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SENSITIVITY ANALYSIS OF
PROJECT APPRAISAL VARIABLES

VOLUME I: KEY VARIABLES

Prepared for

Division of Fossil Fuel Utilization
Department of Energy
Germantown, MD

AC03-77ET15078

Contract No. ~~EE-77-C-03-1705~~
Task No. DPS-79-052

Prepared by

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July 1979

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SECTION I - INTRODUCTION

The Division of Fossil Fuel Utilization within the U.S. Department of Energy (DOE) uses a project appraisal methodology for annual assessment of its research and development projects. Exercise of the methodology provides input to the budget preparation and planning process. Consequently, it is essential that all appraisal inputs and outputs are as accurate and credible as possible. The purpose of this task is to examine the accuracy and credibility of 1979 appraisal results¹ by conducting a sensitivity analysis of several appraisal inputs. This sensitivity analysis is designed to:

- Examine the sensitivity of the results to adjustments in the values of selected parameters.
- Explain the differences between computed ranks and professional judgment ranks.
- Revise the final results of 1979 project appraisal and provide the first inputs to refinement of the appraisal methodology for future applications.

The variables and parameters analyzed in this task are divided into two classes. The breakdown is as follows:

1. KEY VARIABLES

- Cost of Energy (COE): The cost of final energy product to ultimate user, given in mills/kwh for electricity and in mills/10⁴ Btu for industrial steam.
- Commercialization Date: The year in which a new technology is commercially available. This date does not include lead time required for construction and licensing.
- Maximum Market Fraction: The fraction of a market captured by a technology in the absence of all competition.
- Effects and Impacts Score (Value and Weight): The score is an assessment of environmental impact and social, legal, and institutional effects. To reflect DOE priorities, the score is weighted when incorporated with other appraisal outputs into an overall project rating.

¹Results of FY 1979 Project Appraisal, Santa Fe Corporation, April 1979.

--Data Tolerance Factor (D_T): D_T is a probability of success measure (between 0 and 1) used to gauge the relative confidence in a project's data.

--Planning Horizon (Evaluation Cut-Off Date): The last year in which project benefits are assessed (2000 for the base case).

2. ADDITIONAL VARIABLES

--Market Potential/Rate of Growth: Market potential is the amount of available capacity expansion due to growth, scheduled replacements, and conversions in a sector for any one year.

--Market Score Worksheet Weights: The weights used to obtain a score which is in turn used to allocate a particular market among competing technologies.

--Energy Benefits Weights and Type: The weights are used to reflect DOE priorities on coal use and the near term; the benefit type is one of three: coal utilization, alternative fuels use, efficiency improvement.

This report is the first of a two-volume set. This first volume documents the analysis of "key variables." Volume two documents results of sensitivity analyses of "additional variables."

SECTION II - REVIEW OF 1979 PROJECT APPRAISAL

The Division of Fossil Fuel Utilization's annual project appraisal was held in February and March of 1979. Program proponents (Branch Chiefs of the Fuel Cells, Combustion Systems, Heat Engines, and Cleanup Technology branches) were responsible for the initial project data collection and market penetration analysis. An appraisal panel validated data submissions and discussed several issues concerning the data, the methodology, and initial appraisal results. Acting in conjunction with division management as systems integrators, the Santa Fe Corporation prepared a draft of appraisal results giving project ratings, a summary of project benefits and costs, and both division-wide and branch ranking of projects.¹

The 16 projects appraised in 1979 are grouped by branch below.

FUEL CELLS

- Molten Carbonate
- Phosphoric Acid
- Thermionic Energy Conversion (TEC)

COMBUSTION SYSTEMS

- Atmospheric Fluidized-Bed (AFB) - Industrial Application
- Atmospheric Fluidized-Bed (AFB) - Utility Application
- Coal-Oil Mixtures (COM)
- Pressurized Fluidized-Bed (PFB) - Utility Application

HEAT ENGINES

- Advanced Diesel (DARE)
- Advanced Gas Turbine (RALFE)
- Closed Cycle Gas Turbine (CCGT)
- Open Cycle Gas Turbine (OCGT)
- Organic Rankine Cycle (ORC)
- Stirling Engine

¹Results of FY 1979 Project Appraisal, April 1979.

CLEANUP TECHNOLOGY

- Advanced Flue Gas Cleanup (AFGC)
- Advanced Flue Gas Desulphurization (AFGD)
- Reliable Lime/Limestone (L/L)

The 1979 project appraisal was a successful mechanism for collecting and displaying valuable project information to division budget planners. To ensure even further success, the Division of Fossil Fuel Utilization has decided to examine the following items more closely:

- Project data refinement for possibilities of attaining full consistency and maximum credibility
- The correlation of ranks computed from project data with the judgmental ranks given by program proponents
- An alternative approach to calculation of consumer savings.

Sensitivity analysis can address these concerns and provide a basis for future refinement of the appraisal methodology and implementation procedures.

SECTION III - ANALYSIS AND RESULTS

This section presents the results of sensitivity analysis on key project appraisal variables in two stages. First, a set of tables is presented (see Section A) which provide an overview for each project of: (a) the alternative values considered for the "key variables" and (b) the corresponding results. Second, detailed discussion and evaluation of the information presented in Section A is provided in Sections B through G.

A. PROJECT SCENARIOS

For purposes of this volume a scenario is defined as a particular specification of project appraisal inputs. The base case scenario is the specification of original values: the "no change" case. All other scenarios give specifications which constitute a change in the value of one of the "key variables." Composite scenarios which involve changes in more than one "key variable" are considered in Volume 2. The use of composite scenarios is briefly discussed in Section IV.

Lists of scenarios analyzed for each project are given as Tables 1 to 16. These tables also include the calculated results for the base case and for each scenario which gives a change in a key project appraisal variable. Calculated results for the additional variables are documented in Volume 2. Calculated results consist of three terms: quads supplied¹, consumer savings², and project ratings.³

¹The quads supplied may be due to utilization of coal or alternative fuels or due to efficiency improvement in use of oil or natural gas. A quad is 1 quadrillion (10^{15}) British thermal units.

²Consumer savings are cumulative for the 1981-2000 period.

³Project ratings are a composite measure of a project's merit incorporating quads supplied, consumer savings, R&D costs, the EIS, and the Data Tolerance Factor.

The scenarios in Tables 1-16 are of two types: the first 10 scenarios apply to all 16 division projects. Scenarios 11 through 20 each apply only to selected technologies. All 20 scenarios were chosen by DOE. The changes in "key variables" corresponding to each scenario are:

1. Base case: no change
2. Change EIS weight from 0.5 to 0.25.
3. Change EIS weight from 0.5 to 0.
4. Change EIS value (amount of change various by project).
5. Set all D_T values equal to 1.
6. No "key variable" changes (analysis performed in Volume 2).
7. Set R&D cost equal to 1 for calculation of public savings (PS). That is, compute ratings with normalized consumer savings (numerator of PS).
- 8-10. No "key variable" changes (analysis performed in Volume 2).
11. Extend planning horizon from the year 2000 to 2005.
12. Extend planning horizon from the year 2000 to 2010.
13. Change cost of energy value to ECAS⁴ estimate.
14. Set D_T equal to values derived from ECAS study.
15. Set commercialization date 1 year later than base case.⁵
16. Set commercialization date 3 years later than base case.
- 17,18. Reduce maximum market fraction. (Amount of reduction varies by project).
19. Change D_T to alternative values selected by DOE.
20. No change to "key variables" (analysis performed in Volume 2).

Tables 1 to 16 follow. The branch associated with each project is given in the upper right corner of the table.

⁴ECAS: Energy Conversion Alternatives Study, Summary Report, NASA (prepared for ERDA and NSF), 1977.

⁵There is one exception (AFB-Utility) where this scenario is a change of the commercialization date to 2 years earlier than the base case.

TABLE 1

RELIABLE LIME/LIMESTONE SCENARIOS: CHANGES IN "KEY VARIABLES"

Scenario #	INDIRECT INPUTS					DIRECT INPUTS				OUTPUTS ⁵			REMARKS
	Cost of Energy---COE (mills/kwh)	Commercial Date ² (year)	Maximum Market Fraction-- $F_q(t)$ ³	Size of Markets-- Growth	Market Score Weights	EIS-- Value ⁴ /wt.	Data Tolerance (D _T)	Planning Horizon (cut off date)	Energy Benefits: w-factors and type	Total Quads Supplied	Consumer Savings (Billion \$)	Project Rating (R)	
1	37.3	82	0.9	--6	--6	8/.5	.9	2000	--6	251.6	5.0	1.23	Base Case-enhanced funding ⁶
2	--	--	--	--	--	wt. = .25	--	--	--	251.6	5.0	1.10	EIS wieght = .25
3	--	--	--	--	--	wt. = 0	--	--	--	251.6	5.0	0.94	EIS weight = 0
4	--	--	--	--	--	val. = 2	--	--	--	251.6	5.0	1.17	Revised EIS (Systems Integrators)
5	--	--	--	--	--	--	all D _T = 1	--	--	251.6	5.0	1.37	Comparison without D _T
6	--	--	--	--	--	--	--	--	all w = 1	251.6	5.0	1.41	All energy weights set = 1
7	--	--	--	--	--	--	--	--	--	251.6	5.0	1.20	RD cost set = 1 for Public Savings
8	--	--	--	--	Alternative weights	--	--	--	--	268.7	5.3	1.30	All weights approximately equal
9	--	--	--	0%	--	--	--	--	--	131.2	2.6	0.78	Assume 0% growth
10	--	--	--	3%	--	--	--	--	--	227.8	4.5	1.14	Assume 3% growth
11													
12													
13													
14													
15													
16													
17	--	--	-15%	--	--	--	--	--	--	217.5	4.3	1.10	Eliminate conversions share
18													
19													
20													

¹COE is based on "new plant" economics and is used to compute consumer savings by comparison to conventional technology.

²Given in Tables 1-4 of Results of FY 1979 Project Appraisal, April 1979.

³ $F_q(t)$ calculated in Figure 6 of Market Penetration Handbook, February 1979.

⁴EIS values range on a scale of -20 to +20.

⁵All outputs are given for the enhanced funding level.

⁶Tables (--) denote "no change".

TABLE 2

ADVANCED FLUE GAS DESULPHURIZATION SCENARIOS: CHANGES IN "KEY VARIABLES"

Scenario #	INDIRECT INPUTS					DIRECT INPUTS				OUTPUTS ⁵			REMARKS
	Cost of Energy ¹ -- COE (mills/kwh)	Commercial Date ² (year)	Maximum Market Fraction-- $F_q(t)$ ³	Size of Markets-- Growth	Market Score Weights	EIS-- Value ⁴ /wt.	Data Tolerance (D_T)	Planning Horizon (cut off date)	Energy Benefits: w-factors and type	Total Quads Supplied	Consumer Savings (Billion \$)	Project Rating (R)	
1	42.0	1980-81	1.00	-- ⁶	-- ⁶	8/.5	1.0	2000	-- ⁶	235.5	-105.6	0.29	Base Case-enhanced funding ⁶
2	--	--	--	--	--	wt. = .25	--	--	--	235.5	-105.6	0.24	EIS wieght = .25
3	--	--	--	--	--	wt. = 0	--	--	--	235.5	-105.6	0.08	EIS weight = 0
4	--	--	--	--	--	val. = 2	--	--	--	235.5	-105.6	0.22	Revised EIS (Systems Integrators)
5	--	--	--	--	--	--	all $D_T = 1$	--	--	235.5	-105.6	0.29	Comparison without D_T
6	--	--	--	--	--	--	--	--	all w = 1	235.5	-105.6	0.38	All energy weights set = 1
7	--	--	--	--	--	--	--	--	--	235.5	-105.6	0.42	RD cost set = 1 for Public Savings
8													
9	--	--	--	0%	--	--	--	--	--	110.9	-50.0	0.31	Assume 0% growth
10	--	--	--	3%	--	--	--	--	--	193.6	-87.0	0.30	Assume 3% growth
11	--	--	--	--	--	--	--	2005	--	327.4	-146.8	0.27	Extend horizon to year 2005
12	--	--	--	--	--	--	--	2010	--	419.4	-188.0	0.27	Extend horizon to year 2010
13													
14													
15	--	81	--	--	--	--	--	--	--	212.2	-95.1	0.28	Move Com. Date one year later
16	--	83	--	--	--	--	--	--	--	158.0	-70.7	0.26	Move Com. Date three years later
17													
18													
19													
20													

¹COE is based on "new plant" economics and is used to compute consumer savings by comparison to conventional technology.

²Given in Tables 1-4 of Results of FY 1979 Project Appraisal, April 1979.

³ $F_q(t)$ calculated in Figure 6 of Market Penetration Handbook, February 1979.

⁴EIS values range on a scale of -20 to +20.

⁵All outputs are given for the enhanced funding level.

⁶Dashes (--) denote "no change".

TABLE 3

ADVANCED FLUE GAS CLEANUP SCENARIOS: CHANGES IN "KEY VARIABLES"

Scenario #	INDIRECT INPUTS					DIRECT INPUTS				OUTPUTS ⁵			REMARKS
	Cost of Energy ¹ -- COE (mills/kwh)	Commercial Date ² (year)	Maximum Market Fraction-- $F_q(t)$ ³	Size of Markets-- Growth	Market Score Weights	EIS-- Value ⁴ /wt.	Data Tolerance (D_T)	Planning Horizon (cut off date)	Energy Benefits: w-factors and type	Total Quads Supplied	Consumer Savings (Billion \$)	Project Rating (R)	
1	32.4	86	1.00	-- ⁶	-- ⁶	8/1.5	1.0	2000	-- ⁶	67.4	0.7	0.34	Base Case-enhanced funding ⁶
2	--	--	--	--	--	wt. = .25	--	--	--	67.4	0.7	0.13	EIS weight = .25
3	--	--	--	--	--	wt. = 0	--	--	--	67.4	0.7	0.03	EIS weight = 0
4	--	--	--	--	--	val. = 2	--	--	--	67.4	0.7	0.33	Revised EIS (Systems Integrators)
5	--	--	--	--	--	--	all $D_T = 1$	--	--	67.4	0.7	0.34	Comparison without D_T
6	--	--	--	--	--	--	--	--	all w = 1	67.4	0.7	0.42	All energy weights set = 1
7	--	--	--	--	--	--	--	--	--	67.4	0.7	0.40	RD cost set = 1 for Public Savings
8													
9	--	--	--	0%	--	--	--	--	--	21.5	0.2	0.31	Assume 0% growth
10	--	--	--	3%	--	--	--	--	--	57.4	0.6	0.32	Assume 3% growth
11													
12													
13													
14													
15													
16													
17													
18													
19													
20													

¹COE is based on "new plant" economics and is used to compute consumer savings by comparison to conventional technology.²Given in Tables 1-4 of Results of FY 1979 Project Appraisal, April 1979.³ $F_q(t)$ calculated in Figure 6 of Market Penetration Handbook, February 1979.⁴EIS values range on a scale of -20 to +20.⁵All outputs are given for the enhanced funding level.⁶Dashes (--) denote "no change".

TABLE 4

FUEL CELLS BRANCH

MOLTEN CARBONATE SCENARIOS: CHANGES IN "KEY VARIABLES"

Scenario #	INDIRECT INPUTS					DIRECT INPUTS				OUTPUTS ⁵			REMARKS
	Cost of Energy ¹ -- COE (mills/kwh)	Commercial Date ² (year)	Maximum Market Fraction-- $F_q(t)$ ³	Size of Markets-- Growth	Market Score Weights	EIS-- Value ⁴ /wt.	Data Tolerance (D_T)	Planning Horizon (cut off date)	Energy Benefits: w-factors and type	Total Quads Supplied	Consumer Savings (Billion \$)	Project Rating (R)	
1	32.5	90	0.8	-- ⁶	-- ⁶	10/.5	.8	2000	-- ⁶	76.1	66.0	0.44	Base Case-enhanced funding ⁶
2	--	--	--	--	--	wt. = .25	--	--	--	76.1	66.0	0.28	EIS weight = .25
3	--	--	--	--	--	wt. = 0	--	--	--	76.1	66.0	0.12	EIS weight = 0
4	--	--	--	--	--	val. = 2	--	--	--	76.1	66.0	0.32	Revised EIS (Systems Integrators)
5	--	--	--	--	--	--	all $D_T = 1$	--	--	76.1	66.0	0.55	Comparison without D_T
6	--	--	--	--	--	--	--	--	all w = 1	76.1	66.0	0.45	All energy weights set = 1
7	--	--	--	--	--	--	--	--	--	76.1	66.0	0.51	RD cost set = 1 for Public Savings
8	--	--	--	--	--	--	--	--	--	82.4	71.5	0.45	All weights approximately equal
9	--	--	--	0%	--	--	--	--	--	9.7	8.4	0.34	Assume 0% growth
10	--	--	--	3%	--	--	--	--	--	37.7	32.6	0.38	Assume 3% growth
11	--	--	--	--	--	--	--	2005	--	227.79	197.6	0.69	Extend horizon to year 2005
12	--	--	--	--	--	--	--	2010	--	490.71	425.6	1.11	Extend horizon to year 2010
13	30.2	--	--	--	--	--	--	--	--	76.1	99.0	0.48	COE from ECAS II
14	--	--	--	--	--	--	.75	--	--	76.1	66.0	0.38	D_T derived from ECAS II
15	--	91	--	--	--	--	--	--	--	57.6	49.9	0.41	Move Com. Date 1 year later
16	--	93	--	--	--	--	--	--	--	29.6	25.7	0.37	Move Com Date 3 years later
17	--	--	-25%	--	--	--	--	--	--	73.1	63.4	0.43	Reduce F_q by 25%
18	--	--	-50%	--	--	--	--	--	--	63.2	54.8	0.42	Reduce F_q by 50%
19 E/B	--	--	--	--	--	--	.6/.4	--	--	76.1	66.0	.31/.20	Alternative D_T values
20													

¹COE is based on "new plant" economics and is used to compute consumer savings by comparison to conventional technology.

²Given in Tables 1-4 of Results of FY 1979 Project Appraisal, April 1979.

³ $F_q(t)$ calculated in Figure 6 of Market Penetration Handbook, February 1979.

⁴EIS values range on a scale of -20 to +20.

⁵All outputs are given for the enhanced funding level.

⁶Dashes (--) denote "no change".

TABLE 5

FUEL CELLS BRANCH

PHOSPHORIC ACID SCENARIOS: CHANGES IN "KEY VARIABLES"

Scenario #	INDIRECT INPUTS					DIRECT INPUTS				OUTPUTS ⁵			REMARKS
	Cost of Energy ¹ -- COE (mills/kwh)	Commercial Date ² (year)	Maximum Market Fraction-- $F_q(t)$ ³	Size of Markets-- Growth	Market Score Weights ⁴	EIS-- Value ⁴ /wt.	Data Tolerance (D_T)	Planning Horizon (cut off date)	Energy Benefits: w-factors and type	Total Quads Supplied	Consumer Savings (Billion \$)	Project Rating (R)	
1	37.0	85	0.90	-- ⁶	-- ⁶	12/.5	.9	2000	-- ⁶	13.9	10.0	0.47	Base Case-enhanced funding ⁶
2	--	--	--	--	--	wt. = .25	--	--	--	13.9	10.0	0.26	EIS weight = .25
3	--	--	--	--	--	wt. = 0	--	--	--	13.9	10.0	0.04	EIS weight = 0
4	--	--	--	--	--	val. = 4	--	--	--	13.9	10.0	0.49	Revised EIS (Systems Integrators)
5	--	--	--	--	--	--	all $D_T = 1$	--	--	13.9	10.0	0.53	Comparison without D_T
6	--	--	--	--	--	--	--	--	all w = 1	13.9	10.0	0.50	All energy weights set = 1
7	--	--	--	--	--	--	--	--	--	13.9	10.0	0.59	RD cost set = 1 for Public Savings
8													
9	--	--	--	0%	--	--	--	--	--	4.0	2.9	0.44	Assume 0% growth
10	--	--	--	3%	--	--	--	--	--	9.5	6.8	0.46	Assume 3% growth
11	--	--	--	--	--	--	--	2005	--	27.0	19.4	0.51	Extend horizon to year 2005
12	--	--	--	--	--	--	--	2010	--	44.9	32.9	0.56	Extend horizon to year 2010
13													
14													
15													
16													
17													
18													
19 A/B	--	--	--	--	--	--	.8/.6	--	--	13.9	10.0	.42/.32	Alternative D_T values
20													

¹COE is based on "new plant" economics and is used to compute consumer savings by comparison to conventional technology.

²Given in Tables 1-4 of Results of FY 1979 Project Appraisal, April 1979.

³ $F_q(t)$ calculated in Figure 6 of Market Penetration Handbook, February 1979.

⁴EIS values range on a scale of -20 to +20.

⁵All outputs are given for the enhanced funding level.

⁶Dashes (--) denote "no change".

TABLE 6

TEC (PLANT WITH THERMIONIC TOPPING CYCLE) SCENARIOS: CHANGES IN "KEY VARIABLES"

FUEL CELLS BRANCH

Scenario #	INDIRECT INPUTS					DIRECT INPUTS				OUTPUTS ⁵			REMARKS
	Cost of Energy ¹ -- COE (mills/kwh)	Commercial Date ² (year)	Maximum Market Fraction-- $F_Q(t)$ ³	Size of Markets-- Growth	Market Score Weights	EIS-- Value ⁴ /wt.	Data Tolerance (D_T)	Planning Horizon (cut off date)	Energy Benefits: w-factors and type	Total Quads Supplied	Consumer Savings (Billion \$)	Project Rating (R)	
1	52.4	92	0.85	-- ⁶	-- ⁶	5/.5	.8	2000	-- ⁶	53.9	-356.9	-0.60	Base Case-enhanced funding ⁶
2	--	--	--	--	--	wt. = .25	--	--	--	53.9	-356.9	-0.79	EIS weight = .25
3	--	--	--	--	--	wt. = 0	--	--	--	53.9	-356.9	-0.89	EIS weight = 0
4	--	--	--	--	--	val. = 1	--	--	--	53.9	-356.9	-0.74	Revised EIS (Systems Integrators)
5	--	--	--	--	--	--	all $D_T = 1$	--	--	53.9	-356.9	-0.50	Comparison without D_T
6	--	--	--	--	--	--	--	--	all w = 1	53.9	-356.9	-0.36	All energy weights set = 1
7	--	--	--	--	--	--	--	--	--	53.9	-356.9	-0.89	RD cost set = 1 for Public Savings
8													
9	--	--	--	0%	--	--	--	--	--	10.1	-66.9	-0.08	Assume 0% growth
10	--	--	--	3%	--	--	--	--	--	27.4	-181.3	-0.11	Assume 3% growth
11													
12													
13													
14													
15	--	93	--	--	--	--	--	--	--	44.0	-291.7	-0.45	Move Com. Date 1 year later
16	--	95	--	--	--	--	--	--	--	28.3	-187.5	-0.28	Move Com. Date 3 years later
17													
18													
19 A/B	--	--	--	--	--	--	.6/.4	--	--	53.9	-356.9	-.70/-.80	Alternative D_T values
20													

¹COE is based on "new plant" economics and is used to compute consumer savings by comparison to conventional technology.

²Given in Tables 1-4 of Results of FY 1979 Project Appraisal, April 1979.

³ $F_Q(t)$ calculated in Figure 6 of Market Penetration Handbook, February 1979.

⁴EIS values range on a scale of -20 to +20.

⁵All outputs are given for the enhanced funding level.

⁶Dashes (--) denote "no change".

TABLE 7

AFB - INDUSTRIAL SCENARIOS: CHANGES IN "KEY VARIABLES"

COMBUSTION SYSTEMS BRANCH

Scenario #	INDIRECT INPUTS					DIRECT INPUTS				OUTPUTS ⁵			REMARKS
	Cost of Energy, ¹ -- COE (mills, 10 ⁴ Btu) ²	Commercial Date ² (year)	Maximum Market Fraction-- F _q (t) ³	Size of Markets-- Growth	Market Score Weights	EIS-- Value ⁴ /wt.	Data Tolerance (D _T)	Planning Horizon (cut off date)	Energy Benefits: w-factors and type	Total Quads Supplied	Consumer Savings (Billion \$)	Project Rating (R)	
1	40.6	79	1.00	--6	--6	11/.5	1.0	2000	--6	16.7	0.00	0.54	Base Case-enhanced funding ⁶
2	--	--	--	--	--	wt. = .25	--	--	--	16.7	0.00	0.32	EIS weight = .25
3	--	--	--	--	--	wt. = 0	--	--	--	16.7	0.00	0.10	EIS weight = 0
4	--	--	--	--	--	val. = 1	--	--	--	16.7	0.00	0.23	Revised EIS (Systems Integrators)
5	--	--	--	--	--	--	all D _T = 1	--	--	16.7	0.00	0.54	Comparison without D _T
6	--	--	--	--	--	--	--	--	all w = 1	16.7	0.00	0.56	All energy weights set = 1
7	--	--	--	--	--	--	--	--	--	16.7	0.00	0.54	RD cost set = 1 for Public Savings
8													
9	--	--	--	0%	--	--	--	--	--	8.0	0.00	0.54	Assume 0% growth
10	--	--	--	3%	--	--	--	--	--	12.1	0.00	0.53	Assume 3% growth
11													
12													
13													
14													
15													
16													
17													
18													
19 A/B	--	--	--	--	--	--	.8/.6	--	--	16.7	0.00	.43/.32	Alternative D _T values
20													

¹COE is based on "new plant" economics and is used to compute consumer savings by comparison to conventional technology.

²Given in Tables 1-4 of Results of FY 1979 Project Appraisal, April 1979.

³F_q(t) calculated in Figure 6 of Market Penetration Handbook, February 1979.

⁴EIS values range on a scale of -20 to +20.

⁵All outputs are given for the enhanced funding level.

⁶Dashes (--) denote "no change".

TABLE 8

AFB - UTILITY SCENARIOS: CHANGES IN "KEY VARIABLES"

COMBUSTION SYSTEMS BRANCH

Scenario #	INDIRECT INPUTS					DIRECT INPUTS				OUTPUTS ⁵			REMARKS
	Cost of Energy ¹ -- COE (mills/kwh)	Commercial Date ² (year)	Maximum Market Fraction-- $F_q(t)$ ³	Size of Markets-- Growth	Market Score Weights	EIS ⁴ -- Value /wt.	Data Tolerance (D _T)	Planning Horizon (cut off date)	Energy Benefits: w-factors and type	Total Quads Supplied	Consumer Savings (Billion \$)	Project Rating (R)	
1	34.0	87	0.98	-- ⁶	-- ⁶	11/.5	.99	2000	-- ⁶	217.8	80.0	0.62	Base Case-enhanced funding ⁶
2	--	--	--	--	--	wt. = .25	--	--	--	217.8	80.0	0.41	EIS wieght = .25
3	--	--	--	--	--	wt. = 0	--	--	--	217.8	80.0	0.19	EIS weight = 0
4	--	--	--	--	--	val. = 1	--	--	--	217.8	80.0	0.31	Revised EIS (Systems Integrators)
5	--	--	--	--	--	--	all D _T = 1	--	--	217.8	80.0	0.64	Comparison without D _T
6	--	--	--	--	--	--	--	--	all w = 1	217.8	80.0	0.65	All energy weights set = 1
7	--	--	--	--	--	--	--	--	--	217.8	80.0	0.75	RD cost set = 1 for Public Savings
8	--	--	--	--	alternative weights	--	--	--	--	215.7	79.2	0.62	All weights approximately equal
9	--	--	--	0%	--	--	--	--	--	93.0	34.2	0.51	Assume 0% growth
10	--	--	--	3%	--	--	--	--	--	191.2	70.2	0.60	Assume 3% growth
11													
12													
13	32.5	--	--	--	--	--	--	--	--	217.8	114.3	0.66	COE from ECAS II
14	--	--	--	--	--	--	.9	--	--	217.8	80.0	0.58	D _T derived from ECAS II
15	--	85	--	--	--	--	--	--	--	269.0	98.8	0.67	Move Com. date 2 years earlier
16													
17	--	--	-15%	--	--	--	--	--	--	211.6	77.7	0.62	Eliminate conversions share
18													
19 A/B	--	--	--	--	--	--	.8/.6	--	--	217.8	80.0	.51/.38	Alternative D _T values
20													

¹COE is based on "new plant" economics and is used to compute consumer savings by comparison to conventional technology.

²Given in Tables 1-4 of Results of FY 1979 Project Appraisal, April 1979.

³ $F_q(t)$ calculated in Figure 6 of Market Penetration Handbook, February 1979.

⁴EIS values range on a scale of -20 to +20.

⁵All outputs are given for the enhanced funding level.

⁶Dashes (--) denote "no change".

TABLE 9
COAL-OIL MIXTURES SCENARIOS: CHANGES IN "KEY VARIABLES"

Scenario #	INDIRECT INPUTS					DIRECT INPUTS				OUTPUTS ⁵			REMARKS ¹
	Cost of Energy ¹ -- COE (mills/kwh)	Commercial Date ² (year)	Maximum Market Fraction-- $F_q(t)$ ³	Size of Markets-- Growth	Market Score Weights	EIS-- Value /wt. ⁴	Data Tolerance (D_T)	Planning Horizon (cut off date)	Energy Benefits: w-factors and type	Total Quads Supplied	Consumer Savings (Billion \$)	Project Rating (R)	
1	38.6	81	1.0	-- 6	-- 6	9/.5	1.0	2000	-- 6	19.3	-15.7	0.24	Base Case-enhanced funding ⁶
2	--	--	--	--	--	wt. = .25	--	--	--	19.3	-15.7	0.06	EIS wieght = .25
3	--	--	--	--	--	wt. = 0	--	--	--	19.3	-15.7	-0.12	EIS weight = 0
4	--	--	--	--	--	val. = 1	--	--	--	19.3	-15.7	0.01	Revised EIS (Systems Integrators)
5	--	--	--	--	--	--	all $D_T = 1$	--	--	19.3	-15.7	0.24	Comparison without D_T
6	--	--	--	--	--	--	--	--	all w = 1	19.3	-15.7	0.26	All energy weights set = 1
7	--	--	--	--	--	--	--	--	--	19.3	-15.7	0.46	RD cost set = 1 for Public Savings
8													
9	--	--	--	0%	--	--	--	--	--	19.3	-15.7	0.24	Assume 0% growth
10	--	--	--	3%	--	--	--	--	--	19.3	-15.7	0.24	Assume 3% growth
11													
12													
13													
14													
15	--		--	--	--	--	--	--	--	18.0	-14.7	0.25	Move Com. Date 1 year later
16	--		--	--	--	--	--	--	--	9.8	-8.1	0.30	Move Com. Date 2 years later
17	--		-25%	--	--	--	--	--	--	18.5	-15.0	0.25	Reduce F_q by 25%
18	--		-50%	--	--	--	--	--	--	12.5	-10.2	0.28	Reduces F_q by 50%
19													
20													

¹COE is based on "new plant" economics and is used to compute consumer savings by comparison to conventional technology.

²Given in Tables 1-4 of Results of FY 1979 Project Appraisal, April 1979.

³ $F_q(t)$ calculated in Figure 6 of Market Penetration Handbook, February 1979.

⁴EIS values range on a scale of -20 to +20.

⁵All outputs are given for the enhanced funding level.

⁶Dashes (--) denote "no change".

COMBUSTION SYSTEMS BRANCH

TABLE 10
PFB - UTILITY SCENARIOS: CHANGES IN "KEY VARIABLES"

Scenario #	INDIRECT INPUTS					DIRECT INPUTS				OUTPUTS ⁵			REMARKS
	Cost of Energy ¹ -- COE (mills/kwh)	Commercial Date ² (year)	Maximum Market Fraction-- $F_q(t)$ ³	Size of Markets-- Growth	Market Score Weights	EIS-- Value δ wt.	Data Tolerance (D_T)	Planning Horizon (cut off date)	Energy Benefits: w-factors and type	Total Quads Supplied	Consumer Savings (Billion \$)	Project Rating (R)	
1	31.7	88	0.90	-- 6	-- 6	12.5/.5	.9	2000	-- 6	155.9	103.8	0.76	Base Case-enhanced funding ⁶
2	--	--	--	--	--	wt. = .25	--	--	--	155.9	103.8	0.54	EIS weight = .25
3	--	--	--	--	--	wt. = 0	--	--	--	155.9	103.8	0.31	EIS weight = 0
4	--	--	--	--	--	val. = 2	--	--	--	155.9	103.8	0.53	Revised EIS (Systems Integrators)
5	--	--	--	--	--	--	all $D_T = 1$	--	--	155.9	103.8	0.84	Comparison without D_T
6	--	--	--	--	--	--	--	--	all w = 1	155.9	103.8	0.79	All energy weights set = 1
7	--	--	--	--	--	--	--	--	--	155.9	103.8	0.83	RD cost set = 1 for Public Savings
8	--	--	--	--	Alternative Weights	--	--	--	--	157.6	105.0	0.76	All weights approximately equal
9	--	--	--	0%	--	--	--	--	--	42.7	28.5	0.53	Assume 0% growth
10	--	--	--	3%	--	--	--	--	--	139.7	93.1	0.65	Assume 3% growth
11	--	--	--	--	--	--	--	2005	--	341.7	277.5	1.13	Extend horizon to year 2005
12	--	--	--	--	--	--	--	2010	--	623.5	415.2	1.87	Extend horizon to year 2010
13	34.5	--	--	--	--	--	--	--	--	155.9	53.7	0.67	COE from ECAS II
14	--	--	--	--	--	--	.92	--	--	155.9	103.8	0.77	D_T derived from ECAS II
15	--	89	--	--	--	--	--	--	--	122.8	81.8	0.69	Move Com. Date 1 year later
16	--	91	--	--	--	--	--	--	--	77.0	51.3	0.60	Move Com. Date 3 years later
17	--	--	0.35	--	--	--	--	--	--	68.7	45.8	0.58	Growth market only
18	--	--	0.50	--	--	--	--	--	--	96.4	64.2	0.64	Reduce F_q to 0.50
19													
20													

¹COE is based on "new plant" economics and is used to compute consumer savings by comparison to conventional technology.

²Given in Tables 1-4 of Results of FY 1979 Project Appraisal, April 1979.

³ $F_q(t)$ calculated in Figure 6 of Market Penetration Handbook, February 1979.

⁴EIS values range on a scale of -20 to +20.

⁵All outputs are given for the enhanced funding level.

⁶Dashes (--) denote "no change".

TABLE 11

ADVANCED DIESEL (DARE) SCENARIOS: CHANGES IN "KEY VARIABLES"

Scenario #	INDIRECT INPUTS					DIRECT INPUTS				OUTPUTS ⁵			REMARKS
	Cost of Energy ¹ -- COE (mills/kwh)	Commercial Date ² (year)	Maximum Market Fraction-- $F_q(t)$ ³	Size of Markets-- Growth	Market Score Weights	EIS-- Value ⁴ , wt.	Data Tolerance (D_T)	Planning Horizon (cut off date)	Energy Benefits: w-factors and type	Total Quads Supplied	Consumer Savings (Billion \$)	Project Rating (R)	
1	Util = 40.5	85	0.85	-- ⁶	-- ⁶	3.3/.5	.85	2000	-- ⁶	7.2	8.5	0.40	Base Case-enhanced funding ⁶
2	Ind = 37.8	--	--	--	--	wt. = .25	--	--	--	7.2	8.5	0.34	EIS weight = .25
3	RES = 39.2	--	--	--	--	wt. = 0	--	--	--	7.2	8.5	0.28	EIS weight = 0
4	--	--	--	--	--	val. = 0	--	--	--	7.2	8.5	0.28	Revised EIS (Systems Integrators)
5	--	--	--	--	--	--	all $D_T = 1$	--	--	7.2	8.5	0.47	Comparison without D_T
6	--	--	--	--	--	--	--	--	all w = 1	7.2	8.5	0.44	All energy weights set = 1
7	--	--	--	--	--	--	--	--	--	7.2	8.5	0.19	RD cost set = 1 for Public Savings
8													
9	--	--	--	0%	--	--	--	--	--	6.1	7.1	0.35	Assume 0% growth
10	--	--	--	3%	--	--	--	--	--	6.4	7.5	0.36	Assume 3% growth
11													
12													
13													
14													
15	--	86	--	--	--	--	--	--	--	6.1	7.4	0.36	Move Com. Date 1 year later
16	--	88	--	--	--	--	--	--	--	4.4	5.3	0.29	Move Com. Date 3 years later
17	--	--	-100%R	--	--	--	--	--	--	4.0	-1.0	0.13	Eliminate Res/Com. market
18	--	--	-50%I	--	--	--	--	--	--	7.1	8.6	0.40	Reduce Industrial Share by 50%
19 A/B	--	--	--	--	--	--	.8/.6	--	--	7.2	8.5	.38/.28	Alternative D_T values
20	--	--	--	--	--	--	--	--	EI	4.8	8.5	0.35	All benefits Efficiency Improvement

¹ COE is based on "new plant" economics and is used to compute consumer savings by comparison to conventional technology.

² Given in Tables 1-4 of Results of FY 1979 Project Appraisal, April 1979.

³ $F_q(t)$ calculated in Figure 6 of Market Penetration Handbook, February 1979.

⁴ EIS values range on a scale of -20 to +20.

⁵ All outputs are given for the enhanced funding level.

⁶ Dashes (--) denote "no change".

HEAT ENGINES BRANCH

TABLE 12
ADVANCED GAS TURBINE (RALFE) SCENARIOS: CHANGES IN "KEY VARIABLES"

Scenario #	INDIRECT INPUTS					DIRECT INPUTS				OUTPUTS ⁵			REMARKS
	Cost of Energy ¹ -- COE (mills/kwh)	Commercial Date ² (year)	Maximum Market Fraction-- $F_{q(t)}$ ³	Size of Markets-- Growth	Market Score Weights	EIS-- Value ⁴ /wt.	Data Tolerance (D_T)	Planning Horizon (cut off date)	Energy Benefits: w-factors and type	Total Quads Supplied	Consumer Savings (Billion \$)	Project Rating (R)	
1	39.4	87	0.85	-- ⁶	-- ⁶	2.9/.5	.85	2000	-- ⁶	24.6	-26.4	-0.07	Base Case-enhanced funding ⁶
2	--	--	--	--	--	wt. = .25	--	--	--	24.6	-26.4	-0.15	EIS weight = .25
3	--	--	--	--	--	wt. = 0	--	--	--	24.6	-26.4	-0.20	EIS weight = 0
4	--	--	--	--	--	val. = -1	--	--	--	24.6	-26.4	-0.34	Revised EIS (Systems Integrators)
5	--	--	--	--	--	--	all $D_T = 1$	--	--	24.6	-26.4	-0.06	Comparison without D_T
6	--	--	--	--	--	--	--	--	all w = 1	24.6	-26.4	-0.03	All energy weights set = 1
7	--	--	--	--	--	--	--	--	--	24.6	-26.4	0.11	RD cost set = 1 for Public Savings
8													
9	--	--	--	0%	--	--	--	--	--	9.1	-9.8	0.04	Assume 0% growth
10	--	--	--	3%	--	--	--	--	--	21.8	-23.3	-0.04	Assume 3% growth
11													
12													
13	32.6	--	--	--	--	--	--	--	--	24.6	62.2	0.73	COE from ECAS II
14	--	--	--	--	--	--	.7	--	--	24.6	-26.4	-0.08	D_T derived from ECAS II
15	--	88	--	--	--	--	--	--	--	20.1	-21.6	-0.02	Move Com. Date 1 year later
16	--	90	--	--	--	--	--	--	--	13.0	-13.9	0.02	Move Com. Date 3 years later
17													
18													
19 A/B	--	--	--	--	--	--	.8/.6	--	--	24.6	-26.4	-.07/.08	Alternative D_T values
20	--	--	--	--	--	--	--	--	EI	14.3	-26.4	-0.13	All benefits: <u>E</u> fficiency <u>I</u> mportant

¹COE is based on "new plant" economics and is used to compute consumer savings by comparison to conventional technology.

²Given in Tables 1-4 of Results of FY 1979 Project Appraisal, April 1979.

³ $F_q(t)$ calculated in Figure 6 of Market Penetration Handbook, February 1979.

⁴EIS values range on a scale of -20 to +20.

⁵All outputs are given for the enhanced funding level.

⁶Dashes (--) denote "no change".

HEAT ENGINES BRANCH

TABLE 13
CLOSED CYCLE GAS TURBINE SCENARIOS: CHANGES IN "KEY VARIABLES"

Scenario #	INDIRECT INPUTS					DIRECT INPUTS				OUTPUTS ⁵			REMARKS
	Cost of Energy ¹ -- COE (mills/kwh)	Commercial Date ² (year)	Maximum Market Fraction-- $F_q(t)$ ³	Size of Markets-- Growth	Market Score Weights	EIS-- Value /wt.	Data Tolerance (D_T)	Planning Horizon (cut off date)	Energy Benefits: w-factors and type	Total Quads Supplied	Consumer Savings (Billion \$)	Project Rating (R)	
1	19.5	90	0.80	-- 6	-- 6	1/.5	.8	2000	--6	19.7	-9.3	0.03	Base Case-enhanced funding ⁶
2	--	--	--	--	--	wt. = .25	--	--	--	19.7	-9.3	0.02	EIS wieght = .25
3	--	--	--	--	--	wt. = 0	--	--	--	19.7	-9.3	0	EIS weight = 0
4	--	--	--	--	--	val. = -2	--	--	--	19.7	-9.3	0.03	Revised EIS (Systems Integrators)
5	--	--	--	--	--	--	all $D_T = 1$	--	--	19.7	-9.3	0.04	Comparison without D_T
6	--	--	--	--	--	--	--	--	all w = 1	19.7	-9.3	0.04	All energy weights set = 1
7	--	--	--	--	--	--	--	--	--	19.7	-9.3	0.05	RD cost set = 1 for Public Savings
8													
9	--	--	--	0%	--	--	--	--	--	8.2	-2.2	0.04	Assume 0% growth
10	--	--	--	3%	--	--	--	--	--	17.3	-7.2	0.03	Assume 3% growth
11													
12													
13													
14													
15	--	91	--	--	--	--	--	--	--	16.2	-6.6	0.03	Move Com. Date 1 year later
16	--	93	--	--	--	--	--	--	--	10.8	-4.1	0.03	Move Com. Date 3 years later
17													
18													
19													
20													

¹COE is based on "new plant" economics and is used to compute consumer savings by comparison to conventional technology.

²Given in Tables 1-4 of Results of FY 1979 Project Appraisal, April 1979.

³ $F_q(t)$ calculated in Figure 6 of Market Penetration Handbook, February 1979.

⁴EIS values range on a scale of -20 to +20.

⁵All outputs are given for the enhanced funding level.

⁶Dashes (--) denote "no change".

HEAT ENGINES BRANCH

TABLE 14
OPEN CYCLE GAS TURBINE SCENARIOS: CHANGES IN "KEY VARIABLES"

Scenario #	INDIRECT INPUTS					DIRECT INPUTS				OUTPUTS ⁵			REMARKS
	Cost of Energy ¹ — COE (mills/kwh)	Commercial Date ² (year)	Maximum Market Fraction-- $F_T(t)$ ³	Size of Markets-- Growth	Market Score Weights	EIS-- Value ⁴ /wt.	Data Tolerance (D_T)	Planning Horizon (cut off date)	Energy Benefits: w-factors and type	Total Quads Supplied	Consumer Savings (Billion \$)	Project Rating (R)	
1	40.6	84	0.90	-- 6	-- 6	6/.5	.9	2000	--	5.9	-25.7	0.17	Base Case-enhanced funding ⁶
2	--	--	--	--	--	wt. = .25	--	--	--	5.9	-25.7	0.06	EIS weight = .25
3	--	--	--	--	--	wt. = 0	--	--	--	5.9	-25.7	0.06	EIS weight = 0
4	--	--	--	--	--	val. = -1	--	--	--	5.9	-25.7	0.19	Revised EIS (Systems Integrators)
5	--	--	--	--	--	--	all $D_T = 1$	--	--	5.9	-25.7	0.19	Comparison without D_T
6	--	--	--	--	--	--	--	--	all w = 1	5.9	-25.7	0.18	All energy weights set = 1
7	--	--	--	--	--	--	--	--	--	5.9	-25.7	0.37	RD cost set = 1 for Public Savings
8	--	--	--	--	Alternative Weights	--	--	--	--	5.0	-22.1	0.18	All weights approximately equal
9	--	--	--	0%	--	--	--	--	--	.3	-1.2	0.21	Assume 0% growth
10	--	--	--	3%	--	--	--	--	--	1.0	-4.3	0.21	Assume 3% growth
11	--	--	--	--	--	--	--	2005	--	15.4	-67.11	0.12	Extend horizon to year 2005
12	--	--	--	--	--	--	--	2010	--	31.2	-135.7	0	Extend horizon to year 2010
13	36.1	--	--	--	--	--	--	--	--	5.9	114.8	0.21	COE from ECAS II
14	--	--	--	--	--	--	.85	--	--	5.9	-25.7	0.16	D_T derived from ECAS II
15	--	85	--	--	--	--	--	--	--	5.0	-22.0	0.16	Move Com. Date 1 year later
16	--	87	--	--	--	--	--	--	--	3.4	-14.8	0.19	Move Com. Date 3 years later
17													
18													
19 A/B	--	--	--	--	--	--	.8/.6	--	--	5.9	-25.7	.15/.11	Alternative D_T values
20													

¹COE is based on "new plant" economics and is used to compute consumer savings by comparison to conventional technology.

²Given in Tables 1-4 of Results of FY 1979 Project Appraisal, April 1979.

³ $F_T(t)$ calculated in Figure 6 of Market Penetration Handbook, February 1979.

⁴EIS values range on a scale of -20 to +20.

⁵All outputs are given for the enhanced funding level.

⁶Dashes (--) denote "no change".

HEAT ENGINES BRANCH

TABLE 15
ORGANIC RANKINE CYCLE (BOTTOM CYCLE) SCENARIOS: CHANGES IN "KEY VARIABLES"

Scenario #	INDIRECT INPUTS					DIRECT INPUTS				OUTPUTS ⁵			REMARKS
	Cost of Energy ¹ -- COE (mills/kwh)	Commercial Date ² (year)	Maximum Market Fraction-- $F_q(t)$ ³	Size of Markets-- Growth	Market Score Weights	EIS-- Value ⁴ /wt.	Data Tolerance (D_T)	Planning Horizon (cut off date)	Energy Benefits: w-factors and type	Total Quads Supplied	Consumer Savings (Billion \$)	Project Rating (R)	
1	Util: 35.6 Ind: 36.6	32	0.75	-- ⁶	-- ⁶	2/.5	.75	2000	--	0.8	7.3	0.26	Base Case-enhanced funding ⁶
2	--	--	--	--	--	wt. = .25	--	--	--	0.8	7.3	0.24	EIS weight = .25
3	--	--	--	--	--	wt. = 0	--	--	--	0.8	7.3	0.21	EIS weight = 0
4	--	--	--	--	--	val. = 0	--	--	--	0.8	7.3	0.21	Revised EIS (Systems Integrators)
5	--	--	--	--	--	--	all $D_T = 1$	--	--	0.8	7.3	0.35	Comparison without D_T
6	--	--	--	--	--	--	--	--	all w = 1	0.8	7.3	0.27	All energy weights set = 1
7	--	--	--	--	--	--	--	--	--	0.8	7.3	0.8	RD cost set = 1 for Public Savings
8													
9	--	--	--	0%	--	--	--	--	--	0.8	7.3	0.26	Assume 0% growth
10	--	--	--	3%	--	--	--	--	--	0.8	7.3	0.26	Assume 3% growth
11													
12													
13													
14													
15	--	83	--	--	--	--	--	--	--	0.7	7.0	0.26	Move Com. Date 1 year later
16	--	85	--	--	--	--	--	--	--	0.4	3.8	0.17	Move Com. Date 3 years later
17													
18													
19 A/B	--	--	--	--	--	--	.6/.4	--	--	0.8	7.3	.21/.14	Alternative D_T values
20													

¹ COE is based on "new plant" economics and is used to compute consumer savings by comparison to conventional technology.
² Given in Tables 1-4 of Results of FY 1979 Project Appraisal, April 1979.
³ $F_q(t)$ calculated in Figure 6 of Market Penetration Handbook, February 1979.

⁴ EIS values range on a scale of -20 to +20.
⁵ All outputs are given for the enhanced funding level.
⁶ Dashes (--) denote "no change".

HEAT ENGINES BRANCH

TABLE 16
STIRLING ENGINE SCENARIOS: CHANGES IN "KEY VARIABLES"

Scenario #	INDIRECT INPUTS					DIRECT INPUTS				OUTPUTS ⁵			REMARKS
	Cost of Energy ¹ -- COE (mills/kwh)	Commercial Date ² (year)	Maximum Market Fraction-- $F_Q(t)$ ³	Size of Markets-- Growth	Market Score Weights	EIS-- Value ⁴ /wt.	Data Tolerance (D _T)	Planning Horizon (cut off date)	Energy Benefits: w-factors and type	Total Quads Supplied	Consumer Savings (Billion \$)	Project Rating (R)	
1	Util = 44.8	90	0.85	-- ⁶	-- ⁶	5.7/.5	.8	2000	-- ⁶	3.3	10.9	0.34	Base Case-enhanced funding ⁶
2	Ind = 44.7	--	--	--	--	wt. = .25	--	--	--	3.3	10.9	0.25	EIS weight = .25
3	Res = 34.8	--	--	--	--	wt. = 0	--	--	--	3.3	10.9	0.16	EIS weight = 0
4	--	--	--	--	--	val. = 1	--	--	--	3.3	10.9	0.28	Revised EIS (Systems Integrators)
5	--	--	--	--	--	--	all D _T = 1	--	--	3.3	10.9	0.43	Comparison without D _T
6	--	--	--	--	--	--	--	--	all w = 1	3.3	10.9	0.35	All energy weights set = 1
7	--	--	--	--	--	--	--	--	--	3.3	10.9	0.21	RD cost set = 1 for Public Savings
8	--	--	--	--	--	--	--	--	--	--	--	--	--
9	--	--	--	0%	--	--	--	--	--	2.0	6.6	0.28	Assume 0% growth
10	--	--	--	3%	--	--	--	--	--	2.9	9.6	0.32	Assume 3% growth
11	--	--	--	--	--	--	--	2005	--	7.1	11.4	0.37	Extend horizon to year 2005
12	--	--	--	--	--	--	--	2010	--	12.7	10.1	0.39	Extend horizon to year 2010
13	--	--	--	--	--	--	--	--	--	--	--	--	--
14	--	--	--	--	--	--	--	--	--	--	--	--	--
15	--	91	--	--	--	--	--	--	--	2.6	8.9	0.31	Move Com. date 1 year later
16	--	93	--	--	--	--	--	--	--	1.6	5.4	0.26	Move Com. date 3 years later
17	--	--	--	--	--	--	--	--	--	--	--	--	--
18	--	--	--	--	--	--	--	--	--	--	--	--	--
19 A/B	--	--	--	--	--	--	.6/.4	--	--	3.3	10.9	.26/.17	Alternate D _T values
20	--	--	--	--	--	--	--	--	EI	3.2	10.9	0.26	All benefits: Efficiency Improvement

¹ COE is based on "new plant" economics and is used to compute consumer savings by comparison to conventional technology.

² Given in Tables 1-4 of Results of FY 1979 Project Appraisal, April 1979.

³ $F_Q(t)$ calculated in Figure 6 of Market Penetration Handbook, February 1979.

⁴ EIS values range on a scale of -20 to +20.

⁵ All outputs are given for the enhanced funding level.

⁶ Dashes (--) denote "no change".

B. COST OF ENERGY (COE)

Cost of Energy (COE) is used to calculate estimates of consumer savings for each project. To find consumer savings, the projected COE is compared to the conventional technology COE for the appropriate market. The difference between these values is called cost savings (CS):¹

$$CS = COE_{\text{Conventional}} - COE_{\text{New Technology}} \quad (1.0)$$

Cost savings is then used to compute the public savings (PS) benefit/cost ratio as follows:

$$PS = \frac{\sum_{t=1981}^{2000} [CS \times CUI(t)]}{\$RD} \quad (1.1)$$

where:

CS = cost savings in \$/MW

CUI(t) = cumulative units installed through year t

\$RD = R&D cost required to complete project (new technology)

The numerator of PS is consumer savings which is given for division projects in Tables 1 through 16. The COE values for division projects and conventional technologies are given in Table 17. Table 18 lists the cost savings values. All values are expressed in 1978 dollars.

¹This approach differs from that used in Results of FY 1979 Project Appraisal, Santa Fe Corporation, April 1979. In the former approach cost savings was calculated as the difference between conventional total operating cost and total operating cost of the new technology.

The conventional technologies used in this cost comparison meet the following requirements: (a) they are all presently available and commonly used, (b) they use the same fuels as the new technologies (division projects they are compared to (e.g., coal-using projects are compared to coal technologies), and (c) they meet the present environmental regulations established by federal legislation. The conventional technologies for each market are:

- Utilities and Industrial Cogeneration: The conventional technology for nearly all comparisons is the pulverized coal plant with scrubber which has a capital cost of \$661,000 per megawatt (MW) capacity--in 1978 dollars. This technology applies to comparison for both electric utility applications and the industrial cogeneration of electricity application. Many division projects apply to both of these two areas. However, the efficiency rate (which determines fuel costs) and operations and maintenance costs for this conventional technology vary by application (i.e., baseload utility, non-baseload utility, industrial cogeneration). These same points hold true for efficiency improvement projects in which the conventional technology is an oil- or gas-fired plant.
- Industrial Steam Power: The conventional technology used for comparison to the AFB-Industrial project is a stoker/pulverized coal (PC) burner with a size of 400,000 pounds pressure per hour. (All other industrial applications of division projects fall under the cogeneration application discussed above). The stoker/PC burner uses sulphur emissions control which is depreciated (tax write-off) in five years. Because sulfur removal is intrinsic to the AFB system, finance of the technology is somewhat different. DOE estimates that although the calculated COE of the AFB system is slightly higher there is essentially no real cost difference between the two technologies because of the difference in pollution-control financing. Hence, a value of zero is used for the AFB-Industrial cost savings.
- Residential/Commercial: The conventional residential/commercial technology used for comparison is individual heating, ventilating and air conditioning (HVAC) systems with a \$300,000 per MW capital cost. The conventional residential/commercial systems are assumed to have annual operations and maintenance costs of \$11,400 per MW capacity and a 75 percent efficiency resulting in fuel costs of \$1.70 per million British thermal units (all figures in 1978 dollars). These individual HVAC systems are compared to district heating systems using new technologies (division projects).

Table 17
Cost of Energy (COE)--(1978 \$)

TECHNOLOGY	Computed COE ¹ (mills/kwh)	COE From ECAS ² (mills/kwh)
CLEANUP TECHNOLOGY		
Adv. Flue Gas Cleanup	37.4	
Adv. Flue Gas Desulfurization (FGD)	42.0	
Rel. Lime/Limestone	37.3	
FUEL CELLS		
Molten Carbonate	32.5	30.2
Thermionics (TEC)	52.4	
Phosphoric Acid	37.0	
COMBUSTION SYSTEMS		
AFB-Industrial	40.6 ³	
PFB-Utility	31.7	34.5
AFB-Utility	34.0	32.5
Coal-Oil Mixtures (COM)	38.6	
HEAT ENGINES		
Organic Rankine Cycle (ORC)	36.6	
Open Cycle Gas Turbine	40.6	36.1
Stirling Engine - Industrial	44.5	
Stirling Engine - Utility	44.7	
Stirling Engine - Res./Comm.	34.8	
Adv. Diesel (DARE) - Industrial	37.8	
Adv. Diesel (DARE) - Utility	40.5	
Adv. Diesel (DARE) - Res./Comm.	39.2	
Adv. Gas Turbine (RALFE)	39.4	32.6
Closed Cycle Gas Turbine - Industrial	35.5	
Closed Cycle Gas Turbine - Utility	39.5	
Closed Cycle Gas Turbine - Res./Comm.	46.3	
CONVENTIONAL TECHNOLOGY IN EACH MARKET		
-Industrial (for AFB-Industrial)	39.9 ³	
-Baseload Utilities	37.5	37.5
-Non-Baseload Utilities	40.0	
-Residential/Commercial	42.3	

¹ Computed COE values use the data in Results of FY 1979 Project Appraisal, Appendices A-D, Santa Fe Corporation, April 1979. The formulae for computed COE are given in the appendix to this report.

² ECAS: Energy Conversion Alternatives Study, Summary Report, NASA (prepared for ERDA and NSF), 1977.

³ Expressed in mills/10⁴ Btu

Table 18
Cost Savings (CS)--(1978 \$)

TECHNOLOGY	CS ¹ Based on Computed COE (1000\$/MW)	CS ¹ Based on ECAS COE (1000\$/MW)
CLEANUP TECHNOLOGY		
Adv. Flue Gas Cleanup	0.88	
Adv. Flue Gas Desulphuriza- tion (FGD)	-39.42	
Rel. Lime/Limestone	1.75	
FUEL CELLS		
Molten Carbonate	43.80	65.70
Thermionics (TEC)	-130.52	
Phosphoric Acid	4.38	
COMBUSTION SYSTEMS		
AFB-Industrial	0.00 ²	
PFB-Utility	50.81	26.28
AFB-Utility	30.66	43.80
Coal-Oil Mixtures (COM)	-9.63	
HEAT ENGINES		
Organic Rankine Cycle (ORC)	38.54	
Open Cycle Gas Turbine	-27.16	12.26
Stirling Engine - Industrial	-63.95	
Stirling Engine - Utility	-41.17	
Stirling Engine - Res./Comm.	65.70	
Adv. Gas Turbine (RALFE)	-16.64	42.92
Adv. Diesel (DARE) - Indus- trial	-2.63	
Adv. Diesel (DARE) - Utility	-4.38	
Adv. Diesel (DARE) - Res./Comm.	27.16	
Closed Cycle Gas Turbine - Industrial	17.52	
Closed Cycle Gas Turbine - Utility	-17.52	
Closed Cycle Gas Turbine - Res./Comm.	-35.00	

¹CS computed using equation (1.0) and data in Table 17.

²To compensate for the difference in financing of pollution control equipment between AFB-Industrial and the conventional pulverized coal burner the cost difference is estimated at 0 instead of the computed difference based strictly on COE values (see text, page 24.)

The ECAS COE values represent a fairly significant change from computed COE values. With the exception of PFB-Utility, the ECAS COE's are less than the computed values. The differences range from 1.5 mills/kwh for AFB-Utility to 6.8 mills/kwh for RALFE. These differences represent a significant difference in consumer savings given in Tables 1 through 16. The percentage differences in savings for the ECAS technologies are summarized in Table 19 below.

Table 19

Comparison of Consumer Savings: Computed vs. ECAS

Project	(A) Consumer Savings Based on Computed COE (Billion 1978 \$)	(B) Consumer Savings Based on ECAS COE (Billion 1978 \$)	$\frac{(B) - (A)}{(A)}$ Percentage Difference
Molten Carbonate	66.0	99.0	+50
PFB-Utility	103.8	53.7	-48
AFB-Utility	80.0	114.3	+43
Open Cycle Gas Turbine	-25.7	114.8	+546
Adv. Gas Turbine (RALFE)	-26.4	62.2	+335

Although the differences in consumer savings estimates are large, as can be seen in Table 19, using ECAS COE values would have little impact on the division-wide ranking derived from project ratings. The only major change would be for RALFE and it occurs for the following reasons: (a) the difference between computed and ECAS COE's is greatest for RALFE: 6.8 mills/kwh (the other differences are all less than 4.5 mills/kwh), and (b) RALFE has negative consumer savings with the computed COE and positive savings with the ECAS COE. These two facts combine to make a major change in project rating.

Table 20

Comparison of Computed and ECAS Ratings

Project ¹	(A) Rating Based on Computed COE	(B) Rating Based on ECAS COE	(C) = (B) - (A)
			Difference
Molten Carbonate	0.44	0.48	+0.04
PFB-Utility	0.76	0.67	-0.09
AFB-Utility	0.62	0.66	+0.04
Open Cycle Gas Turbine	0.17	0.21	+0.04
Adv. Gas Turbine (RALFE)	-0.07	0.73	+0.81

¹Ratings are for the enhanced funding level

C. COMMERCIALIZATION DATE

The analysis of commercialization dates was performed for 12 of the 16 division projects. The base case commercialization dates were considered as "optimistic" estimates. Hence tests of the impact of postponed commercialization (1 year later and 3 years later) on benefits and project ratings were made. There was one exception to this approach; the AFB-Utility project was tested with a commercialization date 2 years earlier than the base case. Results for the analyses of later commercialization dates are presented in Tables 21 and 22. These results indicate that a change of 1 year has fairly small impact but a change of 3 years has a large impact. The average drop in quads supplied is only 15% for a commercialization of 1 year later. However, that drop averages 46% for the "3 year later" case. Similarly, the average percentage change in consumer savings is 16% for 1 year later and 47% for 3 years later. Table 22 shows that the effect of later commercialization dates has almost no effect on project ratings for 1 year differences and only moderate effect for 3 year differences. Some ratings actually increase with later commercialization (e.g., RALFE and Coal-Oil Mixtures). This phenomenon occurs because later commercialization means fewer units installed and hence an increase in consumer savings for those projects with negative savings.

Table 21

Effect of a 1 and 3 Year Postponment in Commercialization Date on Benefits

Project ¹	Quads Supplied			Consumer Savings (Billion 1978 \$)		
	Base Case	1 Year Postponement	3 Year Postponement	Base	1 Year Postponement	3 Year Postponement
Adv. Flue Gas Desulphur.	235.5	212.2	158.0	-105.6	-95.1	-70.7
Molten Carbonate	76.1	57.6	29.6	66.0	49.9	25.7
TEC (Plant with topping cycle)	53.9	44.0	28.3	-356.9	-291.7	-187.5
PFB-Utility	155.9	122.8	77.0	103.8	81.8	51.3
Coal-Oil Mixtures	19.3	18.0	9.8	-15.7	-14.7	-8.1
Organic Rankine Cycle	0.8	0.7	0.4	7.3	7.0	3.8
Open Cycle Gas Turbine	5.9	5.0	3.4	-25.7	-22.0	-14.8
Stirling Engine	3.3	2.6	1.6	10.9	8.9	5.4
Adv. Diesel (DARE)	7.2	6.1	4.4	8.5	7.4	5.3
Adv. Gas Turbine (FALFE)	24.6	20.1	13.0	-26.4	-21.6	-13.9
Closed Cycle Gas Turbine	19.7	16.2	10.8	-9.3	-6.6	-4.1

¹For enhanced funding

Table 22

Effect of a 1 and 3 Year Postponement Commercialization Date on Ratings

Project	Rating ¹ (R)		
	Base Case	1 Year Postponement	3 Year Postponement
Adv. Flue Gas Desulphur.	0.29	0.29	0.29
Molten Carbonate	0.44	0.41	0.37
TEC (Plant with topping Cycle)	-0.60	-0.45	-0.28
PFB-Utility	0.76	0.69	0.60
Coal-Oil Mixtures	0.24	0.25	0.30
Organic Rankine Cycle	0.26	0.26	0.17
Open Cycle Gas Turbine	0.17	0.16	0.19
Stirling Engine	0.34	0.31	0.26
Adv. Diesel (DARE)	0.40	0.36	0.29
Adv. Gas Turbine (RALFE)	-0.07	-0.02	0.02
Closed Cycle Gas Turbine	0.03	0.03	0.03

¹For enhanced funding

The analysis of commercialization date for AFB-Utility consisted of comparison of the base case to results for commercialization 2 years earlier. Quads supplied increased from 217.8 to 269.0--a 23% change--in going from the base case to 2 years earlier. Similarly, consumer savings increased 23% from \$80.0 billion to \$98.8 billion. Finally, the overall project rating went up from 0.62 to 0.67. These results indicate a substantial--though a not dramatic--difference, implying that earlier commercialization could be a worthy goal.

D. MAXIMUM MARKET FRACTION

Three types of changes in this "key variable" were considered: (a) it was assumed that no oil and gas conversions to coal as mandated in the National Energy Act will apply to selected technologies; (b) it was assumed that additional fuels availability constraints apply to technologies which will require gasified coal or other substitute fuels; and, (c) it was assumed that selected market sectors would not be applicable to selected technologies. The actual changes made in each of these three categories and the impact of these changes on quads supplied, consumer savings, and project ratings is summarized in Table 23.

The results in Table 23 indicate that very large decreases in maximum market fractions must be made in order to effect significant changes in results. This phenomenon occurs because of a variety of factors: the presence of strong competition, the reality of penetration delay, and the relatively late commercialization of many technologies. These and other market factors mean that projects do not achieve their maximum market fractions until several years after commercialization--and possibly not at all --even in the base case.

E. EIS VALUES AND WEIGHT

Two types of analysis were conducted on the effects and impacts score (EIS). First, the weight used in computing overall project ratings was varied to determine what impact different weights would have on ratings and consequent project ranks. Second, the actual EIS values were revised to present an alternative set of project ratings for comparison to the base case (which used original EIS values). Both of these analyses were applied to all 16 division projects.

1. EIS Weight Analysis

The base case weight of 0.5 reflects the fact that the environmental, legal, social, and institutional criteria are considered less important than the benefits and cost criteria forming the Figure of Merit and the Public Savings terms. Two alternatives to the 0.5 weight are considered: 0.25 and 0. The weight of 0 essentially eliminates the EIS and bases project ratings on the FOM and PS only. Results for these analyses are given in Table 24 which shows that reducing the weight by half--from 0.5 to 0.25--has little effect on the relative order of projects. The only significant change is the jump of

Table 23

Comparison of Results for Maximum Market Fraction (MMF) Analysis

Project ¹ (Change made to MMF)	Quads Supplied		Consumer Savings (Billion 1978 \$)		Ratings	
	Using Base Case MMF	Using Revised MMF	Using Base Case MMF	Using Revised MMF	Using Base Case MMF	Using Revised MMF
Reliable Lime/Lime- stone (Conversions eliminated) ²	251.6	217.5	5.0	4.3	1.23	1.10
Molten Carbonate (Reduce MMF 25%)	76.1	73.1	66.0	63.4	0.44	0.43
Molten Carbonate (Reduce MMF 50%)	76.1	63.2	66.0	54.8	0.44	0.42
PFB-Utility (Reduce MMF 50%)	155.9	96.4	103.8	64.2	0.76	0.64
PFB-Utility (Growth market only)	155.9	68.7	103.8	45.8	0.76	0.58
AFB-Utility (Conversions eliminated)	217.8	211.6	80.0	77.7	0.62	0.62
Coal-Oil Mixtures (Reduce MMF 25%)	19.3	18.5	-15.7	-15.0	0.24	0.25
Coal-Oil Mixtures (Reduce MMF 25%)	19.3	12.5	-15.7	-10.2	0.24	0.28
Adv. Diesel (DARE) (Reduce MMF 50%)	7.2	7.1	8.5	8.6	0.40	0.40
Adv. Diesel (DARE) (Eliminate Res./Comm. share)	7.2	4.0	8.5	-1.0	0.40	0.13

¹Results for enhanced funding²Words in parentheses indicate change made to the maximum market fraction.

Table 24

Analysis of Alternative EIS Weights

Project ¹	weight=0.5 (Base Case)		weight=0.25		weight=0	
	Rating	Rank	Rating	Rank	Rating	Rank
Reliable Lime/ Limestone	1.23	1	1.10	1	0.94	1
PFB-Utility	0.76	2	0.54	2	0.31	2
AFB-Utility	0.62	3	0.41	3	0.19	5
AFB-Industrial	0.54	4	0.32	5	0.10	8
Phosphoric Acid	0.47	5	0.26	7	0.04	10
Molten Carbonate	0.44	6	0.28	6	0.12	7
Adv. Flue Gas Cleanup	0.40	7	0.24	9	0.08	9
Adv. Diesel (DARE)	0.40	8	0.34	4	0.28	3
Stirling Engine	0.34	9	0.25	8	0.16	6
Adv. FGD	0.29	10	0.13	11	-0.03	12
Organic Rankine Cycle	0.26	11	0.24	10	0.21	4
Coal-Oil Mixtures	0.24	12	0.06	12	-0.12	14
Open Cycle Gas Turbine	0.17	13	0.06	13	-0.06	13
Closed Cycle Gas Turbine	0.03	14	0.02	14	0.00	11
Adv. Gas Turbine (RALFE)	-0.07	15	-0.15	15	-0.20	15
TEC (plant with topping)	-0.60	16	-0.79	16	-0.89	16

¹Results for enhanced funding

Advanced Diesel (DARE) from a rank of 8 to 4. In the case of DARE, most of its rating is based on the FOM and PS. Hence a reduction in the EIS weight has little impact on the rating. However, because other ratings fall significantly, the DARE rank improves.

Eliminating the EIS--using a weight of zero--results in fairly significant rank changes. The two biggest rank increases occur in DARE and Organic Rankine Cycle (ORC) projects. DARE jumps .5 places--from a rank of 8 to 3--and ORC jumps 7 places--from a rank of 11 to 4. The reasoning is identical to that of above: both the DARE and ORC projects have low EIS values. Hence eliminating the EIS role has very little impact on their project ratings. At the same time, all other projects--with moderate to high EIS values--suffer significantly when the EIS weight is set equal to zero. For example, Phosphoric Acid drops rank by 5 places. This project has a high EIS value which constitutes a large share of the base case project rating. In summary, projects with a low base case EIS value tend to improve their rating relative to other projects as the EIS weight is reduced.

2. EIS Values Analysis

The base case EIS values are those originally submitted by program proponents (division branch chiefs). Each proponent was responsible for scoring the projects for his branch (i.e., Fuel Cells, Cleanup Technology, Heat Engines, or Combustion Systems). An alternative set of EIS values--based on the information supplied by program proponents -- was used for comparison to the original values. The results are presented in Table 25. The set of revised values shows a major reduction in all EIS scores. However, because these revised values must be normalized against the new maximum EIS, the project ratings do not change dramatically. The only two significant changes occur with the AFB-Utility project which drops by half in project rating and 3 places in rank and the AFB-Industrial project which drops from a 0.54 to a 0.23 rating and drops 5 places in rank. These changes are not due so much to the absolute change in EIS as to the fact that the EIS constitutes a large share of the project rating for both AFB projects.

Table 25

Comparison of Base Case and Revised EIS Values¹

Project	Base Case			Revised Values		
	EIS ²	Rating	Rank	EIS ²	Rating	Rank
Reliable Lime/ Limestone	8	1.23	1	2	1.17	1
PFB-Utility	12.5	0.76	2	2	0.53	2
AFB-Utility	11	0.62	3	1	0.31	6
AFB-Industrial	11	0.56	4	1	0.23	9
Phosphoric Acid	12	0.47	5	4	0.49	3
Molten Carbonate	10	0.44	6	2	0.32	5
Adv. Flue Gas Cleanup	8	0.40	7	2	0.33	4
Adv. Diesel (DARE)	3.3	0.40	8	0	0.28	7
Stirling Engine	5.7	0.34	9	1	0.28	8
Adv. FGD	8	0.29	10	2	0.22	10
Organic Rankine Cycle	2	0.26	11	0	0.21	11
Coal-Oil Mixtures	9	0.24	12	1	0.01	14
Open Cycle Gas Turbine	6	0.17	13	-1	0.19	12
Closed Cycle Gas Turbine	1	0.03	14	-2	0.02	13
Adv. Gas Turbine (RAIFFE)	2.9	-0.07	15	-1	-0.34	15
TEC (plant with topping cycle)	6	-0.60	16	1	-0.74	16

¹ Results for enhanced funding² EIS values can range from -20 to +20

F. DATA TOLERANCE FACTORS (D_T)

Three types of analyses were performed on data tolerance factors:

- All D_T values set equal to one (eliminate D_T effect).
- Compare base case values to those derived from ECAS.
- Compare base case to two sets of alternative judgmental D_T values.

These three analyses are discussed below. The first analysis applies to all 16 projects while the second and third analyses only apply to selected projects.

1. D_T Effect Eliminated

The comparison of base case results to the case where all D_T values were set equal to 1 indicated very little difference in both ratings and ranks. Because all original D_T values ranged from 0.75 to 1 (with most values between 0.9 and 1) the elimination of the multiplier--that is, setting all D_T equal to one--made only a small impact on project ratings. Furthermore, comparison for the enhanced funding level demonstrated only 1 change in the ranking of 16 projects: Organic Rankine Cycle (with an original D_T of 0.75) moved from the rank of 10 to 9. These results indicate that a larger range of D_T values is needed to have a significant impact on project ratings and ranks.

2. D_T Values Derived from ECAS

The Energy Conversion Alternatives Study (ECAS)¹ examined several new technologies for generation of electricity. Five of those technologies are supported as projects for the Division of Fossil Fuel Utilization:

- Molten Carbonate Fuel Cell
- PFB-Utility
- AFB-Utility
- Open Cycle Gas Turbine
- Adv. Gas Turbine (RALFE)

¹ECAS: Energy Conversion Alternatives Study, Summary Report, NASA (prepared for ERDA and NSF), 1977.

The ECAS study compares cost of electricity estimates and estimated utilization efficiencies. A range of values for each technology was generated. The size of these ranges indicates a level of confidence in technology data from which D_T values can be derived. The results of this process are summarized in Table 26.

Table 26
Comparison of Base Case vs. ECAS D_T Values

Project ¹	Base Case		ECAS		Percent Change	
	D_T	Rating	D_T	Rating	D_T	Rating
Molten Carbonate	0.80	0.44	0.75	0.38	-6.3	-13.6
PFB-Utility	0.90	0.76	0.92	0.77	2.2	1.3
AFB-Utility	0.98	0.62	0.90	0.58	-8.2	-6.5
Open Cycle Gas Turbine	0.90	0.17	0.85	0.16	-5.5	-5.9
Adv. Gas Turbine (RALFE)	0.85	-0.07	0.70	-0.08	-17.6	-14.3

¹Ratings for enhanced funding.

The analysis of ECAS ranges indicates that PFB should have the highest D_T value, AFB should be second, Open Cycle Gas Turbine third, Molten Carbonate fourth, and RALFE fifth. Originally submitted D_T values have a significantly different order with AFB and PFB switching places for highest and second highest and RALFE and Molten Carbonate switching places for lowest and next-to-lowest.

3. Alternative D_T Values

Ten of the sixteen projects were chosen for analysis of alternative D_T values. In all cases, these alternatives were reductions of original values. If the original value was lower than 0.85 the two alternatives were 0.6 and 0.4.

If the original value was 0.85 or higher the alternatives were 0.8 and 0.6. The effects of these changes were roughly the same for each project. Ratings declined by slightly under 20% for the higher of the two alternative values and by slightly over 30% for the lower of the alternatives. Since the alternative values represent decreases in D_T by 20 to 50% the changes in ratings are somewhat proportional to changes in D_T values. The impact on project ranks is summarized in Table 27. No major jumps in rank take place. The greatest change in rank is a move upward of 4 places: from rank 7 to 3 for Adv. Flue Gas Cleanup which is not one of the projects given alternative D_T values. This takes place because three projects with base case ratings higher than Adv. Flue Gas Cleanup fall below the base case Adv. Flue Gas Cleanup rating when the lower alternative D_T values are used. The three top ranking projects remain in place as do the bottom four ranking projects. This finding is in keeping with the fact that project ratings are closer together in middle-ranking projects, hence allowing shifts in ranks more easily.

G. PLANNING HORIZON

The planning horizon for 1979 project appraisal was set at the year 2000. Six projects were selected for assessment of the additional benefits accrued between 2000 and the year 2010. The analysis was done for two new horizons: 2010 and the halfway point of 2005. Results are given in Table 28 which shows very large increases in both quads supplied and consumer savings (decreases where savings is negative) for the additional 5 and 10 year periods. The average increase in quads supplied is 121% for the extension to 2005 and an extremely large 310% for the extension from 2000 to 2010. The largest percentage increase is for Molten Carbonate: 545% from 2000 to 2010. These figures appear to be perhaps overly optimistic estimates since they assume a rate of growth roughly equal to current growth in the utilities sector. Many forecasts project much lower growth in the future which would yield significantly smaller results.

Where consumer savings is positive, the average increases are 104% for extension to 2005 and 265% for extension from 2000 to 2010. The decreases associated with the two sets of negative savings are of similar proportions. Once again, these estimates assume optimistic growth rates which yield results significantly higher than would occur using the lower growth rates assumed by other forecasts. Nevertheless, these results indicate that large additional

Table 27

Impact of Extended Planning Horizon

Project ¹	Horizon=2000			Horizon=2005			Horizon=2010		
	Quads Sup- plied	Consumer Savings (Billion 1978\$)	Rating	Quads Sup- plied	Consumer Savings (Billion 1978\$)	Rating	Quads Sup- plied	Consumer Savings (Billion 1978\$)	Rating
Adv. FGD	235.5	-105.6	0.29	327.4	-146.8	0.27	419.4	-188.0	0.27
Molten Carbonate	76.1	66.0	0.44	227.79	197.6	0.69	490.	425.6	1.11
Phosphoric Acid	13.9	10.0	0.47	27.0	19.4	0.51	44.9	32.9	0.56
FFB-Utility	155.9	103.8	0.76	341.7	227.5	1.13	623.5	415.2	1.87
Open Cycle Gas Turbine	5.9	-25.7	0.17	15.4	-67.11	0.12	31.2	-135.7	0.00
Stirling Engine	3.3	10.9	0.34	7.1	11.4	0.37	12.7	10.1	0.39

Results for enhanced funding

Table 28

Base Case vs. Alternative D_T Values

Project ¹	Base Case			Alternative 1			Alternative 2		
	D _T	Rating	Rank	D _T	Rating	Rank	D _T	Rating	Rank
Reliable Lime/ Limestone	0.9	1.23	1	0.9	1.23	1	0.9	1.23	1
Advanced FGD	1.0	0.29	10	1.0	0.29	9	1.0	0.29	7
Adv. Flue Gas Cleanup	1.0	0.40	7	1.0	0.40	6	1.0	0.40	3
Coal-Oil Mixtures	1.0	0.24	12	1.0	0.24	11	1.0	0.24	9
PFB-Utility	0.9	0.76	2	0.9	0.76	2	0.9	0.76	2
Closed Cycle Gas Turbine	0.8	0.03	14	0.8	0.03	14	0.8	0.03	14
Molten Carbonate	0.8	0.44	6	0.6	0.31	8	0.4	0.20	10
Phosphoric Acid	0.9	0.47	5	0.8	0.42	5	0.6	0.32	5
TEC (plant with topping cycle)	0.8	-0.60	16	0.6	-0.70	16	0.4	-0.80	16
AFF-Industrial	1.0	0.54	4	0.8	0.43	4	0.6	0.32	6
AFF-Utility	0.98	0.62	3	0.8	0.51	3	0.6	0.38	4
Advanced Diesel (DARE)	0.85	0.40	8	0.8	0.38	7	0.6	0.28	8
Advanced Gas Tur- bine (RALFE)	0.85	0.07	15	0.8	-0.07	15	0.6	-0.08	15
Open Cycle Gas Turbine	0.9	0.17	13	0.8	0.15	13	0.6	0.11	13
Organic Rankine Cycle	0.75	0.26	11	0.6	0.21	12	0.4	0.14	12
Stirling Engine	0.8	0.34	9	0.6	0.26	10	0.4	0.17	11

¹ For enhanced funding level.

benefits may be expected to accrue for long-term projects (i.e., those commercializing after 1990) relative to benefits accruing for short-term projects if the planning horizon is extended beyond 2000. This is particularly true where short-term project market applications disappear prior to 2000 (e.g., AFB utility). This result indicates that a longer planning horizon should be used in future project appraisal exercises.

SECTION IV - CONCLUSIONS

A primary purpose of the sensitivity analysis was to explain differences between computed ranks--derived from project ratings--and professional judgment ranks--submitted by program proponents (division branch chiefs). These two sets of ranks are not expected to coincide. However, some degree of correlation between the two rankings is highly desirable since this adds credibility to appraisal results and provides division management with confidence that professional judgment ranks are valid. The comparison of computed and judgmental ranks is done on a branch-by-branch basis since this is the way judgmental ranking is done. The differences between ranks are summarized in Section A below. In Section B, the impact of the various sensitivity analyses on these differences is summarized. Finally, the overall conclusions for the analysis of "key variables" and an outline of work for "additional variables" is given in Section C.

A. COMPUTED VS. JUDGMENTAL RANKS

Tables 29 to 32 list the ranks computed by using the base case project ratings given in this report and the corresponding judgment ranks assigned by division branch chiefs. The only set of ranks which correlate well are those of Fuel Cells where there is complete agreement on Phosphoric Acid first, Molten Carbonate second, and TEC third. The only deviations in the Fuel Cells ranks are between funding levels: enhanced ratings receive highest ratings for Phosphoric Acid and Molten Carbonate while the Branch Chief prefers to fund these incrementally--from minimum to current to enhanced. Correlation is almost non-existent for the remaining three branches.

A major factor causing these differences is the use of consumer savings in computed project ratings. Because many projects received relatively low or negative savings, their ratings were low and caused low ranks. Professional judgment ranks tended not to account for the possibility of negative consumer savings. Several of the projects with negative savings were given high judgmental ranks.

B. IMPACT OF SENSITIVITY ANALYSIS

Although major differences in quads supplied and consumer savings result from several of the analysis scenarios, the impact on overall ratings was not

Table 29
Cleanup Technology Ranks

Project-level ¹	Judgmental Rank	Computed Rank
Adv. FGD-minimum	1	9
Rel. Lime/Limestone-minimum	2	3
Adv. Flue Gas Cleanup-minimum	3	6
Rel. Lime/Limestone-current	4	2
Adv. FGD-enhanced	5	8
Rel. Lime/Limestone-enhanced	6	1
Adv. Flue Gas Cleanup-current	7	5
Adv. Flue Gas Cleanup-enhanced	8	4
Adv. FGC-current	9	7

¹Level of funding: minimum, current, or enhanced

Table 30
Fuel Cell Ranks

Project-level	Judgmental Rank	Computed Rank
Phosphoric Acid-minimum	1	3
Phosphoric Acid-current	2	2
Phosphoric Acid-enhanced	3	1
Molten Carbonate-minimum	4	6
Molten Carbonate-current	5	5
Molten Carbonate-enhanced	6	4
TEC-minimum	7	7
TEC-current	8	8
TEC-enhanced	9	9

Table 31
Combustion Systems Ranks

Project-level	Judgmental Rank	Computed Rank
Coal-Oil Mixtures-current	1	12
Coal-Oil Mixtures-minimum	2	10
AFB-Industrial-minimum	3	4
AFB-Industrial-current	4	7
PFB-Utility-minimum	5	8
PFB-Utility-current	6	1
Coal-Oil Mixtures-enhanced	7	11
AFB-Industrial-enhanced	8	9
AFB-Utility-minimum	9	6
PFB-Utility-enhanced	10	3
AFB-Utility-current	11	2
AFB-Utility-enhanced	12	5

*Ranks 1-4 considered essentially equal by the Branch Chief

**Ranks 7-8 considered essentially equal by the Branch Chief

Table 32
Heat Engines Ranks

Project	Judgmental Rank	Computed ¹ Rank
Open Cycle Gas Turbine	1	4
Adv. Gas Turbine (RALFE)	2	6
Adv. Diesel (DARE)	3	1
Stirling Engine	4	2
Closed Cycle Gas Turbine	5	5
Organic Rankine Cycle	6	3

¹Based on average rating

great enough to evidence any significant changes in project rankings. In the Cleanup Technology branch no significant changes in ranks occur with any set of alternative scenarios. Combustion Systems results also indicate no significant changes. The Fuel Cells results tend to validate the base case results which already agree closely with judgmental ranks. The most significant results occur in the Head Engines Analysis. Using ECAS estimates of cost of electricity would place the RALFE project nearer to its professional judgment rank. A significant improvement in the Open Cycle Gas Turbine rank would occur if the ECAS cost of electricity estimate were combined with extension of the planning horizon. Very little change in the other Heat Engines projects is evident in the sensitivity analysis performed here.

C. CONCLUSIONS AND NEXT STEPS

The major conclusion of this report is that the correlation between judgmental and computed project ranks is not highly sensitive to the changes made in the "key variables" herein.

Other major conclusions to be drawn from this analysis are:

1. The use of ECAS cost of electricity estimates gives all but one ECAS project a significant increase in consumer savings.
2. The impact of a commercialization date postponed 3 years (as compared to the base case) is quite extensive while a 1-year postponement has very little effect.
3. Changes in the maximum market fraction do not cause dramatic changes in results unless entire market sectors (e.g., the residential/commercial sector for DARE or very large parts of sectors are removed.
4. Changing the EIS weight has very little impact unless it is set equal to 0 (removing the EIS from ratings). Similarly, significant changes in the EIS values do not cause much change in ratings or ranks.
4. Eliminating the Data Tolerance (D_T) factors has very little impact on ranks due to the fact that most D_T values were chosen quite high. However, using a larger range of values (e.g., the alternative judgmental D_T values) can have some significant impact. A composite of several alternative values could have even greater impact on ranks.
6. Extension of the appraisal planning horizon from the year 2000 to 2005 or 2010 has the greatest impact of all scenarios on results. The extension increases benefits by proportions larger than those attained in the 1981-2000 period (i.e., changes well over +100%).

The next steps are to perform sensitivity analysis on "additional variables" (see Volume 2) as follows:

1. Analyze the impact of using different market potential estimates:
 - assume a 0% growth rate
 - assume a 3% growth rate
2. Analyze the impact of using alternative market score worksheet weights. The weights are used to compute market scores which are in turn used to allocate markets among competing technologies (i.e., to obtain market penetration estimates).
3. Analyze the impact of removing energy benefits weights. Currently these weights are used to reflect the priorities on coal use and the near term. Also, the impact of considering some projects as "efficiency improvement" instead of "coal utilization" projects will be measured.
4. Select an appropriate mix of scenarios to attain the most realistic and credible appraisal results possible.

APPENDIX A

COST OF ENERGY (COE) CALCULATION

The cost of energy (COE) is used to compute consumer savings (see Tables 1 through 16). Computed COE values were obtained by using equations (1) through (4). The data required to use these equations were supplied by program proponents.

$$COE = COE_{Fuel} + COE_{OM} + COE_{Capital} \quad (1)$$

where COE = cost of energy (mills/kwh)

COE_{Fuel} = cost of energy due to fuel costs (mills/kwh)

COE_{OM} = cost of energy due to operations and maintenance costs (mills/kwh)

$COE_{Capital}$ = cost of energy due to capital change (mills/kwh)

The fuel, O&M, and capital contributions to COE are computed as follows:

$$COE_{Fuel}^1 = \frac{3413 \text{ Btu}}{1 \text{ kwh}} \times \frac{1}{\text{Efficiency}} \times \frac{1 \text{ lb}}{11825 \text{ Btu}} \times \frac{1 \text{ ton}}{2000 \text{ lbs.}} \times \frac{22\$}{1 \text{ ton}} \times \frac{1000 \text{ mills}}{1\$} \quad (2)$$

$$= 3.175 \div \text{Efficiency}$$

$$COE_{OM} = \frac{OMS}{\text{MW-year}} \times \frac{1000 \text{ mills}}{1\$} \times \frac{1 \text{ MW}}{1000 \text{ kw}} \times \frac{1 \text{ year}}{8760 \text{ hours}} \times \frac{1}{CF} \quad (3)$$

$$= OM \div (8760 \times CF)$$

$$COE_{Capital} = \frac{\text{Capital \$}}{\text{MW}} \times [ACC + 0.1 \text{ ACC}] \times \frac{1 \text{ year}}{8760 \text{ hours}} \times \frac{1}{CF} \quad (4)$$

$$= (\text{Capital} \times 1.1 \text{ ACC}) \div (8760 \times CF)$$

where:

OM = operations and maintenance cost (\$/MW/year)

Capital = capital required for procurement of equipment (\$/MW)

¹ COE_{Fuel} is shown for coal use. A similar formula--substituting heat rate (Btus per unit of fuels)--applies to oil, natural gas, and alternative fuels.

$$\text{ACC} = \text{Annual Capital Change} = \begin{cases} 0.20 & \text{for plant life} = 10 \text{ years} \\ 0.18 & \text{for plant life} = 15 \text{ years} \\ 0.17 & \text{for plant life} = 20 \text{ years} \\ 0.165 & \text{for plant life} = 25 \text{ years} \\ 0.16 & \text{for plant life} = 30 \text{ years} \\ 0.16 & \text{for plant life} = 40 \text{ years} \\ 0.16 & \text{for plant life} = 50 \text{ years or more} \end{cases}$$

CF^2 = capacity factor = fraction of year in operation

²As an example, the capacity factor used for baseload utilities is 0.70 representing 6132 operating hours.

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