2010	623.7	0.	0.2	0.8	0.	3.3	680.6	0.	0.	1308.6
2015	902.9	0.	0.0	1.4	0.	7.1	943.7	0.	0.	1855.2
2020	1188.9	0.	0.0	2.0	0.	6.9	1243.1	0.	0.	2440.9
2025	1588.0	0.	0.0	2.5	0.	6.8	1500.5	0.	0.	3097.8
2030	1454.0	0.	0.0	2.5	0.	6.8	1390.1	0.	0.	2853.4
2035	1277.6	0.	0.0	2.3	0.	6.6	1243.2	0.	0.	2529.7
2040	1062.7	0.	0.0	1.8	0.	3.5	1043.7	0.	0.	2111.7
2045	781.9	0.	0.0	1.1	0.	0.0	780.0	0.	0.	1563.0
2050	421.0	0.	0.0	0.6	0.	0.0	419.9	0.	0.	841.5
2054	51.9	0.	0.0	0.1	0.	0.0	51.7	0.	0.	103.6

Table F-28 (Cont'd)

		STLWR	STSCR8	GT/OIL	GT/SCL	GTCC/OIL	GTCC/SCL	STAFB	GTWCCE	OCMHD
		-----	-----	-----	-----	-----	-----	-----	-----	-----
FUTURE LIFE-CYCLE WORTHS (\$/KW):										
CAPITAL										
	1985	1479.46	0.	221.16	221.16	0.	537.64	852.22	0.	0.
	1990	2026.99	0.	303.00	303.00	0.	736.61	1167.61	0.	0.
	1995	2777.16	0.	415.14	415.14	0.	1009.22	1599.73	0.	0.
	2000	3884.95	0.	568.78	568.78	0.	1382.73	2191.77	0.	0.
	2005	5213.11	0.	779.28	779.28	0.	1894.45	3002.91	0.	0.
	2010	7142.41	0.	1067.68	1067.68	0.	2595.57	4114.25	0.	0.
	2015	9785.72	0.	1462.81	1462.81	0.	3556.15	5636.88	0.	0.
	2020	13407.28	0.	2004.18	2004.18	0.	4872.23	7723.01	0.	0.
	2024	17248.02	0.	2578.31	2578.31	0.	6267.96	9935.39	0.	0.
FUT L-C WORTH (\$/KW):										
FIXED O&M										
	1985	96.25	0.	19.10	19.10	0.	51.91	96.61	0.	0.
	1990	131.86	0.	26.18	26.18	0.	71.12	132.36	0.	0.
	1995	180.67	0.	35.86	35.86	0.	97.44	181.34	0.	0.
	2000	247.53	0.	49.13	49.13	0.	133.50	248.45	0.	0.
	2005	339.13	0.	67.32	67.32	0.	182.90	340.40	0.	0.
	2010	464.64	0.	92.23	92.23	0.	250.59	466.38	0.	0.
	2015	636.60	0.	126.37	126.37	0.	343.34	638.99	0.	0.
	2020	872.20	0.	173.13	173.13	0.	470.40	875.47	0.	0.
	2024	1122.05	0.	222.73	222.73	0.	605.15	1126.26	0.	0.
FUT L-C WORTH (\$/KW):										
VAR. O&M										
	1985	136.39	0.	8.98	1.07	0.	2.55	208.44	0.	0.
	1990	198.02	0.	11.90	1.97	0.	5.58	324.72	0.	0.
	1995	273.43	0.	12.10	3.31	0.	10.94	442.64	0.	0.
	2000	380.25	0.	10.38	4.39	0.	20.29	601.81	0.	0.
	2005	533.13	0.	6.24	5.89	0.	34.64	826.98	0.	0.
	2010	733.44	0.	5.24	8.10	0.	47.65	1137.70	0.	0.
	2015	994.43	0.	2.74	10.98	0.	64.61	1542.54	0.	0.
	2020	1343.81	0.	3.71	14.84	0.	87.30	2084.48	0.	0.
	2024	1717.58	0.	4.74	18.96	0.	111.59	2664.26	0.	0.
FUT L-C WORTH (\$/KW):										
FUEL										
	1985	1323.23	0.	216.74	36.12	0.	69.40	1251.98	0.	0.
	1990	1926.91	0.	301.85	67.44	0.	153.96	1995.84	0.	0.
	1995	2876.68	0.	340.58	115.11	0.	306.13	2811.20	0.	0.
	2000	4179.20	0.	333.74	157.88	0.	574.85	3950.82	0.	0.
	2005	6084.20	0.	252.34	219.25	0.	997.17	5608.68	0.	0.
	2010	8722.27	0.	256.34	311.46	0.	1416.55	7967.49	0.	0.
	2015	12330.71	0.	206.16	436.26	0.	1984.14	11159.92	0.	0.
	2020	17377.79	0.	334.77	609.14	0.	2770.38	15582.19	0.	0.
	2024	22965.49	0.	495.35	799.07	0.	3634.19	20440.76	0.	0.

Table F-28 (Cont'd)

	STLWR	STSCRB	GT/OIL	GT/SCL	GTCC/OIL	GTCC/SCL	STAFB	GTWCCE	OCMHD	TOTAL
	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
1975 WORTH (B\$) OF UNITS INSTALLED IN:										
1985	63.644	0.	0.	0.	0.	0.	0.	0.	0.	63.644
1990	0.	0.	0.582	0.	0.	0.	59.080	0.	0.	59.661
1995	34.339	0.	0.	0.419	0.	0.	39.237	0.	0.	73.995
2000	34.745	0.	0.	0.472	0.	0.	44.787	0.	0.	85.003
2005	33.395	0.	0.	1.410	0.	4.072	40.989	0.	0.	79.865
2010	37.858	0.	0.	1.573	0.	4.564	46.381	0.	0.	90.376
2015	51.389	0.	0.	1.153	0.	0.	67.964	0.	0.	120.506
2020	52.311	0.	0.	1.295	0.	0.	76.801	0.	0.	136.407
2024	64.687	0.	0.	1.423	0.	0.	84.954	0.	0.	151.064
INTEGRATED 1975 WORTHS (B\$):										
CAPITAL	623.156	0.	1.946	23.582	0.	26.961	630.613	0.	0.	1306.257
FIXED O&M	40.539	0.	0.168	2.037	0.	2.603	71.485	0.	0.	116.832
VAR. O&M	62.388	0.	0.074	0.178	0.	0.494	172.921	0.	0.	236.054
FUEL	733.234	0.	1.886	6.913	0.	14.602	1186.597	0.	0.	1943.232
TOTAL FOR GEN.	1459.316	0.	4.074	32.709	0.	44.660	2061.615	0.	0.	3602.375
R&D PROGRAM	0.	0.	0.	0.	0.	0.	0.201	0.	0.	0.201
TOTAL	1459.316	0.	4.074	32.709	0.	44.660	2061.817	0.	0.	3602.577
										=====

WORTH OF SAVINGS = -8,300 B\$

WITH INTANGIBLES, WITHOUT TAXES

Table F-29

BASE
GTWCCE — MINIMUM COMPETITION

	STLWR -----	STSCRB -----	GT/OIL -----	GT/SCL -----	GTCC/OIL -----	GTCC/SCL -----	STAFB -----	GTWCCE -----	OCMHD -----	
MARKET PEN MULT.	0.5598	0.5966	0.7680	0.4406	0.7690	0.4266	0.6981	0.7173	0.5970	NORM.
ADJUSTED MKT PEN:										FACTOR
1990	0.7443	0.1774	0.0783	0.	0.	0.	0.	0.	0.	1.7288
1995	0.7443	0.1774	0.0783	0.	0.	0.	0.	0.	0.	1.7288
2000	0.	0.	0.	0.0118	0.	0.	0.	0.9882	0.	1.4044
2005	0.	0.	0.	0.2189	0.	0.0509	0.	0.7302	0.	1.6341
2010	0.	0.	0.	0.2189	0.	0.0509	0.	0.7302	0.	1.6341
2015	0.	0.	0.	0.1047	0.	0.	0.	0.8953	0.	1.4858
2020	0.	0.	0.	0.1047	0.	0.	0.	0.8953	0.	1.4858
2024	0.	0.	0.	0.1047	0.	0.	0.	0.8953	0.	1.4858
CAPY ADDN RATE (GW/YR):										TOTAL
1985										54.4
1990	53.5	12.8	5.6	0.	0.	0.	0.	0.	0.	71.9
1995	70.9	16.9	7.5	0.	0.	0.	0.	0.	0.	95.2
2000	0.	0.	0.	1.5	0.	0.	0.	124.5	0.	126.0
2005	0.	0.	0.	36.5	0.	8.5	0.	121.8	0.	166.8
2010	0.	0.	0.	47.5	0.	11.1	0.	158.6	0.	217.2
2015	0.	0.	0.	29.9	0.	0.	0.	255.7	0.	285.6
2020	0.	0.	0.	39.3	0.	0.	0.	336.3	0.	375.6
2024	0.	0.	0.	49.0	0.	0.	0.	418.7	0.	467.6
INSTALLED CAPY (GW):										TOTAL
1985	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
1990	233.6	55.7	24.6	0.	0.	0.	0.	0.	0.	313.9
1995	542.6	129.3	57.1	0.	0.	0.	0.	0.	0.	729.1
2000	542.6	129.3	57.1	6.5	0.	0.	0.	543.1	0.	1278.7
2005	542.6	129.3	57.1	48.6	0.	8.3	0.	1220.2	0.	2006.1
2010	542.6	129.3	57.1	256.8	0.	56.7	0.	1914.8	0.	2957.4
2015	542.6	129.3	57.1	498.6	0.	106.1	0.	2873.2	0.	4207.0
2020	309.1	73.7	32.5	670.7	0.	106.1	0.	4344.5	0.	5536.5
2025	0.0	-0.0	0.0	846.7	0.	106.1	0.	5848.7	0.	6801.5
2030	0.0	-0.0	0.0	840.2	0.	106.1	0.	5305.6	0.	6252.0
2035	0.0	-0.0	0.0	798.1	0.	97.8	0.	4628.6	0.	5524.5
2040	0.0	-0.0	0.0	589.9	0.	49.4	0.	3933.9	0.	4573.3
2045	0.0	-0.0	0.0	348.1	0.	0.0	0.	2975.5	0.	3323.6
2050	0.0	-0.0	0.0	176.0	0.	0.0	0.	1504.3	0.	1680.3
2054	0.0	-0.0	0.0	-0.0	0.	0.0	0.	0.0	0.	0.0

Table F-29 (Cont'd)

	STLWR	STSCRB	GT/OIL	GT/SCL	GTCC/OIL	GTCC/SCL	STAFB	GTWCCE	OCMHD	
	-----	-----	-----	-----	-----	-----	-----	-----	-----	
ADJUSTED CAPY FACTORS:										CORR. FACTOR
1990	0.5764	0.2470	0.0552	0.	0.	0.	0.	0.	0.	0.8234
1995	0.5711	0.2448	0.0547	0.	0.	0.	0.	0.	0.	0.8159
2000	0.6154	0.1387	0.0173	0.0043	0.	0.	0.	0.4507	0.	0.8668
2005	0.6032	0.0922	0.0034	0.0059	0.	0.0461	0.	0.4775	0.	0.8378
2010	0.6467	0.0988	0.0036	0.0063	0.	0.0494	0.	0.5119	0.	0.8981
2015	0.6282	0.1396	0.	0.0087	0.	0.0480	0.	0.5409	0.	0.8725
2020	0.6148	0.1366	0.	0.0085	0.	0.0470	0.	0.5294	0.	0.8539
2025	0.6083	0.1352	0.	0.0084	0.	0.0465	0.	0.5238	0.	0.8449
2030	0.6149	0.1366	0.	0.0085	0.	0.0470	0.	0.5295	0.	0.8540
2035	0.6237	0.1386	0.	0.0087	0.	0.0476	0.	0.5371	0.	0.8663
2040	0.6091	0.1354	0.	0.0085	0.	0.0465	0.	0.5245	0.	0.8460
2045	0.5844	0.1299	0.	0.0081	0.	0.0446	0.	0.5033	0.	0.8117
2050	0.5848	0.1299	0.	0.0081	0.	0.0447	0.	0.5036	0.	0.8122
2054	0.5896	0.1310	0.	0.0082	0.	0.0450	0.	0.5077	0.	0.8189
ENERGY GENERATED (GW-YR PER YEAR):										TOTAL
1990	119.6	12.2	1.2	0.	0.	0.	0.	0.	0.	133.0
1995	290.2	29.7	2.9	0.	0.	0.	0.	0.	0.	322.8
2000	334.0	17.9	1.0	0.0	0.	0.	0.	217.5	0.	570.4
2005	327.3	11.9	0.2	0.2	0.	0.2	0.	554.4	0.	894.2
2010	350.9	12.8	0.2	1.5	0.	2.5	0.	940.7	0.	1308.6
2015	340.9	18.1	0.	4.2	0.	5.1	0.	1486.9	0.	1855.2
2020	306.0	10.9	0.	5.6	0.	5.0	0.	2213.4	0.	2440.9
2025	21.0	1.1	0.	7.2	0.	4.9	0.	3063.7	0.	3097.8
2030	0.0	-0.0	0.	7.2	0.	5.0	0.	2841.3	0.	2853.4
2035	0.0	-0.0	0.	7.1	0.	4.9	0.	2517.8	0.	2529.7
2040	0.0	-0.0	0.	5.2	0.	2.6	0.	2103.9	0.	2111.7
2045	0.0	-0.0	0.	2.9	0.	0.0	0.	1560.1	0.	1563.0
2050	0.0	-0.0	0.	1.6	0.	0.0	0.	839.9	0.	841.5
2054	0.0	-0.0	0.	0.2	0.	0.0	0.	103.4	0.	103.6

Table F-29 (Cont'd)

		STLWR	STSCRB	GT/OIL	GT/SCL	GTCC/OIL	GTCC/SCL	STAFB	GTWCCE	OCMHD
		-----	-----	-----	-----	-----	-----	-----	-----	-----
FUTURE LIFE-CYCLE WORTHS (\$/KW):										
CAPITAL										
	1985	1479.46	1126.76	221.16	221.16	0.	537.64	0.	903.69	0.
	1990	2026.99	1543.75	303.00	303.00	0.	736.61	0.	1238.14	0.
	1995	2777.16	2115.08	415.14	415.14	0.	1009.22	0.	1696.36	0.
	2000	3804.95	2897.84	568.78	568.78	0.	1382.73	0.	2324.16	0.
	2005	5213.11	3970.29	779.28	779.28	0.	1894.45	0.	3184.29	0.
	2010	7142.41	5439.64	1067.68	1067.68	0.	2595.57	0.	4362.76	0.
	2015	9795.72	7452.78	1462.81	1462.81	0.	3556.15	0.	5977.36	0.
	2020	13467.28	10210.96	2004.18	2004.18	0.	4872.23	0.	8189.50	0.
	2024	17248.02	13136.05	2578.31	2578.31	0.	6267.96	0.	10535.51	0.
FUT L-C WORTH (\$/KW):										
FIXED O&M										
	1985	96.25	87.95	19.10	19.10	0.	51.91	0.	45.06	0.
	1990	131.86	120.51	26.18	26.18	0.	71.12	0.	61.73	0.
	1995	180.67	165.10	35.86	35.86	0.	97.44	0.	84.58	0.
	2000	247.53	226.20	49.13	49.13	0.	133.50	0.	115.88	0.
	2005	339.13	309.92	67.32	67.32	0.	182.90	0.	158.77	0.
	2010	464.64	424.62	92.23	92.23	0.	250.59	0.	217.53	0.
	2015	636.60	581.76	126.37	126.37	0.	343.34	0.	298.03	0.
	2020	872.20	797.07	173.13	173.13	0.	470.40	0.	408.33	0.
	2024	1122.05	1025.40	222.73	222.73	0.	605.15	0.	525.31	0.
FUT L-C WORTH (\$/KW):										
VAR. O&M										
	1985	129.46	121.63	13.17	1.27	0.	5.18	0.	153.01	0.
	1990	180.01	143.83	11.95	2.60	0.	11.16	0.	291.70	0.
	1995	250.84	161.95	6.93	4.89	0.	21.80	0.	526.58	0.
	2000	345.20	215.90	5.33	7.58	0.	40.35	0.	751.06	0.
	2005	474.45	293.98	2.21	11.62	0.	68.75	0.	1062.53	0.
	2010	647.91	431.74	1.50	17.00	0.	93.89	0.	1476.42	0.
	2015	870.93	620.47	0.	24.37	0.	126.21	0.	2018.29	0.
	2020	1184.15	843.61	0.	33.13	0.	171.60	0.	2744.14	0.
	2024	1517.38	1081.01	0.	42.46	0.	219.89	0.	3516.39	0.
FUT L-C WORTH (\$/KW):										
FUEL										
	1985	1252.45	642.17	279.86	43.62	0.	140.92	0.	739.39	0.
	1990	1815.05	787.93	277.26	90.53	0.	308.02	0.	1428.97	0.
	1995	2633.04	928.52	187.47	173.15	0.	609.55	0.	2614.19	0.
	2000	3775.59	1284.66	161.61	276.55	0.	1142.24	0.	3845.90	0.
	2005	5408.96	1814.85	81.53	435.67	0.	1977.84	0.	5612.94	0.
	2010	7701.71	2744.44	60.60	656.83	0.	2790.25	0.	8051.56	0.
	2015	10836.60	4059.11	0.	968.98	0.	3878.11	0.	11367.52	0.
	2020	15318.60	5701.01	0.	1360.93	0.	5446.80	0.	15965.65	0.
	2024	20293.51	7497.03	0.	1789.67	0.	7162.74	0.	20995.40	0.

Table F-29 (Cont'd)

	STLWR	STSCRB	GT/OIL	GT/SCL	GTCC/OIL	GTCC/SCL	STAFB	GTWCCE	OCMHD	TOTAL
	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
1975 WORTH (B\$) OF UNITS INSTALLED IN:										
1985	46.155	7.360	0.876	0.	0.	0.	0.	0.	0.	54.390
1990	53.247	7.932	0.834	0.	0.	0.	0.	0.	0.	62.013
1995	30.762	4.231	0.358	0.052	0.	0.	0.	34.414	0.	69.817
2000	0.	0.	0.	0.123	0.	0.	0.	80.876	0.	81.000
2005	0.	0.	0.	2.707	0.	2.006	0.	69.945	0.	74.658
2010	0.	0.	0.	3.102	0.	2.254	0.	79.638	0.	84.994
2015	0.	0.	0.	1.707	0.	0.	0.	111.091	0.	112.798
2020	0.	0.	0.	1.928	0.	0.	0.	125.985	0.	127.913
2024	0.	0.	0.	2.127	0.	0.	0.	139.555	0.	141.681
INTEGRATED 1975 WORTHS (B\$):										TOTAL
CAPITAL	260.446	47.281	4.098	29.011	0.	10.015	0.	849.842	0.	1200.693
FIXED O&M	16.943	3.691	0.354	2.506	0.	0.967	0.	42.374	0.	66.834
VAR. O&M	23.155	4.358	0.156	0.464	0.	0.362	0.	282.453	0.	310.947
FUEL	233.920	23.897	3.599	18.239	0.	10.691	0.	1553.482	0.	1843.828
TOTAL FOR GEN.	534.464	79.227	8.207	50.220	0.	22.035	0.	2728.150	0.	3422.303
R&D PROGRAM	0.	0.	0.	0.	0.	0.	0.	0.375	0.	0.375
TOTAL	534.464	79.227	8.207	50.220	0.	22.035	0.	2728.525	0.	3422.677
										=====

WORTH OF SAVINGS = 171.600 B\$

WITH INTANGIBLES, WITHOUT TAXES

Table F-30

BASE CASE
OCMHD — MINIMUM COMPETITION (1932 MW)

	STLWR	STSCRB	GT/OIL	GT/SCL	GTCC/OIL	GTCC/SCL	STAFB	GTWCCE	OCMHD	
	-----	-----	-----	-----	-----	-----	-----	-----	-----	
MARKET PEN MULT.	0.5598	0.5966	0.7680	0.4406	0.7690	0.4266	0.6981	0.7173	0.5970	NORM.
ADJUSTED MKT PEN:										FACTOR
1985	0.7241	0.1924	0.0834	0.	0.	0.	0.	0.	0.	1.7247
1995	0.8620	0.0985	0.	0.0395	0.	0.	0.	0.	0.	1.7946
2000	0.8620	0.0985	0.	0.0395	0.	0.	0.	0.	0.	1.7946
2005	0.5693	0.	0.	0.2240	0.	0.2066	0.	0.	0.	2.0099
2010	0.	0.	0.	0.0389	0.	0.	0.	0.	0.9611	1.6981
2015	0.	0.	0.	0.0572	0.	0.	0.	0.	0.9428	1.7090
2020	0.	0.	0.	0.0572	0.	0.	0.	0.	0.9428	1.7090
2024	0.	0.	0.	0.0572	0.	0.	0.	0.	0.9428	1.7090
CAPY ADDN RATE (GW/YR):										TOTAL
1985										54.4
1990	52.1	13.8	6.0	0.	0.	0.	0.	0.	0.	71.9
1995	82.1	9.4	0.	3.8	0.	0.	0.	0.	0.	95.2
2000	108.6	12.4	0.	5.0	0.	0.	0.	0.	0.	126.0
2005	95.0	0.	0.	37.4	0.	34.5	0.	0.	0.	166.8
2010	0.	0.	0.	8.5	0.	0.	0.	0.	208.8	217.2
2015	0.	0.	0.	16.3	0.	0.	0.	0.	269.3	285.6
2020	0.	0.	0.	21.5	0.	0.	0.	0.	354.1	375.6
2024	0.	0.	0.	26.8	0.	0.	0.	0.	440.9	467.6
INSTALLED CAPY (GW):										TOTAL
1985	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
1990	227.3	60.4	26.2	0.	0.	0.	0.	0.	0.	313.9
1995	540.7	131.6	53.1	3.7	0.	0.	0.	0.	0.	729.1
2000	1014.4	185.7	53.1	25.4	0.	0.	0.	0.	0.	1278.7
2005	1594.0	241.4	53.1	84.1	0.	33.5	0.	0.	0.	2006.1
2010	1901.2	241.4	53.1	221.0	0.	145.0	0.	0.	395.6	2957.4
2015	1901.2	241.4	53.1	274.7	0.	145.0	0.	0.	1591.6	4207.0
2020	1673.9	181.0	26.9	368.7	0.	145.0	0.	0.	3140.9	5536.5
2025	1360.5	109.8	0.0	461.2	0.	145.0	0.	0.	4725.0	6801.5
2030	886.8	55.7	0.0	439.5	0.	145.0	0.	0.	4725.0	6252.0
2035	307.2	0.0	0.0	380.8	0.	111.5	0.	0.	4725.0	5524.5
2040	-0.0	0.0	0.0	243.9	0.	0.0	0.	0.	4329.4	4573.3
2045	-0.0	0.0	0.0	190.2	0.	0.0	0.	0.	3133.4	3323.6
2050	-0.0	0.0	0.0	96.2	0.	0.0	0.	0.	1584.1	1680.3
2054	-0.0	0.0	0.0	-0.0	0.	0.0	0.	0.	0.0	0.0

Table F-30 (Cont'd)

	STLWR	STSCRB	GT/OIL	GT/SCL	GTCC/OIL	GTCC/SCL	STAFB	GTWCCE	OCMHD	
	-----	-----	-----	-----	-----	-----	-----	-----	-----	
ADJUSTED CAPY FACTORS:										CORR. FACTOR
1990	0.5867	0.2479	0.0545	0.	0.	0.	0.	0.	0.	0.8263
1995	0.5769	0.2472	0.0467	0.0110	0.	0.	0.	0.	0.	0.9157
2000	0.5467	0.2343	0.0443	0.0104	0.	0.	0.	0.	0.	0.8678
2005	0.5511	0.1588	0.0243	0.0112	0.	0.0504	0.	0.	0.	0.9340
2010	0.5472	0.2304	0.0048	0.0298	0.	0.0960	0.	0.	0.6528	0.9601
2015	0.4858	0.1524	0.0057	0.0257	0.	0.0781	0.	0.	0.6001	0.9525
2020	0.4464	0.1401	0.0053	0.0236	0.	0.0718	0.	0.	0.5515	0.8753
2025	0.4232	0.1328	0.0050	0.0224	0.	0.0680	0.	0.	0.5227	0.8297
2030	0.4170	0.1308	0.0049	0.0221	0.	0.0671	0.	0.	0.5151	0.8177
2035	0.4059	0.1274	0.0048	0.0215	0.	0.0653	0.	0.	0.5014	0.7960
2040	0.3849	0.1207	0.0045	0.0204	0.	0.0619	0.	0.	0.4754	0.7546
2045	0.3866	0.1213	0.0045	0.0205	0.	0.0622	0.	0.	0.4776	0.7580
2050	0.3868	0.1214	0.0046	0.0205	0.	0.0622	0.	0.	0.4778	0.7585
2054	0.3900	0.1224	0.0046	0.0206	0.	0.0627	0.	0.	0.4818	0.7647
ENERGY GENERATED (GW-YR PER YEAR):										TOTAL
1990	118.5	13.3	1.3	0.	0.	0.	0.	0.	0.	133.0
1995	288.9	31.4	2.5	0.0	0.	0.	0.	0.	0.	322.8
2000	525.7	42.1	2.4	0.2	0.	0.	0.	0.	0.	570.4
2005	853.0	38.3	1.3	0.7	0.	0.8	0.	0.	0.	894.2
2010	1040.4	55.6	0.3	6.5	0.	13.9	0.	0.	191.9	1308.6
2015	923.5	36.8	0.3	6.9	0.	11.3	0.	0.	876.4	1855.2
2020	758.6	26.3	0.2	8.5	0.	10.4	0.	0.	1637.0	2440.9
2025	592.6	15.2	0.0	10.4	0.	9.9	0.	0.	2469.8	3097.8
2030	391.8	8.1	0.0	9.8	0.	9.7	0.	0.	2434.0	2853.4
2035	143.5	0.0	0.0	8.6	0.	8.4	0.	0.	2369.3	2529.7
2040	-0.0	0.0	0.0	5.1	0.	0.0	0.	0.	2106.6	2111.7
2045	-0.0	0.0	0.0	4.1	0.	0.0	0.	0.	1559.0	1563.0
2050	-0.0	0.0	0.0	2.2	0.	0.0	0.	0.	839.3	841.5
2054	-0.0	0.0	0.0	0.3	0.	0.0	0.	0.	103.4	103.6

Table F-30 (Cont'd)

		STLWR	STSCRH	GT/OIL	GT/SCL	GTCC/OIL	GTCC/SCL	STAFB	GTWCCE	OCMHD
		-----	-----	-----	-----	-----	-----	-----	-----	-----
FUTURE LIFE-CYCLE WORTHS (\$/KW):										
CAPITAL										
	1985	1479.46	1126.76	221.16	221.16	0.	537.64	0.	0.	909.41
	1990	2026.99	1543.75	303.00	303.00	0.	736.61	0.	0.	1245.97
	1995	2777.16	2115.08	415.14	415.14	0.	1009.22	0.	0.	1707.09
	2000	3804.95	2897.84	568.78	568.78	0.	1382.73	0.	0.	2338.87
	2005	5213.11	3970.29	779.28	779.28	0.	1894.45	0.	0.	3204.45
	2010	7142.41	5439.64	1067.68	1067.68	0.	2595.57	0.	0.	4390.37
	2015	9785.72	7452.78	1462.81	1462.81	0.	3556.15	0.	0.	6015.19
	2020	13407.28	10210.96	2004.18	2004.18	0.	4872.23	0.	0.	8241.33
	2024	17248.02	13136.05	2578.31	2578.31	0.	6267.96	0.	0.	10602.19
FUT L-C WORTH (\$/KW):										
FIXED O&M										
	1985	96.25	87.95	19.10	19.10	0.	51.91	0.	0.	49.38
	1990	131.86	120.51	26.18	26.18	0.	71.12	0.	0.	67.66
	1995	180.67	165.10	35.86	35.86	0.	97.44	0.	0.	92.70
	2000	247.53	226.20	49.13	49.13	0.	133.50	0.	0.	127.01
	2005	339.13	309.92	67.32	67.32	0.	182.90	0.	0.	174.01
	2010	464.64	424.62	92.23	92.23	0.	250.59	0.	0.	238.41
	2015	636.60	581.76	126.37	126.37	0.	343.34	0.	0.	326.65
	2020	872.20	797.07	173.13	173.13	0.	470.40	0.	0.	447.53
	2024	1122.05	1025.40	222.73	222.73	0.	605.15	0.	0.	575.74
FUT L-C WORTH (\$/KW):										
VAR. O&M										
	1985	120.95	158.25	17.48	3.95	0.	7.98	0.	0.	46.09
	1990	160.46	203.30	19.36	7.90	0.	17.28	0.	0.	113.73
	1995	210.70	256.02	19.48	14.25	0.	33.52	0.	0.	234.04
	2000	277.19	317.81	17.78	22.25	0.	61.54	0.	0.	444.39
	2005	364.05	396.38	12.20	34.90	0.	105.45	0.	0.	806.85
	2010	463.92	502.48	10.37	49.79	0.	144.40	0.	0.	1254.40
	2015	601.50	604.97	14.26	64.16	0.	183.47	0.	0.	1639.03
	2020	795.91	800.50	18.87	84.89	0.	242.77	0.	0.	2168.79
	2024	1005.97	1011.77	23.84	107.30	0.	306.84	0.	0.	2741.17
FUT L-C WORTH (\$/KW):										
FUEL										
	1985	1163.23	846.84	399.88	135.92	0.	217.98	0.	0.	267.15
	1990	1607.05	1120.82	489.56	276.34	0.	478.04	0.	0.	668.72
	1995	2197.87	1455.69	559.71	506.34	0.	938.73	0.	0.	1394.03
	2000	3011.35	1866.76	600.62	811.63	0.	1743.55	0.	0.	2680.28
	2005	4120.41	2407.75	549.04	1301.59	0.	3029.01	0.	0.	4922.90
	2010	5467.44	3152.48	646.53	1906.38	0.	4269.37	0.	0.	7810.07
	2015	7434.88	3945.91	1056.23	2543.28	0.	5620.68	0.	0.	10555.19
	2020	10273.63	5400.44	1689.98	3480.78	0.	7692.54	0.	0.	14445.99
	2024	13438.36	7010.50	2483.19	4518.52	0.	9985.96	0.	0.	18752.85

Table F-30 (Cont'd)

	STLWR	STSCR	GT/OIL	GT/SCL	GTCC/OIL	GTCC/SCL	STAFB	GTWCCE	OCMHD	TOTAL
	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
1975 WORTH (B\$) OF UNITS INSTALLED IN:										
1985	43.423	8.956	1.151	0.	0.	0.	0.	0.	0.	53.530
1990	48.969	9.904	1.204	0.	0.	0.	0.	0.	0.	60.077
1995	65.457	5.564	0.	0.544	0.	0.	0.	0.	0.	71.564
2000	73.590	6.081	0.	0.667	0.	0.	0.	0.	0.	80.338
2005	54.631	0.	0.	4.676	0.	10.295	0.	0.	0.	69.603
2010	0.	0.	0.	0.937	0.	0.	0.	0.	101.730	102.667
2015	0.	0.	0.	1.516	0.	0.	0.	0.	110.292	111.808
2020	0.	0.	0.	1.694	0.	0.	0.	0.	122.936	124.629
2024	0.	0.	0.	1.862	0.	0.	0.	0.	134.978	136.840
INTEGRATED 1975 WORTHS (B\$):										
CAPITAL	714.127	78.110	3.882	17.106	0.	15.211	0.	0.	592.515	1420.951
FIXED O&M	46.457	6.097	0.335	1.478	0.	1.469	0.	0.	32.176	88.011
VAR. O&M	53.190	9.645	0.251	0.747	0.	0.856	0.	0.	160.571	225.260
FUEL	564.613	54.278	6.283	28.808	0.	24.728	0.	0.	1043.489	1722.199
TOTAL FOR GEN.	1378.388	148.130	10.751	48.138	0.	42.263	0.	0.	1828.751	3456.421
R&D PROGRAM	0.	0.	0.	0.	0.	0.	0.	0.	1.318	1.318
TOTAL	1378.388	148.130	10.751	48.138	0.	42.263	0.	0.	1830.069	3457.740
										=====

WORTH OF SAVINGS = 136.537 B\$

WITH INTANGIBLES, WITHOUT TAXES

Table F-31
BASE CASE
CROWDED MARKET

	STLWR	STSCRB	GT/OIL	GT/SCL	GTCC/OIL	GTCC/SCL	STAFB	GTWCCE	OCMHD	
	-----	-----	-----	-----	-----	-----	-----	-----	-----	
MARKET PEN MULT.	0.5598	0.5966	0.7680	0.4406	0.7690	0.4266	0.6981	0.7173	0.5970	NORM.
ADJUSTED MKT PEN:										FACTOR
1990	0.	0.	0.0472	0.0445	0.	0.	0.9083	0.	0.	1.4636
1995	0.	0.	0.0472	0.0445	0.	0.	0.9083	0.	0.	1.4636
2000	0.	0.	0.	0.0359	0.	0.	0.1228	0.8413	0.	1.4303
2005	0.	0.	0.	0.0359	0.	0.	0.1228	0.8413	0.	1.4303
2010	0.	0.	0.	0.1915	0.	0.	0.	0.2762	0.5323	1.7113
2015	0.	0.	0.	0.0889	0.	0.	0.	0.5824	0.3287	1.5643
2020	0.	0.	0.	0.0889	0.	0.	0.	0.5824	0.3287	1.5643
2024	0.	0.	0.	0.0889	0.	0.	0.	0.5824	0.3287	1.5643
CAPY ADDN RATE (GW/YR):										TOTAL
1985										54.4
1990	0.	0.	3.4	3.2	0.	0.	65.3	0.	0.	71.9
1995	0.	0.	4.5	4.2	0.	0.	86.5	0.	0.	95.2
2000	0.	0.	0.	4.5	0.	0.	15.5	106.0	0.	126.0
2005	0.	0.	0.	6.0	0.	0.	20.5	140.3	0.	166.8
2010	0.	0.	0.	41.6	0.	0.	0.	60.0	115.6	217.2
2015	0.	0.	0.	25.4	0.	0.	0.	166.3	93.9	285.6
2020	0.	0.	0.	33.4	0.	0.	0.	218.7	123.5	375.6
2024	0.	0.	0.	41.6	0.	0.	0.	272.3	153.7	467.6
INSTALLED CAPY (GW):										TOTAL
1985	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
1990	115.1	0.	9.4	8.8	0.	0.	180.5	0.	0.	313.9
1995	115.1	0.	29.0	27.3	0.	0.	557.7	0.	0.	729.1
2000	115.1	0.	29.0	47.1	0.	0.	625.2	462.3	0.	1278.7
2005	115.1	0.	29.0	73.2	0.	0.	714.5	1074.3	0.	2006.1
2010	115.1	0.	29.0	255.4	0.	0.	714.5	1337.1	506.3	2957.4
2015	115.1	0.	29.0	466.2	0.	0.	714.5	1767.3	1114.9	4207.0
2020	0.	0.	19.6	603.4	0.	0.	534.0	2724.3	1655.2	5536.5
2025	0.	0.	0.0	734.3	0.	0.	156.8	3702.8	2207.5	6801.5
2030	0.	0.	0.0	714.6	0.	0.	89.3	3240.5	2207.5	6252.0
2035	0.	0.	0.0	688.5	0.	0.	0.0	2628.5	2207.5	5524.5
2040	0.	0.	0.0	506.3	0.	0.	0.0	2365.8	1701.2	4573.3
2045	0.	0.	0.0	295.5	0.	0.	0.0	1935.5	1092.6	3323.6
2050	0.	0.	0.0	149.4	0.	0.	0.0	978.5	552.4	1680.3
2054	0.	0.	0.0	0.0	0.	0.	0.0	0.	0.0	0.0

Table F-31 (Cont'd)

	STLWR	STSCRB	GT/OIL	GT/SCL	GTCC/OIL	GTCC/SCL	STAFB	GTWCCE	OCMHD	
	-----	-----	-----	-----	-----	-----	-----	-----	-----	
ADJUSTED CAPY FACTORS:										CORR. FACTOR
1990	0.6214	0.	0.0369	0.0034	0.	0.	0.4115	0.	0.	0.8398
1995	0.7044	0.	0.0419	0.0038	0.	0.	0.4664	0.	0.	0.9519
2000	0.6722	0.	0.0212	0.0037	0.	0.	0.3315	0.6999	0.	0.9209
2005	0.5917	0.	0.0186	0.0032	0.	0.	0.2918	0.6160	0.	0.8105
2010	0.6474	0.	0.0090	0.0108	0.	0.	0.2518	0.5935	0.6115	0.8992
2015	0.6755	0.	0.0009	0.0113	0.	0.	0.1970	0.5629	0.6380	0.9382
2020	0.6319	0.	0.0009	0.0105	0.	0.	0.1843	0.5266	0.5968	0.8776
2025	0.5911	0.	0.0008	0.0099	0.	0.	0.1724	0.4926	0.5582	0.8210
2030	0.5861	0.	0.0008	0.0098	0.	0.	0.1709	0.4884	0.5535	0.8140
2035	0.5820	0.	0.0008	0.0097	0.	0.	0.1698	0.4850	0.5497	0.8083
2040	0.5763	0.	0.0008	0.0096	0.	0.	0.1691	0.4802	0.5442	0.8004
2045	0.5662	0.	0.0008	0.0094	0.	0.	0.1651	0.4718	0.5347	0.7864
2050	0.5665	0.	0.0008	0.0094	0.	0.	0.1652	0.4721	0.5350	0.7868
2054	0.5712	0.	0.0008	0.0095	0.	0.	0.1666	0.4760	0.5395	0.7933
ENERGY GENERATED (GW-YR PER YEAR):										TOTAL
1990	71.5	0.	0.3	0.0	0.	0.	61.2	0.	0.	133.0
1995	81.1	0.	1.1	0.1	0.	0.	240.5	0.	0.	322.8
2000	77.4	0.	0.6	0.2	0.	0.	204.8	287.5	0.	570.4
2005	68.1	0.	0.5	0.2	0.	0.	205.6	619.7	0.	894.2
2010	74.5	0.	0.3	2.5	0.	0.	179.9	776.2	275.2	1308.6
2015	77.8	0.	0.0	5.1	0.	0.	140.8	949.3	682.2	1855.2
2020	0.	0.	0.0	6.2	0.	0.	104.3	1378.5	951.9	2440.9
2025	0.	0.	0.0	7.3	0.	0.	34.3	1823.9	1232.3	3097.8
2030	0.	0.	0.0	7.0	0.	0.	16.6	1607.9	1222.0	2853.4
2035	0.	0.	0.0	6.7	0.	0.	1.7	1307.9	1213.4	2529.7
2040	0.	0.	0.0	5.1	0.	0.	0.0	1150.1	956.5	2111.7
2045	0.	0.	0.0	2.9	0.	0.	0.0	951.4	608.7	1563.0
2050	0.	0.	0.0	1.6	0.	0.	0.0	512.2	327.7	841.5
2054	0.	0.	0.0	0.2	0.	0.	0.0	63.1	40.4	103.6

Table F-31 (Cont'd)

		STLWR	STSCRB	GT/OIL	GT/SCL	GTCC/OIL	GTCC/SCL	STAFB	GTWCCE	OCMHD
		-----	-----	-----	-----	-----	-----	-----	-----	-----
FUTURE LIFE-CYCLE WORTHS (\$/KW):										
CAPITAL										
	1985	0.	0.	221.16	221.16	0.	0.	852.22	903.69	909.41
	1990	0.	0.	303.00	303.00	0.	0.	1167.61	1238.14	1245.97
	1995	0.	0.	415.14	415.14	0.	0.	1599.73	1696.36	1707.09
	2000	0.	0.	568.78	568.78	0.	0.	2191.77	2324.16	2338.87
	2005	0.	0.	779.28	779.28	0.	0.	3002.91	3184.29	3204.45
	2010	0.	0.	1067.68	1067.68	0.	0.	4114.25	4362.76	4390.37
	2015	0.	0.	1462.81	1462.81	0.	0.	5636.88	5977.36	6015.19
	2020	0.	0.	2004.18	2004.18	0.	0.	7723.01	8189.50	8241.33
	2024	0.	0.	2578.31	2578.31	0.	0.	9935.39	10535.51	10602.19
FUT L-C WORTH (\$/KW):										
FIXED O&M										
	1985	0.	0.	19.10	19.10	0.	0.	96.61	45.06	49.38
	1990	0.	0.	26.18	26.18	0.	0.	132.36	61.73	67.66
	1995	0.	0.	35.86	35.86	0.	0.	181.34	84.58	92.70
	2000	0.	0.	49.13	49.13	0.	0.	248.45	115.88	127.01
	2005	0.	0.	67.32	67.32	0.	0.	340.40	158.77	174.01
	2010	0.	0.	92.23	92.23	0.	0.	466.38	217.53	238.41
	2015	0.	0.	126.37	126.37	0.	0.	638.99	298.03	326.65
	2020	0.	0.	173.13	173.13	0.	0.	875.47	408.33	447.53
	2024	0.	0.	222.73	222.73	0.	0.	1126.26	525.31	575.74
FUT L-C WORTH (\$/KW):										
VAR. O&M										
	1985	137.64	0.	9.50	2.13	0.	0.	172.53	213.25	67.98
	1990	197.77	0.	12.02	3.82	0.	0.	245.91	389.70	152.36
	1995	266.94	0.	10.29	6.19	0.	0.	284.52	677.83	299.81
	2000	348.87	0.	9.10	9.86	0.	0.	335.61	856.25	555.41
	2005	476.02	0.	6.49	15.90	0.	0.	408.23	1113.56	983.62
	2010	638.72	0.	5.04	21.45	0.	0.	511.72	1461.37	1330.67
	2015	856.99	0.	2.40	28.78	0.	0.	643.27	1921.92	1785.39
	2020	1139.68	0.	3.19	38.27	0.	0.	855.46	2555.90	2374.33
	2024	1449.06	0.	4.05	48.66	0.	0.	1087.68	3249.73	3018.88
FUT L-C WORTH (\$/KW):										
FUEL										
	1985	1331.37	0.	223.79	72.07	0.	0.	1024.67	1023.46	390.08
	1990	1984.66	0.	299.59	137.42	0.	0.	1489.35	1891.42	886.86
	1995	2790.22	0.	294.24	220.25	0.	0.	1782.55	3326.99	1767.95
	2000	3811.85	0.	298.50	359.43	0.	0.	2177.66	4349.65	3314.53
	2005	5415.67	0.	257.05	591.03	0.	0.	2743.81	5849.37	5942.24
	2010	7578.40	0.	241.82	823.55	0.	0.	3562.25	7938.43	8300.67
	2015	10605.23	0.	178.65	1141.78	0.	0.	4646.65	10802.19	11508.11
	2020	14732.35	0.	287.54	1570.86	0.	0.	6392.89	14861.70	15832.91
	2024	19304.62	0.	424.78	2051.29	0.	0.	8348.08	19406.98	20675.22

Table F-31 (Cont'd)

	STLWR	STSCRB	GT/OIL	GT/SCL	GTCC/OIL	GTCC/SCL	STAFB	GTWCCE	OCMHD	TOTAL
	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
1975 WORTH (B\$) OF UNITS INSTALLED IN:										
1985	63.841	0.	0.	0.	0.	0.	0.	0.	0.	63.841
1990	0.	0.	0.521	0.357	0.	0.	47.482	0.	0.	48.360
1995	0.	0.	0.252	0.385	0.	0.	28.074	34.439	0.	63.151
2000	0.	0.	0.	0.412	0.	0.	7.075	74.806	0.	82.293
2005	0.	0.	0.	1.580	0.	0.	3.813	55.052	26.219	86.665
2010	0.	0.	0.	2.968	0.	0.	0.	29.847	58.675	91.490
2015	0.	0.	0.	1.549	0.	0.	0.	69.831	40.738	112.118
2020	0.	0.	0.	1.735	0.	0.	0.	78.074	45.564	125.373
2024	0.	0.	0.	1.909	0.	0.	0.	86.045	50.235	138.189
INTEGRATED 1975 WORTHS (B\$):										
CAPITAL	63.530	0.	2.021	27.383	0.	0.	181.230	551.783	297.930	1123.877
FIXED O&M	4.133	0.	0.175	2.365	0.	0.	20.544	27.512	16.179	70.908
VAR. O&M	5.996	0.	0.073	0.524	0.	0.	35.163	187.911	88.598	318.264
FUEL	58.417	0.	1.861	20.329	0.	0.	216.333	1017.311	567.553	1881.804
TOTAL FOR GEN.	132.076	0.	4.130	50.601	0.	0.	453.269	1784.518	970.259	3394.852
R&D PROGRAM	0.	0.	0.	0.	0.	0.	0.201	0.375	1.318	1.895
TOTAL	132.076	0.	4.130	50.601	0.	0.	453.471	1784.893	971.577	3396.747
										=====

WORTH OF SAVINGS = 197.530 B\$

WITH INTANGIBLES, WITHOUT TAXES

F.7 NET PRESENT WORTH OF SAVINGS — SENSITIVITY TO DATE OF FIRST COMMERCIAL SERVICE

In order to gain an appreciation of the sensitivity to date of first commercial service, this time was varied ± 1 year and ± 2 years for the three Minimum Competition Scenarios. It must be kept in mind that OGP was not rerun for these variations in T_1 ; it was assumed that the OGP outputs of market penetration f and capacity factor F on either side of T_1 could be extended as T_1 is changed. For variations in T_1 larger than ± 2 years, the market penetration will most likely be affected and OGP should be rerun to obtain a good estimate. Refer to the variation scenario data files in Appendix D.4, Table D-24.

These variations were made for two cases, the base case (with intangibles, without taxes) and the OGP case (without intangibles, with taxes). Results are tabulated in Tables F-32 and F-33, respectively. (These tables have the same format as Table F-25 for the various cases without T_1 variation.) Also, results for the OGP case are plotted in Figure F-20.

Table F-32
EFFECT OF VARYING DATE OF INTRODUCTION OF NEW CYCLES
BASE CASE

	Variation in T_1 (Yr)				
	-2	-1	STD	+1	+2
Present Worth of Costs* (B\$)					
No New Technology	3594.3	3594.3	3594.3	3594.3	3594.3
Minimum Competition - STAFB	3614.2	3609.8	3602.6	3598.8	3595.7
Minimum Competition - GTWCCE	3418.5	3420.4	3422.7	3424.8	3427.3
Minimum Competition - OCMHD	3451.0	3454.6	3457.7	3461.4	3464.6
Net Present Worth of Savings (B\$)					
Minimum Competition - STAFB	-20.0	-15.6	-8.3	-4.5	-1.4
Minimum Competition - GTWCCE	175.8	173.9	171.6	169.5	167.0
Minimum Competition - OCMHD	143.3	139.7	136.5	132.9	129.7

*1975 Present Worth Expressed in 1975 Dollars

Note: Intangibles are considered;
Taxes are omitted.

Table F-33
EFFECT OF VARYING DATE OF INTRODUCTION OF NEW CYCLES
OGP CASE

	Variation in T_1 (Yr)				
	<u>-2</u>	<u>-1</u>	<u>STD</u>	<u>+1</u>	<u>+2</u>
Present Worth of Costs* (B\$)					
No New Technology	4742.5	4742.5	4742.5	4742.5	4742.5
Minimum Competition - STAFB	4436.6	4443.4	4444.4	4450.7	4457.9
Minimum Competition - GTWCCE	4174.4	4184.6	4195.3	4206.1	4217.4
Minimum Competition - OCMHD	4412.0	4416.4	4420.4	4425.0	4429.2
Net Present Worth of Savings(B\$)					
Minimum Competition - STAFB	305.9	299.1	298.1	291.8	284.6
Minimum Competition - GTWCCE	568.1	557.9	547.2	536.4	525.2
Minimum Competition - OCMHD	330.5	326.1	322.1	317.5	313.3

*1975 Present Worth Expressed in 1975 Dollars

Note: Intangibles are omitted;
Taxes are considered.

Figure F-20. Effect of Delaying Introduction of New Cycles "OGP" Case

From Figure F-20, it may be concluded that varying T_1 has only a slight impact upon savings. As expected, the savings decrease if introduction of a new cycle is delayed, but the decrease is only about 10 B\$ per year, for each of the three new cycles.

Appendix G

DIRECT WEIGHTING METHOD POWER CYCLE RATINGS

Ratings of good, fair, and poor are summarized in this appendix for all of the power cycles considered in this study. These ratings have been assigned with respect to the evaluation criteria definitions listed in Section 5. Figures of merit are also presented here which were computed using the weighting factors derived in Section 7.

G.1 PHASE 1 POWER CYCLES

Twenty-one cycles were analyzed, and ratings with respect to the evaluation criteria were reported at the end of Phase 1.* The Direct Weighting Method has evolved and changed since that time. In particular, the definitions of criteria 8, 9, 15, 18, 22, 23, 24, and 25 have been modified to be more precise and eliminate overlap as much as possible. New ratings have been assigned to the Phase 1 cycles where required to respond to these changes.

The weighting factors have also been modified in response to new inputs from EPRI concerning the utility objectives. Thus, even in cases where the cycle ratings were unchanged from Phase 1, there are changes in the overall figure of merit.

Table G-1 summarizes the ratings and figures of merit which were derived using the criteria definitions of Section 5 and the weighting factors of Section 7.

*Comparative Study and Evaluation of Advanced Cycle Systems, General Electric Phase 1 Report, EPRI Report No. AF-158, NTIS Report No. PB254392, General Electric Company, Schenectady, N.Y., May 1976.

Table G-1

DIRECT WEIGHTING METHOD - PHASE 1 CYCLES

Evaluation Criteria	Power Cycles						
	1 Advanced Steam Atmospheric Fluidized Bed Coal	2 Advanced Steam Conventional Furnace No. 6 Oil	3 Advanced Steam High Temperature Gas Cooled Reactor	4 Advanced Steam Liquid Metal Fast Breeder Reactor	5 Advanced Open Cycle Gas Turbine (Air Cooled) Recuperative High-Btu Gas	6 Advanced Open Cycle Gas Turbine (Air Cooled) Recuperative No. 6 Oil	7 Advanced Open Cycle Gas Turbine (Air Cooled) Combined Cycle Low-Btu Gas
1. Cost of R&D Required	G	G	F	P	F	G	G
2. R&D Time Required	G	G	G	F	G	G	G
3. Prob. of Development Success	G	G	G	G	F	G	G
4. Plant Capital Cost	F	F	P	P	G	G	F
5. Plant O&M Requirements	F	F	P	P	G	G	F
6. Electrical Performance	G	G	G	G	G	G	G
7. Power Plant Efficiency	F	F	F	F	F	P	F
8. Capability for Load Change	P	P	F	F	G	G	F
9. Part Load Efficiency	G	G	G	G	F	F	G
10. Minimum Unit Load	G	G	G	G	G	G	G
11. Forced Outage Rate	F	F	F	F	F	F	F
12. Planned Outage Rate	G	G	F	F	G	G	G
13. Hardware Materials Availability	G	G	G	G	G	G	G
14. Industrial Capability for Manufacture	G	G	G	G	G	G	G
15. Plant Safety	G	G	G	G	G	G	G
16. Dependence on Other Systems	G	G	G	G	G	G	G
17. Adaptability to Fuels	F	F	F	F	F	F	F
18. Life	G	G	G	G	G	G	G
19. Flexibility of Siting	G	G	P	P	G	G	F
20. Waste Handling & Disposal	F	F	P	P	G	G	F
21. Plant Construction Time	F	F	P	P	G	G	F
22. Unit Rating	F	F	P	P	G	G	F
23. Byproducts	F	P	P	P	P	P	F
24. Environmental Intrusion	F	F	G	G	G	F	G
25. Availability of Fuels & Additives	G	G	G	G	G	F	G
26. Startup Power Requirements	G	G	G	G	G	G	G
Figure of Merit	808	804	707	618	871	878	815

Table G-1 (Cont'd)

Evaluation Criteria	Power Cycles						
	8 Advanced Open Cycle Gas Turbine (Water Cooled) Combined Cycle Low-Btu Gas	9 Advanced Open Cycle Gas Turbine (Water Cooled) Combined Cycle Semiclean Liquid	10 Closed Cycle Gas Turbine Supercritical CO ₂ Atmospheric Fluidized Bed Coal	11 Closed Cycle Gas Turbine Helium Atmospheric Fluidized Bed Coal	12 Closed Cycle Gas Turbine High Temperature Gas Cooled Reactor	13 Open Cycle Plasma MHD Coal	14 Closed Cycle Plasma MHD Conventional Furnace Coal
1. Cost of R&D Required	F	F	F	F	P	P	P
2. R&D Time Required	G	G	F	F	F	F	F
3. Prob. of Development Success	F	F	F	F	F	P	P
4. Plant Capital Cost	F	G	P	F	P	P	P
5. Plant O&M Requirements	F	F	F	F	P	F	F
6. Electrical Performance	G	G	F	F	G	F	P
7. Power Plant Efficiency	F	G	F	F	F	G	G
8. Capability for Load Change	F	G	G	G	G	P	P
9. Part Load Efficiency	G	G	G	G	F	F	F
10. Minimum Unit Load	G	G	F	F	G	F	F
11. Forced Outage Rate	F	P	F	F	F	P	P
12. Planned Outage Rate	G	G	F	F	F	F	F
13. Hardware Materials Availability	G	G	G	G	G	G	G
14. Industrial Capability for Manufacture	G	G	G	G	G	G	G
15. Plant Safety	G	G	G	G	G	G	G
16. Dependence on Other Systems	G	G	G	G	G	G	G
17. Adaptability to Fuels	F	F	F	F	F	G	G
18. Life	G	G	G	G	G	G	G
19. Flexibility of Siting	F	G	G	G	P	G	G
20. Waste Handling & Disposal	F	G	F	F	P	F	F
21. Plant Construction Time	F	F	F	F	P	P	P
22. Unit Rating	F	F	F	F	P	P	P
23. Byproducts	F	P	F	F	P	F	P
24. Environmental Intrusion	G	P	F	F	G	G	F
25. Availability of Fuels & Additives	G	G	G	G	G	G	G
26. Startup Power Requirements	G	G	G	G	G	G	G
Figure of Merit	760	829	618	650	610	561	522

Table G-1 (Cont'd)

Evaluation Criteria	Power Cycles						
	15 Liquid Metal MHD Atmospheric Fluidized Bed Coal	16 Metal Vapor Turbine Atmospheric Fluidized Bed Coal	17 Thermionic Conventional Furnace Coal	18 Fuel Cell Low Temperature Hydrogen	19 Fuel Cell Low Temperature No. 6 Oil	20 Advanced Steam Conventional Furnace Stack Gas Scrubbers Coal	21 Simple Cycle Gas Turbine High-Btu Gas
1. Cost of R&D Required	F	F	F	F	F	G	G
2. R&D Time Required	F	F	F	F	F	G	G
3. Prob. of Development Success	P	F	P	G	G	G	G
4. Plant Capital Cost	P	P	P	G	F	F	G
5. Plant O&M Requirements	F	F	P	G	G	F	G
6. Electrical Performance	P	G	F	P	P	G	G
7. Power Plant Efficiency	F	F	F	G	G	F	P
8. Capability for Load Change	P	P	P	G	G	P	G
9. Part Load Efficiency	F	G	G	G	G	G	F
10. Minimum Unit Load	F	G	G	G	G	G	G
11. Forced Outage Rate	P	P	P	G	G	G	G
12. Planned Outage Rate	F	F	P	G	G	G	G
13. Hardware Material Availability	G	G	G	P	P	G	G
14. Industrial Capability for Manufacture	G	G	F	G	G	G	G
15. Plant Safety	G	G	G	G	G	G	G
16. Dependence on Other Systems	G	G	G	G	G	G	G
17. Adaptability to Fuels	F	F	G	F	F	F	G
18. Life	G	G	G	G	G	G	G
19. Flexibility of Siting	F	G	G	G	G	G	G
20. Waste Handling & Disposal	F	F	F	G	F	F	G
21. Plant Construction Time	P	P	P	G	G	F	G
22. Unit Rating	F	F	P	G	G	F	G
23. Byproducts	F	F	P	P	P	F	P
24. Environmental Intrusion	F	F	F	G	G	G	G
25. Availability of Fuels & Additives	G	G	G	G	F	G	G
26. Startup Power Requirements	G	F	G	G	G	G	G
Figure of Merit	482	592	520	808	728	855	968

G.2 PHASE 2 CYCLES AND REFERENCE CYCLES

Table G-2 gives the data and qualitative judgements used in rating the Phase 2 and reference power cycles. Data developed from the conceptual designs (Appendix B) was used in a number of the ratings. For instance, the "Plant Capital Cost" rating is based on the \$/kWe estimated in Appendix B. Where subjective judgement was required, the opinions of the ECAS implementation assessment panel were adapted whenever possible. For instance, the water-cooled gas turbine was judged to have a fair probability of development success in ECAS and the gasifier to have a good probability. These components appeared in two separate plants in ECAS. They are both included in the first Phase 2 plant, and the probability of development success for the combination was assumed to be no worse than the fair assigned to the turbine alone.

The ratings for each cycle are summarized in Tables G-3 through G-8. Note that the conventional gas turbine and gas turbine combined cycle (Tables G-5 and G-6) are rated for two different fuels: oil and semiclean liquid derived from coal.

Table G-2

EVALUATION CRITERIA RATINGS FOR PHASE 2 CYCLES AND REFERENCE CYCLES

Cycle Name	Evaluation Criteria											
	1. Cost of R&D Required		2. R&D Time Required		3. Probability of Development Success		4. Plant Capital Cost		5. Plant O&M Requirements		6. Electrical Performance	
	M\$	Rating	First Commercial Date	Rating	Comment	Rating	\$/kW	Rating	Comment	Rating	Comment	Rating
Open Cycle Gas Turbine Combined – Water Cooled – LBTu Gasifier – Coal	417	F	1966	F	Gasifier has good probability, but gas turbine had fair rating in ECAS*	F	474	F	Gasifier and gas turbine both rated fair in ECAS	F	Turbine/generators have good stability in fault conditions	G
Advanced Steam (2400 P/1000 F/1200 F) Atmospheric Fluidized Bed – Coal	438	F	2000	F	AFB and 1200 F steam turbine probably are comparable; AFB rated good in ECAS	G	542	F	Similar to AFB/steam plant; rated fair in ECAS	F	Turbine/generators have good stability in fault conditions	G
Conventional Open Cycle Gas Turbine – Oil/Semiclean Liquid	—	G	—	G	—	G	116	G	Can be remotely operated	G	Turbine/generators have good stability in fault conditions	G
Conventional Open Cycle Gas Turbine Combined – Oil/Semiclean Liquid	—	G	—	G	—	G	282	G	Steam cycle maintenance requires operators on site	F	Turbine/generators have good stability in fault conditions	G
Conventional Steam, Wet Gas Scrubbers – Coal	—	G	—	G	—	G	591	F	Steam cycle maintenance requires operators on site	F	Turbine/generators have good stability in fault conditions	G
Conventional Steam, Light Water Reactor	—	G	—	G	—	G	776	F	Nuclear specialists required	P	Turbine/generators have good stability in fault conditions	G

*ECAS – Energy Conversion Alternatives Study, General Electric Phase II Final Report, Vol. III, December 1976, NASA Rept. No. NASA-CR-134949

Table G-2 (Cont'd)

Cycle Name	Evaluation Criteria												
	7. Power Plant Efficiency		8. Capability for Load Change		9. Partial Load Efficiency			10. Minimum Load		11. Forced Outage Rate		12. Planned Outage Rate	
	Percent	Rating	Unit Has Capability Similar to:	Rating	$\frac{\eta_{PL}}{\eta_{FL}}$ %	Percent of Full Load	Rating	Percent of Full Load	Rating	Percent	Rating	Percent	Rating
Open Cycle Gas Turbine Combined - Water Cooled - Litha Gasifier - Cont	44.0	P	Cycling steam plant (2400 psi/1000 F/1000 F)	P	0.95	50	G	20	G	12	P	9	G
Advanced Steam (2400 P/1000 F/1200 F) Atmospheric Fluidized Bed - Cont	37.1	P	2400 psi APB probably good; 1200 F reheat steam turbine is poor	P	0.95	50	G	20	G	Similar to AFB - steam (3500 psi/1000 F/1000 F) in ECAS	P	Similar to AFB - steam (3500 psi/1000 F/1000 F) in ECAS	G
Conventional Open Cycle Gas Turbine - Oil/Semicon Liquid	31.0	P	Peaking gas turbine	G	0.85	50	P	30	F	12	P	4	G
Conventional Open Cycle Gas Turbine Combined - Oil/Semicon Liquid	42.6	P	Cycling steam 900 psi/850 F	P	0.95	50	G	20	G	10	P	9	G
Conventional Steam, Wet Gas Scrubbers - Cont	31.8	P	Base load steam (3500 psi/1000 F/1000 F)	P	0.95	50	G	20	G	18	P	9	G
Conventional Steam, Light Water Reactor	32.8	P	Base load steam	P	0.95	50	G	50	F	15	P	15	P

* $\frac{\eta_{PL}}{\eta_{FL}}$ - ratio of part load to full load efficiency

Table G-2 (Cont'd)

Cycle Name	Evaluation Criteria									
	13. Hardware Materials Availability		14. Industrial Capability of Manufacture		15. Plant Safety		16. Dependence on Other Systems		17. Adaptability to Fuels	
	Comment	Rating	Comment	Rating	Comment	Rating	Comment	Rating	Comment	Rating
Open Cycle Gas Turbine Combined – Water Cooled – LBTu Gasifier – Coal	Gasifier and gas turbine both rated good in ECAS	G	Gasifier and gas turbine both rated good in ECAS	G	Designed to meet good specification	G	Gasifier and gas turbine both rated good in ECAS	G	Gasifier rated good in ECAS	G
Advanced Steam (2400 P/1000 F/1200 F) Atmospheric Fluidized Bed – Coal	No worse than potassium topping cycle which was rated good in ECAS	G	Forgings for steam turbine may require expanded facilities	F	Designed to meet good specification	G	AFB/steam rated good in ECAS	G	AFB rated good in ECAS	G
Conventional Open Cycle Gas Turbine – Oil/Semiclean Liquid	No worse than gas turbines which were rated good in ECAS	G	Conventional technology	G	Designed to meet good specification	G	None	G	Can burn oil or gas	G
Conventional Open Cycle Gas Turbine Combined – Oil/Semiclean Liquid	No worse than gas turbines which were rated good in ECAS	G	Conventional technology	G	Designed to meet good specification	G	None	G	Can burn oil or gas	G
Conventional Steam, Wet Gas Scrubbers – Coal	No worse than AFB – steam which was rated good in ECAS	G	Conventional technology	G	Designed to meet good specification	G	None	G	Can only burn coal	F
Conventional Steam, Light Water Reactor	Cycle data supplied by EPRI did not specify material usage; assume that reactor is no worse than potassium topping cycle which was rated good in ECAS	G	Conventional technology	G	Designed to meet good specification	G	None	G	Can only use uranium	F

Table G-2 (Cont'd)

Cycle Name	Evaluation Criteria												
	18. Life		19. Flexibility of Siting		20. Waste Handling and Disposal		21. Plant Construction Time		22. Unit Rating			23. By-Products	
	Years	Rating	Comment	Rating	Comment	Rating	Years	Rating	MWe*	Possible Size Reduction Percent	Rating	Comments	Rating
Open Cycle Gas Turbine Combined - Water Cooled - LDU Gasifier - Coal	30	G	Suitable only for sites zoned for heavy industrial use	P	Gasifier rated good in ECAS	G	5.0	P	640	50	P	Sulfur from cleanup system can be sold	P
Advanced Steam (2400 P/1000 P/1200 P) Atmospheric Fluidized Bed - Coal	30	G	Suitable only for sites zoned for heavy industrial use	P	APB rated fair in ECAS	P	5.5	P	843	60	P	Unreacted lime in ash/sorbent mixture can be sold	P
Conventional Open Cycle Gas Turbine - Oil/Semiclean Liquid	30	G	Can locate adjacent to residential zones	G	No waste	G	1	G	76	0	G	None	P
Conventional Open Cycle Gas Turbine Combined - Oil/Semiclean Liquid	30	G	Heavy industrial	P	No waste	G	3	P	417	25	P	None	P
Conventional Steam, Wet Gas Scrubbers - Coal	30	G	Need large site for sludge disposal ponds	P	Lime sludge ponds provided on site	P	5.5	P	742	30	P	Sludge from scrubber contains gypsum but in useable form	P
Conventional Steam, Light Water Reactor	30	G	Strong public reaction limits available sites	P	Radioactive waste	P	6.0	P	1000	0	P	None	P

*Rating of Conceptual design described in Appendix B

Table G-2 (Cont'd)

Cycle Name	Evaluation Criteria					
	24. Environmental Intrusion		25. Availability of Fuel and Additives		26. Startup Power Requirements	
	Comment	Rating	Material Required	Rating	Comment	Rating
Open Cycle Gas Turbine Combined – Water Cooled – LBTu Gasifier – Coal	Gasifier with alkazid cleanup system rated good in ECAS	G	Coal	G	Gas turbine combined cycles rated good in ECAS	G
Advanced Steam (2400 P/1000 F/1200 F) Atmospheric Fluidized Bed – Coal	AFB rated fair in ECAS due to NO _x from fuel bound nitrogen	F	Coal-limestone	G	AFB steam plants rated good in ECAS	G
Conventional Open Cycle Gas Turbine – Oil/Semiclean Liquid	Oil: Meets NSPS; major combustor design change and/or stack gas scrubbers to meet future standards Semiclean liquid: Does not meet NSPS on NO _x because of high fuel bound nitrogen level	F/P	Oil Semiclean liquid	F G		G
Conventional Open Cycle Gas Turbine Combined – Oil/Semiclean Liquid	Oil: Meets NSPS; major combustor design change and/or stack gas scrubbers to meet future standards Semiclean liquid: Does not meet NSPS on NO _x because of high fuel bound nitrogen level	F/P	Oil Semiclean liquid	F G		G
Conventional Steam, Wet Gas Scrubbers – Coal	Cannot meet future NO _x standard without catalytic reactor in flue gas stream	F	Coal-limestone	G		G
Conventional Steam, Light Water Reactor	None	G	Uranium	G		G

Note: NSPS - New Source Performance Standards

Table G-3

DIRECT WEIGHTING METHOD
ADVANCED OPEN CYCLE GAS TURBINE COMBINED – WATER COOLED – INTEGRATED
LOW-Btu GASIFIER – COAL

Evaluation Criteria	Criteria Rating		Criteria Weight	Product
	Good/Fair/ Poor	Numerical		
1. Cost of R&D Required	F	5	1	5
2. R&D Time Required	F	5	17	85
3. Prob. of Development Success	F	5	10	50
4. Plant Capital Cost	F	5	8	40
5. Plant O&M Requirements	F	5	1	5
6. Electrical Performance	G	10	5	50
7. Power Plant Efficiency	F	5	2	10
8. Capability for Load Change	F	5	3	15
9. Part Load Efficiency	G	10	1	10
10. Minimum Unit Load	G	10	1	10
11. Forced Outage Rate	P	1	4	4
12. Planned Outage Rate	G	10	3	30
13. Hardware Materials Availability	G	10	2	20
14. Industrial Capability for Manufacture	G	10	2	20
15. Plant Safety	G	10	3	30
16. Dependence on Other Systems	G	10	8	80
17. Adaptability to Fuels	G	10	6	60
18. Life	G	10	1	10
19. Flexibility of Siting	F	5	4	20
20. Waste Handling & Disposal	G	10	3	30
21. Plant Construction Time	F	5	2	10
22. Unit Rating	F	5	3	15
23. Byproducts	F	5	1	5
24. Environmental Intrusion	G	10	3	30
25. Availability of Fuels & Additives	G	10	5	50
26. Startup Power Requirements	G	10	1	10
Figure of Merit				704

Table G-4

DIRECT WEIGHTING METHOD
ADVANCED STEAM (2400P/1000F/1200F) – ATMOSPHERIC FLUIDIZED BED – COAL

Evaluation Criteria	Criteria Rating		Criteria Weight	Product
	Good/Fair/Poor	Numerical		
1. Cost of R&D Required	F	5	1	5
2. R&D Time Required	F	5	17	85
3. Prob. of Development Success	G	10	10	100
4. Plant Capital Cost	F	5	8	40
5. Plant O&M Requirements	F	5	1	5
6. Electrical Performance	G	10	5	50
7. Power Plant Efficiency	F	5	2	10
8. Capability for Load Change	P	1	3	3
9. Part Load Efficiency	G	10	1	10
10. Minimum Unit Load	G	10	1	10
11. Forced Outage Rate	F	5	4	20
12. Planned Outage Rate	G	10	3	30
13. Hardware Materials Availability	G	10	2	20
14. Industrial Capability for Manufacture	F	5	2	10
15. Plant Safety	G	10	3	30
16. Dependence on Other Systems	G	10	8	80
17. Adaptability to Fuels	G	10	6	60
18. Life	G	10	1	10
19. Flexibility of Siting	F	5	4	20
20. Waste Handling & Disposal	F	5	3	15
21. Plant Construction Time	P	1	2	2
22. Unit Rating	F	5	3	15
23. Byproducts	F	5	1	5
24. Environmental Intrusion	F	5	3	15
25. Availability of Fuels & Additives	G	10	5	50
26. Startup Power Requirements	G	10	1	10
Figure of Merit				710

Table G-5
DIRECT WEIGHTING METHOD
CONVENTIONAL OPEN CYCLE GAS
TURBINE - OIL/SEMICLEAN LIQUID*

Evaluation Criteria	Criteria Rating		Criteria Weight	Product
	Good Fair Poor	Numerical		
1. Cost of R&D Required	G	10	1	10
2. R&D Time Required	G	10	17	170
3. Prob. of Development Success	G	10	10	100
4. Plant Capital Cost	G	10	8	80
5. Plant O&M Requirements	G	10	1	10
6. Electrical Performance	G	10	5	50
7. Power Plant Efficiency	P	1	2	2
8. Capability for Load Change	G	10	3	30
9. Part Load Efficiency	F	5	1	5
10. Minimum Unit Load	F	5	1	5
11. Forced Outage Rate	P	1	4	4
12. Planned Outage Rate	G	10	3	30
13. Hardware Materials Availability	G	10	2	20
14. Industrial Capability for Manufacture	G	10	2	20
15. Plant Safety	G	10	3	30
16. Dependence on Other Systems	G	10	8	80
17. Adaptability to Fuels	G	10	6	60
18. Life	G	10	1	10
19. Flexibility of Siting	G	10	4	40
20. Waste Handling & Disposal	G	10	3	30
21. Plant Construction Time	G	10	2	20
22. Unit Rating	G	10	3	30
23. Byproducts	P	1	1	1
24. Environmental Intrusion	F/P*	5/1*	3	15/3*
25. Availability of Fuels & Additives	F/G*	5/10*	5	25/50*
26. Startup Power Requirements	G	10	1	10
Figure of Merit				887/900*

Evaluation Criteria	Criteria Rating		Criteria Weight	Product
	Good Fair Poor	Numerical		
1. Cost of R&D Required	G	10	1	10
2. R&D Time Required	G	10	17	170
3. Prob. of Development Success	G	10	10	100
4. Plant Capital Cost	G	10	8	80
5. Plant O&M Requirements	F	5	1	5
6. Electrical Performance	G	10	5	50
7. Power Plant Efficiency	F	5	2	10
8. Capability for Load Change	F	5	3	15
9. Part Load Efficiency	G	10	1	10
10. Minimum Unit Load	G	10	1	10
11. Forced Outage Rate	F	5	4	20
12. Planned Outage Rate	G	10	3	30
13. Hardware Materials Availability	G	10	2	20
14. Industrial Capability for Manufacture	G	10	2	20
15. Plant Safety	G	10	3	30
16. Dependence on Other Systems	G	10	8	80
17. Adaptability to Fuels	G	10	6	60
18. Life	G	10	1	10
19. Flexibility of Siting	F	5	4	20
20. Waste Handling & Disposal	G	10	3	30
21. Plant Construction Time	F	5	2	10
22. Unit Rating	F	5	3	15
23. Byproducts	P	1	1	1
24. Environmental Intrusion	F/P*	5/1*	3	15/3*
25. Availability of Fuels & Additives	F/G*	5/10*	5	25/50*
26. Startup Power Requirements	G	10	1	10
Figure of Merit				856/869*

Table G-6
DIRECT WEIGHTING METHOD
CONVENTIONAL OPEN CYCLE GAS
TURBINE COMBINED -
OIL/SEMICLEAN LIQUID

Table G-7
DIRECT WEIGHTING METHOD
CONVENTIONAL STEAM - WET
GAS SCRUBBERS - COAL

Evaluation Criteria	Criteria Rating		Criteria Weight	Product
	Good Fair Poor	Numerical		
1. Cost of R&D Required	G	10	1	10
2. R&D Time Required	G	10	17	170
3. Prob. of Development Success	G	10	10	100
4. Plant Capital Cost	F	5	8	40
5. Plant O&M Requirements	F	5	1	5
6. Electrical Performance	G	10	5	50
7. Power Plant Efficiency	P	1	2	2
8. Capability for Load Change	P	1	3	3
9. Part Load Efficiency	G	10	1	10
10. Minimum Unit Load	G	10	1	10
11. Forced Outage Rate	P	1	4	4
12. Planned Outage Rate	G	10	3	30
13. Hardware Materials Availability	G	10	2	20
14. Industrial Capability for Manufacture	G	10	2	20
15. Plant Safety	G	10	3	30
16. Dependence on Other Systems	G	10	8	80
17. Adaptability to Fuels	F	5	6	30
18. Life	G	10	1	10
19. Flexibility of Siting	P	1	4	4
20. Waste Handling & Disposal	F	5	3	15
21. Plant Construction Time	P	1	2	2
22. Unit Rating	F	5	3	15
23. Byproducts	P	1	1	1
24. Environmental Intrusion	F	5	3	15
25. Availability of Fuels & Additives	G	10	5	50
26. Startup Power Requirements	C	10	1	10
Figure of Merit				736

Evaluation Criteria	Criteria Rating		Criteria Weight	Product
	Good Fair Poor	Numerical		
1. Cost of R&D Required	G	10	1	10
2. R&D Time Required	G	10	17	170
3. Prob. of Development Success	G	10	10	100
4. Plant Capital Cost	F	5	8	40
5. Plant O&M Requirements	P	1	1	1
6. Electrical Performance	G	10	5	50
7. Power Plant Efficiency	P	1	2	2
8. Capability for Load Change	P	1	3	3
9. Part Load Efficiency	G	10	1	10
10. Minimum Unit Load	F	5	1	5
11. Forced Outage Rate	P	1	4	4
12. Planned Outage Rate	F	5	3	15
13. Hardware Materials Availability	G	10	2	20
14. Industrial Capability for Manufacture	G	10	2	20
15. Plant Safety	G	10	3	30
16. Dependence on Other Systems	G	10	8	80
17. Adaptability to Fuels	F	5	6	30
18. Life	G	10	1	10
19. Flexibility of Siting	P	1	4	4
20. Waste Handling & Disposal	P	1	3	3
21. Plant Construction Time	P	1	2	2
22. Unit Rating	P	1	3	3
23. Byproducts	P	1	1	1
24. Environmental Intrusion	G	10	3	30
25. Availability of Fuels & Additives	G	10	5	50
26. Startup Power Requirements	G	10	1	10
Figure of Merit				703

Table G-8
DIRECT WEIGHTING METHOD
CONVENTIONAL STEAM - LIGHT
WATER REACTOR

G.3 POWER CYCLES FROM ENERGY CONVERSION ALTERNATIVES STUDY

Seven power cycles were analyzed in Phase II of the Energy Conversion Alternatives Study (ECAS). Conceptual designs and development plans for these cycles are described in Appendix C.

During Phase II of ECAS, a panel was convened to evaluate the seven cycles. The panel consisted of experts from the power generation equipment divisions within General Electric, as well as representatives from a boiler manufacturer (Foster Wheeler Energy Corporation) and an architect/engineering firm (Bechtel Corporation). The panelists used a list of evaluation criteria which was similar to the list described in Section 5. The correspondence between the two lists is indicated in Table G-9.

Several of the criteria in Section 5 were not included in the ECAS list, e.g., criterion 22 (unit rating); others have been changed significantly since the ECAS work was completed, e.g., criterion 4 (plant capital cost). The rating of the AFB/steam plant with respect to criterion 11 (forced outage rate) has been changed in response to new information from EPRI which indicates that the ECAS good rating was too optimistic.

The ratings with respect to criterion 1 (cost of R&D required) are based on the revised R&D costs presented in Appendix C, which include new information about furnace and gasifier development costs.

As indicated in Table G-9, the ECAS ratings have been used wherever possible. Table G-10 gives the data and qualitative judgements used to complete rating the seven cycles against the criteria which were not considered by the ECAS panel (second column of Table G-9).

Tables G-11 through G-17 summarize the ratings for each cycle and show the computation of the figures of merit.

Table G-9
SOURCES FOR EVALUATION CRITERIA RATINGS OF ECAS CYCLES

Evaluation Criteria	Sources for Ratings	
	ECAS* Implementation Assessment Criterion Number	Other
1. Cost of R&D Required		Shown in Table G-10
2. R&D Time Required		Shown in Table G-10
3. Prob. of Development Success	21	
4. Plant Capital Cost		Shown in Table G-10
5. Plant O&M Requirements	11	
6. Electrical Performance	20a	
7. Power Plant Efficiency		Shown in Table G-10
8. Capability for Load Change		Shown in Table G-10
9. Part Load Efficiency	9b	
10. Minimum Unit Load	9c	
11. Forced Outage Rate	5a (except AFB - steam)	See text
12. Planned Outage Rate	5b	
13. Hardware Materials Availability		Shown in Table G-10
14. Industrial Capability for Manufacture	13	
15. Plant Safety	6b	
16. Dependence on Other Systems	7b	
17. Adaptability to Fuels	14a	
18. Life		Shown in Table G-10
19. Flexibility of Siting	7a	
20. Waste Handling and Disposal	4b	
21. Plant Construction Time		Shown in Table G-10
22. Unit Rating		Shown in Table G-10
23. Byproducts		Shown in Table G-10
24. Environmental Intrusion		Shown in Table G-10
25. Availability of Fuels and Additives		Shown in Table G-10
26. Startup Power Requirements	20b	

*Energy Conversion Alternatives Study, General Electric Phase II Final Report,
Vol. III, December 1976, NASA Report No. NASA-CR-134949

Table G-10
EVALUATION CRITERIA RATINGS FOR ECAS CYCLES

Cycle Name	Evaluation Criteria									
	1. Cost of R&D Required		2. R&D Time Required		4. Plant Capital Cost		7. Power Plant Efficiency		8. Capability for Load Change	
	M\$	Rating	First Commercial Date	Rating	\$/kW	Rating	Percent	Rating	Unit Has Capability Similar to	Rating
A. Advanced Steam - AFB - Coal	228	F	1988	G	447	F	35.8	F	Base load steam 3500 psi/1000 F/1000 F	P
B. Advanced Steam - PFB - Coal	380	F	1994	F	511	F	39.2	F	Base load steam 3500 psi/1000 F/1000 F	P
C. Closed Cycle Gas Turbine - Helium - AFB - Coal	964	P	1997	F	899	P	39.9	F	Gas turbine combined cycle, except for AFB	F
D. Potassium Topping Cycle - PFB - Coal	845	P	2001	P	661	F	44.4	F	Base load steam 3500 psi/1000 F/1000 F	P
E. Open Cycle Gas Turbine Combined - Water Cooled - Semiclean Liquid	292	F	1996	F	305	F	51.1	G	Cycling steam 2400 psi/1000 F/1000 F	F
F. Open Cycle Gas Turbine Combined - Air Cooled - LBTu Gasifier - Coal	228	F	1993	F	562	F	39.6	F	Cycling steam 1800 psi/950 F/950 F	F
G. Open Cycle MHD - Coal	1444	P	2003	P	447	F	48.3	G	Base load steam 3500 psi/1000 F/1000 F	P

Table G-10 (Cont'd)

Cycle Name	Evaluation Criteria										
	13. Hardware Materials Availability		18. Life		21. Plant Construction Time		22. Unit Rating			23. By-Products	
	Comments*	Rating	Years	Rating	Years	Rating	MWe	Possible Reduction** Percent	Rating	Product	Rating
A. Advanced Steam - AFB - Coal	Uses large amounts of molybdenum nickel and tungsten	G	30	G	5.5	P	814	50	F	Lime	F
B. Advanced Steam - PFB - Coal		G	30	G	5.5	P	904	50	F	Lime	F
C. Closed Cycle Gas Turbine - Helium - AFB - Coal		F	30	G	5.0	F	476	None	F	Lime	F
D. Potassium Topping Cycle - PFB - Coal		G	30	G	5.5	P	996	50	F	Lime	F
E. Open Cycle Gas Turbine Combined - Water Cooled - Semiclean Liquid		G	30	G	5.0	F	846	50	F	None	P
F. Open Cycle Gas Turbine Combined - Air Cooled - LBTu Gasifier - Coal		G	30	G	5.0	F	585	50	F	Sulfur	F
G. Open Cycle MHD - Coal		G	30	G	6.5	P	1932	None	P	Sulfur	F

*Cycles were compared on the basis of materials requirements listed in Appendix C of Energy Conversion Alternatives Study, General Electric Phase II Final Report, Vol. II, Part 4, NASA Report No. NASA-CR-134949, December 1976.

**Reduction in size due to plant modularity which yields a new unit of smaller rating with approximately the same efficiency and cost.

Table G-10 (Cont'd)

Cycle Name	Evaluation Criteria			
	24. Environmental Intrusion		25. Availability of Fuels and Additives	
	Comments*	Rating	Materials	Rating
A. Advanced Steam - AFB - Coal	Meets NSPS, may not meet FPS due to NO _x from fuel bound nitrogen	F	Coal, limestone	G
B. Advanced Steam - PFB - Coal	Meets NSPS, may not meet FPS due to NO _x from fuel bound nitrogen	F	Coal, dolomite	G
C. Closed Cycle Gas Turbine - Helium - AFB - Coal	Meets NSPS, may not meet FPS due to NO _x from fuel bound nitrogen	F	Coal, limestone	G
D. Potassium Topping Cycle - PFB - Coal	Meets NSPS, may not meet FPS due to NO _x from fuel bound nitrogen	F	Coal, dolomite	G
E. Open Cycle Gas Turbine Combined - Water Cooled - Semiclean Liquid	Cannot meet NSPS on NO _x because of fuel bound nitrogen	P	Semiclean liquid derived from coal	G
F. Open Cycle Gas Turbine Combined - Air Cooled - LBtu Gasifier - Coal	Cleanup system can be modified to meet FPS	G	Coal	G
G. Open Cycle MHD - Coal	Radiant furnace, seeding and ESP can control emissions to meet FPS	G	Coal	G

*Comments are based on data and discussion in Appendix E of Energy Conversion Alternatives Study, General Electric Phase II Report, NASA Report No. NASA-CR-134949, December 1976.

NOTE: NSPS - New Source Performance Standards

FPS - Future Performance Standards (estimate given in definition of criterion 24)

ESP - Electrostatic Precipitator

Table G-11

DIRECT WEIGHTING METHOD
CYCLE A – ADVANCED STEAM, ATMOSPHERIC FLUIDIZED BED FURNACE, COAL

Evaluation Criteria	Criteria Rating		Criteria Weight	Product
	Good/Fair/Poor	Numerical		
1. Cost of R&D Required	F	5	1	5
2. R&D Time Required	G	10	17	170
3. Prob. of Development Success	G	10	10	100
4. Plant Capital Cost	F	5	8	40
5. Plant O&M Requirements	F	5	1	5
6. Electrical Performance	G	10	5	50
7. Power Plant Efficiency	F	5	2	10
8. Capability for Load Change	P	1	3	3
9. Part Load Efficiency	G	10	1	10
10. Minimum Unit Load	G	10	1	10
11. Forced Outage Rate	F	5	4	20
12. Planned Outage Rate	G	10	3	30
13. Hardware Materials Availability	G	10	2	20
14. Industrial Capability for Manufacture	G	10	2	20
15. Plant Safety	G	10	3	30
16. Dependence on Other Systems	G	10	8	80
17. Adaptability to Fuels	G	10	6	60
18. Life	G	10	1	10
19. Flexibility of Siting	F	5	4	20
20. Waste Handling & Disposal	F	5	3	15
21. Plant Construction Time	P	1	2	2
22. Unit Rating	F	5	3	15
23. Byproducts	F	5	1	5
24. Environmental Intrusion	F	5	3	15
25. Availability of Fuels & Additives	G	10	5	50
26. Startup Power Requirements	G	10	1	10
Figure of Merit				815

Table G-12

DIRECT WEIGHTING METHOD
CYCLE B - ADVANCED STEAM, PRESSURIZED FLUIDIZED BED FURNACE, COAL

Evaluation Criteria	Criteria Rating		Criteria Weight	Product
	Good/Fair/ Poor	Numerical		
1. Cost of R&D Required	F	5	1	5
2. R&D Time Required	F	5	17	85
3. Prob. of Development Success	P	1	10	10
4. Plant Capital Cost	F	5	8	40
5. Plant O&M Requirements	P	1	1	1
6. Electrical Performance	G	10	5	50
7. Power Plant Efficiency	F	5	2	10
8. Capability for Load Change	P	1	3	3
9. Part Load Efficiency	G	10	1	10
10. Minimum Unit Load	G	10	1	10
11. Forced Outage Rate	P	1	4	4
12. Planned Outage Rate	F	5	3	15
13. Hardware Materials Availability	G	10	2	20
14. Industrial Capability for Manufacture	F	5	2	10
15. Plant Safety	G	10	3	30
16. Dependence on Other Systems	G	10	8	80
17. Adaptability to Fuels	G	10	6	60
18. Life	G	10	1	10
19. Flexibility of Siting	F	5	4	20
20. Waste Handling & Disposal	F	5	3	15
21. Plant Construction Time	P	1	2	2
22. Unit Rating	F	5	3	15
23. Byproducts	F	5	1	5
24. Environmental Intrusion	F	5	3	15
25. Availability of Fuels & Additives	G	10	5	50
26. Startup Power Requirements	G	10	1	10
Figure of Merit				585

Table G-13

DIRECT WEIGHTING METHOD
 CYCLE C – ADVANCED CLOSED CYCLE GAS TURBINE, HELIUM, ORGANIC
 BOTTOMING, ATMOSPHERIC FLUIDIZED BED FURNACE, COAL

Evaluation Criteria	Criteria Rating		Criteria Weight	Product
	Good/Fair/ Poor	Numerical		
1. Cost of R&D Required	P	1	1	1
2. R&D Time Required	F	5	17	85
3. Prob. of Development Success	P	1	10	10
4. Plant Capital Cost	P	1	8	8
5. Plant O&M Requirements	P	1	1	1
6. Electrical Performance	F	5	5	25
7. Power Plant Efficiency	F	5	2	10
8. Capability for Load Change	F	5	3	15
9. Part Load Efficiency	G	10	1	10
10. Minimum Unit Load	G	10	1	10
11. Forced Outage Rate	P	1	4	4
12. Planned Outage Rate	G	10	3	30
13. Hardware Materials Availability	F	5	2	10
14. Industrial Capability for Manufacture	P	1	2	2
15. Plant Safety	G	10	3	30
16. Dependence on Other Systems	G	10	8	80
17. Adaptability to Fuels	G	10	6	60
18. Life	G	10	1	10
19. Flexibility of Siting	F	5	4	20
20. Waste Handling & Disposal	F	5	3	15
21. Plant Construction Time	F	5	2	10
22. Unit Rating	F	5	3	15
23. Byproducts	F	5	1	5
24. Environmental Intrusion	F	5	3	15
25. Availability of Fuels & Additives	G	10	5	50
26. Startup Power Requirements	G	10	1	10
Figure of Merit				541

Table G-14

DIRECT WEIGHTING METHOD
CYCLE D - POTASSIUM TOPPING CYCLE, PRESSURIZED FLUIDIZED
BED FURNACE, COAL

Evaluation Criteria	Criteria Rating		Criteria Weight	Product
	Good/Fair/ Poor	Numerical		
1. Cost of R&D Required	P	1	1	1
2. R&D Time Required	P	1	17	17
3. Prob. of Development Success	P	1	10	10
4. Plant Capital Cost	F	5	8	40
5. Plant O&M Requirements	P	1	1	1
6. Electrical Performance	G	10	5	50
7. Power Plant Efficiency	F	5	2	10
8. Capability for Load Change	P	1	3	3
9. Part Load Efficiency	G	10	1	10
10. Minimum Unit Load	G	10	1	10
11. Forced Outage Rate	P	1	4	4
12. Planned Outage Rate	F	5	3	15
13. Hardware Materials Availability	G	10	2	20
14. Industrial Capability for Manufacture	P	1	2	2
15. Plant Safety	G	10	3	30
16. Dependence on Other Systems	G	10	8	80
17. Adaptability to Fuels	G	10	6	60
18. Life	G	10	1	10
19. Flexibility of Siting	F	5	4	20
20. Waste Handling & Disposal	F	5	3	15
21. Plant Construction Time	P	1	2	2
22. Unit Rating	F	5	3	15
23. Byproducts	F	5	1	5
24. Environmental Intrusion	F	5	3	15
25. Availability of Fuels & Additives	G	10	5	50
26. Startup Power Requirements	G	10	1	10
Figure of Merit				505

Table G-15

DIRECT WEIGHTING METHOD
CYCLE E – ADVANCED OPEN CYCLE GAS TURBINE COMBINED – WATER COOLED –
SEMICLEAN LIQUID FUEL FROM COAL

Evaluation Criteria	Criteria Rating		Criteria Weight	Product
	Good/Fair/ Poor	Numerical		
1. Cost of R&D Required	F	5	1	5
2. R&D Time Required	F	5	17	85
3. Prob. of Development Success	F	5	10	50
4. Plant Capital Cost	F	5	8	40
5. Plant O&M Requirements	F	5	1	5
6. Electrical Performance	G	10	5	50
7. Power Plant Efficiency	G	10	2	20
8. Capability for Load Change	F	5	3	15
9. Part Load Efficiency	G	10	1	10
10. Minimum Unit Load	G	10	1	10
11. Forced Outage Rate	F	5	4	20
12. Planned Outage Rate	G	10	3	30
13. Hardware Materials Availability	G	10	2	20
14. Industrial Capability for Manufacture	G	10	2	20
15. Plant Safety	G	10	3	30
16. Dependence on Other Systems	G	10	8	80
17. Adaptability to Fuels	F	5	6	30
18. Life	G	10	1	10
19. Flexibility of Siting	F	5	4	20
20. Waste Handling & Disposal	G	10	3	30
21. Plant Construction Time	F	5	2	10
22. Unit Rating	F	5	3	15
23. Byproducts	P	1	1	1
24. Environmental Intrusion	P	1	3	3
25. Availability of Fuels & Additives	G	10	5	50
26. Startup Power Requirements	G	10	1	10
Figure of Merit				669

Table G-16

DIRECT WEIGHTING METHOD
CYCLE F - ADVANCED OPEN CYCLE GAS TURBINE COMBINED - AIR COOLED -
INTEGRATED LOW-BTU GASIFIER, COAL

Evaluation Criteria	Criteria Rating		Criteria Weight	Product
	Good/Fair/ Poor	Numerical		
1. Cost of R&D Required	F	5	1	5
2. R&D Time Required	F	5	17	85
3. Prob. of Development Success	G	10	10	100
4. Plant Capital Cost	F	5	8	40
5. Plant O&M Requirements	F	5	1	5
6. Electrical Performance	G	10	5	50
7. Power Plant Efficiency	F	5	2	10
8. Capability for Load Change	F	5	3	15
9. Part Load Efficiency	G	10	1	10
10. Minimum Unit Load	G	10	1	10
11. Forced Outage Rate	F	5	4	20
12. Planned Outage Rate	G	10	3	30
13. Hardware Materials Availability	G	10	2	20
14. Industrial Capability for Manufacture	G	10	2	20
15. Plant Safety	G	10	3	30
16. Dependence on Other Systems	G	10	8	80
17. Adaptability to Fuels	G	10	6	60
18. Life	G	10	1	10
19. Flexibility of Siting	F	5	4	20
20. Waste Handling & Disposal	G	10	3	30
21. Plant Construction Time	F	5	2	10
22. Unit Rating	F	5	3	15
23. Byproducts	F	5	1	5
24. Environmental Intrusion	G	10	3	30
25. Availability of Fuels & Additives	G	10	5	50
26. Startup Power Requirements	G	10	1	10
Figure of Merit				770

Table G-17
DIRECT WEIGHTING METHOD
CYCLE G – OPEN CYCLE MHD, COAL

Evaluation Criteria	Criteria Rating		Criteria Weight	Product
	Good/Fair/Poor	Numerical		
1. Cost of R&D Required	P	1	1	1
2. R&D Time Required	P	1	17	17
3. Prob. of Development Success	P	1	10	10
4. Plant Capital Cost	F	5	8	40
5. Plant O&M Requirements	F	5	1	5
6. Electrical Performance	G	10	5	50
7. Power Plant Efficiency	G	10	2	20
8. Capability for Load Change	P	1	3	3
9. Part Load Efficiency	F	5	1	5
10. Minimum Unit Load	P	1	1	1
11. Forced Outage Rate	P	1	4	4
12. Planned Outage Rate	F	5	3	15
13. Hardware Materials Availability	G	10	2	20
14. Industrial Capability for Manufacture	F	5	2	10
15. Plant Safety	G	10	3	30
16. Dependence on Other Systems	F	5	8	40
17. Adaptability to Fuels	F	5	6	30
18. Life	G	10	1	10
19. Flexibility of Siting	F	5	4	20
20. Waste Handling & Disposal	G	10	3	30
21. Plant Construction Time	P	1	2	2
22. Unit Rating	P	1	3	3
23. Byproducts	F	5	1	5
24. Environmental Intrusion	G	10	3	30
25. Availability of Fuels & Additives	G	10	5	50
26. Startup Power Requirements	G	10	1	10
Figure of Merit				461

Appendix H

DIRECT WEIGHTING METHOD: UTILITY OBJECTIVES AND IMPACTS OF EVALUATION CRITERIA

In this Appendix definitions are given for the utility objectives, and the logic used in arriving at the impacts of the unit criteria on these objectives is discussed.

These impacts are summarized in Table 7-4 which is repeated here as Table H-1 for convenience. The utility objectives are defined as follows:

A. LOW TRANSMISSION COST

Electric power transmission may be considered to have three fundamental functions:

- To provide security interconnection with other power systems or pools.
- To distribute bulk power to loads within the area served by the power systems.
- To bring power generated by remote generating stations to the center of the power transmission system.

In the last named function, the extent and cost of the required power transmission may be influenced by the characteristics of the particular generation types being considered. If the electrical performance (Criterion 6) of the generation is such as to require local VAR* supply or an unusually stiff connection for stability, then the cost of transmission may be increased. Criterion 19 obviously influences the length of transmission required. Criterion 26 may influence transmission system cost by requiring extra transmission for power supply during starting. Criterion 22 may influence transmission cost if higher capacity transmission is required to preserve system stability in the event of the loss of a larger unit.

B. LOW ADMINISTRATIVE COST

With respect to generating units, administrative costs may be considered to include those clerical, scheduling, and management costs associated with the following characteristics of units. Criterion 5: if an advanced cycle has complex operation and maintenance requirements involving rigid inspection and replacement schedules, this could increase

*Volt-Amperes Reactive

Table H-1

IMPACT FRACTIONS - PARAMETER f

Utility Objectives	A Low Transmission Costs	B Low Administn. Costs	C Low Util. Sys. Production Costs	D Good Financial Position	E Good Public Relations	F Good Government Relations	G Good Util. System Frequency	H Good Util. System Voltage	I Reliable Fuel Supply	J Predictable Fuel Costs	K Predictable Const. Sched. & Costs	L Indep. Of Action	M Flexibility Of Operation	N High Service Reliability	O Minimum Reserve Requirement	Criteria Weighting	
																Total Impact	Normalized Impact Fraction
Evaluation Criteria																	
4. Plant Capital Cost				3.00		0.30					0.25	0.11				3.66	0.12
5. Plant O&M Requirements		0.07											0.07			0.14	0.01
6. Electrical Performance	0.50				0.60	0.30	0.50	1.00				0.11	0.07	0.33		2.40	0.08
7. Power Plant Efficiency							0.50					0.11				1.01	0.03
8. Capability for Load Change			0.22									0.11	0.07	0.33		1.23	0.04
9. Part Load Efficiency			0.22										0.07			0.29	0.01
10. Minimum Load			0.22									0.11	0.07			0.40	0.01
11. Forced Outage Rate		0.07	0.22			0.30	0.50					0.11	0.07	0.33		2.10	0.07
12. Planned Outage Rate		0.07	0.22			0.30						0.11	0.07		0.50	1.60	0.05
13. Hardware Materials Availability		0.07									0.25	0.11				0.43	0.01
14. Industrial Capability of Manufacture		0.07									0.25	0.11				0.43	0.01
15. Plant Safety		0.07			0.60	0.30					0.25	0.11	0.07			1.40	0.05
16. Dependence on Other Systems		0.07					0.50	1.00	1.00	1.00	0.25	0.11	0.07			2.00	0.07
17. Adaptability to Fuels		0.07	0.22			0.30						0.11		0.33		3.10	0.10
18. Life		0.07				0.30										0.37	0.01
19. Flexibility of Siting	0.50	0.07			0.60	0.30					0.25	0.11				1.83	0.06
20. Waste Handling & Disposal		0.07			0.60	0.30						0.11				1.08	0.04
21. Plant Construction Time		0.07									0.25	0.11			0.50	0.93	0.03
22. Unit Rating	0.50		0.22									0.11	0.07		0.50	1.40	0.05
23. By-products		0.07	0.22									0.11	0.07			0.47	0.01
24. Environmental Intrusion					0.60	0.30					0.25	0.11	0.07			1.33	0.04
25. Availability of Fuels & Additives		0.07							1.00	1.00		0.11	0.07	0.33		2.58	0.08
26. Startup Power Requirements	0.50		0.22													0.72	0.02
Utility Objective Weighting	2.00	1.00	2.00	3.00	3.00	3.00	2.00	2.00	2.00	2.00	2.00	2.00	1.00	2.00	2.00	31.00	1.00

administrative costs. Similarly, Criteria 11 and 12 influence the difficulty of scheduling total system generation to meet the load. Criteria 13, 14, and 15 affect the complexity of administrative procedures for assuring that the plant can be built and operated safely.

Criterion 16 implies the need for coordination, hence administrative procedures, with respect to other energy systems such as waste heat recovery in total energy systems. Criterion 17 suggests more involved administrative procedures in making sure that appropriate fuels will be available at all times. Criterion 18 is involved because a short-life plant requires administrative procedures for early replacement.

Criterion 19 implies more extensive administrative procedures in the search for suitable sites. Criterion 20 is a factor in low administration cost because of the scheduling and negotiations involved in this process. Criterion 21 merely means that the management of the construction process extends over a longer period of time, hence increases administrative overhead.

Criterion 23 requires administrative procedures in selling the byproducts. Criterion 25 is involved in low administrative costs on the basis of the staff costs of continuously arranging for fuels and additives that are appropriate to the conversion system.

C. LOW UTILITY SYSTEM PRODUCTION COST

In the economic operation of a utility generating system made up of many diverse types of generating units, there are many factors that influence the total system production costs other than the full-load heat rate, the price of fuel, and the operation and maintenance costs of individual units.

Criterion 8 may be a factor if the generating unit is not the lowest fuel cost per kWh unit on the utility system when it would be desirable to reduce its load for a short period of time in favor of a lower cost unit. Similarly, Criterion 9 will determine the economy involved when the requirements of the system load mean that several generation units have to operate at less than rated output.

Criterion 10 can be an important factor at times of power system minimum load, particularly if the generating unit in question is not suitable for daily shutdown and startup. If the sum of the minimum loads of the generating units that must be operating is a high percentage of the required aggregate generating system output, then the ability to dispatch or distribute the output among the most economical units is compromised. In addition to this negative economic effect there is a real possibility that a system could be in the difficult operating situation of having the sum of the minimum loads of the operating units greater than the

required system output. In this case it would be necessary to find a probably uneconomic sale of the excess energy or risk the shutdown and subsequent startup of an intractable generating unit. Criteria 11 and 12 relate to the situation in which the generating unit in question is one of the most economical units to run, but forced and planned outages deny the system the benefit of its low fuel cost.

Criterion 17 suggests that with varying relationships among the costs of alternate fuels a unit which can always use the lowest cost fuel available will contribute to low total system generating cost.

Criterion 23 is involved merely because of the income from the sale of byproducts. Criterion 26 is a factor because of the added power costs associated with starting units with large startup power requirements. Large unit size (Criterion 22) is a negative factor in system generation cost because it makes it more difficult to closely follow the daily load requirements by starting and stopping units.

D. GOOD FINANCIAL POSITION

"Good Financial Position" refers to the financial health of the utility as reflected in its balance sheet and bond ratings. A number of the unit criteria impact on this objective through the requirement that the company produce a high-quality product at an acceptable cost; however, these are indirect impacts and are accounted for under the other objectives in this section. The only direct impact comes from Criterion 4. In the current climate of capital shortage it seems reasonable that a utility which employs high capital cost generation would be at a disadvantage. Utilities sell stocks and bonds to raise capital. If a private utility were judged by the financial community to be irresponsible in its demand for capital this could result in more difficulty in selling securities; for example, the utility might find that its Moody's or Standard and Poors bond ratings were degraded. Public utilities have not been affected by this sort of pressure in the past because their association with Government organizations benefits their reputation in the investment community. However, state and local governments have recently begun to experience difficulty in maintaining investor confidence, and this could cause the public utilities to be more sensitive to capital requirements.

E. GOOD PUBLIC RELATIONS

This objective concerns the general desirability of the maintenance of good relations with the local public, who are perhaps better described as customers. The evaluation criteria involved here are those that are visible to the public through discussion in the media.

F. GOOD GOVERNMENT RELATIONS

On the assumption that public service commissions and other governmental bodies are generally sensitive to the need for rate increases (hence the cost of generation) Criteria 4 and 18 are relevant. Criteria 11 and 12 relate to continuity of electric service. Government involvement in licensing and enforcement of safety and environmental standards is reflected in the impacts of Criteria 15, 19, and 24. In the future, agencies like the Federal Energy Administration may also regulate utility expansion to achieve optimum fuel use (Criteria 7 and 17) and minimize the undesirable side effects of waste disposal (Criterion 20).

G. GOOD UTILITY SYSTEM FREQUENCY

Good frequency means small frequency and waveform excursions and small cumulative time error, which are important to sensitive industrial processes and the average consumer who wants his kitchen clock to be accurate. Criteria 6 and 11 affect the ability of the power system to maintain frequency during emergencies, while Criterion 8 influences the frequency band. Criterion 16 is included because, to the extent that a generating unit depends on another system for its operation and control, the ability to control total system frequency may be compromised.

H. GOOD UTILITY SYSTEM VOLTAGE

Constant voltage, like constant frequency, is a prime requisite of an acceptable electric power supply. While control of voltage at the consumer's connection point is, under normal conditions, not a function of the generating unit, nevertheless all voltage control devices must depend on the ability of excitation systems in generating units to provide the fundamental voltage control. Hence Criterion 6 is involved, and similarly Criterion 16 to the extent that other systems' voltage requirements may inhibit the ability of the generating unit to perform adequately.

I. RELIABLE FUEL SUPPLY

This objective relates to the fact that utility management may be reluctant to employ types of generating units whose fuel supplies seem uncertain. Criteria 17 and 25 obviously influence this objective.

J. PREDICTABLE FUEL COSTS

Fuel costs and fuel supplies are often linked, as in the case of oil, coal, or nuclear fuel, where the market effects of supply and demand are operative. However, this is not always the case. Technologies such as solar thermal, ocean thermal, and hydropower have unpredictable "fuel"

supplies, but the cost is always the same: zero. For this reason the questions of cost and supply are separated here into two objectives. When fuel cost is non-zero it is usually linked to supply through market forces. Therefore fuel availability (Criterion 25) is important, as is the ability to shift to alternate fuels if the price becomes prohibitive for the design fuel (Criterion 17).

K. PREDICTABLE CONSTRUCTION SCHEDULES AND COSTS

Among the most difficult problems of utilities in recent years have been the delays in construction schedules, which not only increase costs but jeopardize a utility's ability to have sufficient generation installed to carry its peak load reliably. Criterion 4 is included because higher \$/kW is generally correlated with the use of more exotic materials and more complex equipment in an effort to achieve higher efficiency or decreased environmental intrusion; greater complexity implies greater uncertainty in the construction time. Criteria 13, 14, and 16 represent factors that may unpredictably delay a construction schedule.

Criterion 15 has been a factor in the delay of many nuclear units. Similarly, Criteria 19 and 24 have been factors in construction delays by public intervenors. Criterion 21 is included on the basis that the longer the planned construction cycle the greater chance there is that something will go wrong to delay it.

The same evaluation criteria that were judged to influence construction schedule uncertainty will also provide uncertainty as to construction cost, both in themselves and as a result of delays.

L. INDEPENDENCE OF ACTION

This objective relates to the ability of the utility to plan, construct, and operate its generating facilities with minimum interference or control by outside parties. Criterion 4 is indicated because high capital cost increases management's dependence upon the investment community. Criteria 7, 8 and 10 through 12 are operative because they influence the extent to which a power pool or interconnection organization may dictate the operations of the utility or impose cost penalties.

Criteria 13 through 16 and 19 are included because they restrict the freedom of the utility to design and build plants to its own requirements.

Lengthy plant construction periods (Criterion 21) can add uncertainty to system expansion planning. Also, the cost of expansion is increased if the units have poor reliability (Criteria 11 and 12), because the system must be overbuilt to supply the reserve needed to maintain system reliability.

Criteria 17, 23, and 25 imply the existence of economic control by fuel suppliers or byproduct purchasers. Criteria 20 and 24 imply external control by government agencies or the public.

Criterion 22 has been included because it may not be feasible for a utility to finance and construct very large generating units by itself. The unit may require joint ownership with other utilities, which limits independence of action. This has been true in the case of large nuclear units with medium and small sized utilities.

M. FLEXIBILITY OF OPERATION

This objective, similar to the preceding one, relates to the hour-by-hour and day-by-day operation of the total electric utility generating system. The evaluation criteria included under this objective are, in general, those which in their negative aspects tend to inhibit the natural operation of the generating system in a way to promote maximum continuity of service and minimum cost. Criterion 22 is included because very large generating units cause special problems if they are suddenly forced out of service, and because it imposes additional restraints on economic scheduling.

N. HIGH SERVICE RELIABILITY

This objective is similar to a combination of objectives, Good Frequency and Good Voltage, except that it contemplates complete loss of frequency and voltage, constituting an outage. It also is concerned with a longer time frame; the previous two objectives were mainly concerned with the second-by-second quality of frequency and voltage, whereas service reliability relates to a period of months or years. The difference in evaluation criteria is the inclusion in this objective of Criterion 12 (Planned Outage Rate) and the omission of 16 (Dependence on Other Systems).

System reliability is affected by the interaction of the power plants through the transmission and distribution network; this concern is addressed through the impacts of Criteria 6 and 8.

Criteria 17 and 25 are included because a plant limited to a single fuel could be shut down by a transportation or mining strike. Criterion 22 is not included in this objective because it is presumed that the negative aspects of large unit size in daily operation and long-term system reliability would be compensated for by extra spinning reserve.

O. MINIMUM RESERVE REQUIREMENT

This objective is very closely related to the preceding one, High Service Reliability, but is included in recognition that, from a long-range planning standpoint, high service reliability

may be attained in theory with adequate reserves, regardless of unit size or forced and planned outage rates (Criteria 11, 12, and 22). It is desirable, however, to have as little excess capacity as possible, in order to reduce total system capital cost.

Plant Construction Time (Criterion 21) also impacts on this objective, because projections of future peak demand become more uncertain as the projection time span is increased. Thus a longer construction time requires a greater planned reserve to account for the increased uncertainty.