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DOE/ET/15078--T9

SENSITIVITY ANALYSIS OF
PROJECT APPRAISAL VARIABLES

DOE/ET/15078--T9

VOLUME II: ADDITIONAL VARIABLES AND
COMPOSITE SCENARIOS

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Prepared for

Division of Fossil Fuel Utilization
Department of Energy
Germantown, MD

AC03-77ET15078
Contract No. ~~EG 77-C-03-1705~~
Task No. DPS-79-052

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July 31, 1979

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SECTION I - INTRODUCTION

This report is the second of a two-volume documentation of sensitivity analysis of project appraisal variables. The variables analyzed consist of various direct and indirect inputs to the project appraisal methodology (PAM) used by the Division of Fossil Fuel Utilization within the U.S. Department of Energy (DOE) for annual assessment of its research and development projects. In 1979, sixteen division projects were assessed using PAM. Nine input variables were selected for analysis following the 1979 application of the methodology. Six of these inputs were considered to be "key variables" and are analyzed in Volume I of this report.¹ The remaining inputs were termed "additional variables" and are reported on in this second volume.

The "additional variables" are:

1. Market Potential/Rate of Growth: Market potential is the amount of available capacity additions due to growth, scheduled replacements, and conversions in a sector for any one year.
2. Market Score Weights: The weights used to obtain a score which is in turn used to allocate a particular market among competing technologies.
3. 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.

1

Sensitivity Analysis of Project Appraisal Variables, Volume I: Key Variables, Santa Fe Corporation, July 1979.

The analysis of changes in "additional variables" (scenarios) is documented in Section II of this volume. As is the case in Volume I, changes made involve one variable at a time. Also as in Volume I, the impact of alternative scenarios is measured by considering the changes caused in three outputs:

- Quads Supplied: the amount of energy -- in quadrillion (10¹⁵) British thermal units -- supplied by use of a new technology in the 1981 through 2000 period.
- Cumulative Consumer Savings: the total amount of money -- in billions of 1978 constant dollars -- saved by users of a new technology in the 1981 through 2000 period as a result of a reduction in the cost of energy (COE) from that of the conventional technology. Note: if the COE of the new technology is higher than that of the conventional, then cumulative consumer savings is negative.
- Project Rating: the overall project score computed as a combination of quads supplied (weighted by DOE priorities on fuel type and time-frame), cumulative consumer savings, research and development costs, a score of environmental impacts and social, legal, and institutional effects, and a measure of confidence in project data (Data Tolerance).

Composite scenarios which consider changes in several variables at a time (both "key" and "additional variables") are discussed in Section III. Finally, a summary of results for all scenarios -- changes to "key variables," changes to "additional variables," and composite scenarios -- is given in Section IV. This last section also presents the major conclusions of the sensitivity analysis task and outlines the next steps in continued refinement of the project appraisal methodology and the appraisal process.

SECTION II - SCENARIOS FOR "ADDITIONAL" PROJECT APPRAISAL VARIABLES

This section provides documentation of the sensitivity of results to changes in the three "additional variables": market potential/growth rate, market score weights, and energy benefits (weights and type). Each scenario considered here constitutes a change in one of these variables. The market potential/growth rate changes apply to all 16 division projects while changes in the other two "additional variables" apply only to selected projects. Tables giving the complete list of scenarios for each project are contained in Volume I.

A. MARKET POTENTIAL/GROWTH RATE

Estimates of market potential are important inputs to the calculation of all three appraisal outputs: quads of energy supplied, cumulative consumer savings, and project ratings. The growth rate is an indirect input to these results since growth rates determine the market for new capacity which is in turn combined with scheduled replacements, conversions, and refurbishments to obtain total market potential. This total potential is then used in a market penetration analysis to determine the estimated effective penetration for a given technology.¹ The effective penetration of a new technology is then used to calculate quads of energy supplied and cumulative consumer savings. These two outputs contribute to formation of project ratings.

Growth rates used in the base case analysis for FY 1979 appraisal vary somewhat by market sector, but average about 5 percent. Two alternatives to this base case were analyzed: a no growth case and a 3 percent growth case.

¹The procedure for forecasting potential and performing the penetration analysis is detailed in the Market Penetration Handbook, Santa Fe Corporation, February 1979.

The results for the alternative growth rates of the base case (average 5 percent), the moderate case (3 percent), and the no growth case (0 percent) are summarized in Tables 1 and 2. Table 1 presents the comparison for quads supplied and cumulative consumer savings. Table 2 gives project ratings and the consequent rank-order of projects for the different growth rates. The results show fairly significant differences in all outputs for comparison of the base case to the no growth case. The results for the 3 percent growth case are closer to the base case, but still exhibit some significant differences. The major results are summarized below:

- Two large decreases occur when comparing the base case to the 3 percent growth case: Molten Carbonate quads supplied and cumulative consumer savings drop by 50.5 percent; Open Cycle Gas Turbine quads supplied and cumulative consumer savings change by 83.5 percent. The reasons for these are that (a) these two projects are the only ones that primarily penetrate the capacity expansion markets (i.e., other projects also demonstrate significant penetration of markets that are less affected by the growth rates -- e.g., replacements and conversions) and (b) the rate of capacity expansion (growth rate) in the markets in which they penetrate in the base case was actually higher than the 5 percent average. Consequently, a decrease in growth rate has a significant impact on Molten Carbonate and Open Cycle Gas Turbine.

Table 1

Quads Supplied and Cumulative Consumer Savings for Alternate Growth Rates

Project ¹	Quads Supplied (1981-2000)					Cumulative Consumer Savings (1981-2000) (Billion 1978 dollars)				
	(a) Base Case (avg. 5% Growth)	(b) 3% Growth	(c) % Change (a) to (b)	(d) 0% Growth	(e) % Change (a) to (d)	(f) Base Case (avg. 5% Growth)	(g) 3% Growth	(h) % Change (f) to (g)	(i) 0% Growth	(j) % Change (f) to (i)
Reliable Lime/Limestone	251.6	227.8	-9.4	131.18	-47.8	5.0	4.53	-9.4	2.61	47.8
PFB-Utility	155.9	139.7	-10.3	42.71	-72.6	103.8	93.11	-10.2	28.45	72.5
AFB-Utility	217.8	191.2	-12.2	93.03	-57.2	80.0	70.2	-12.2	34.16	57.3
AFB-Industrial	16.7	14.6	-12.5	9.32	-44.1	0.0	0.0	0.0	0.0	0.0
Phosphoric Acid	13.9	9.45	-32.0	3.97	-71.4	10.01	6.78	-32.2	2.85	71.5
Molten Carbonate	76.1	37.64	-50.5	9.69	-87.2	66.0	32.64	-50.5	8.41	87.2
Advanced Diesel (DARE)	7.2	6.29	-11.2	6.08	-15.5	8.5	7.5	-11.7	7.09	16.5
Advanced Flue Gas Cleanup	67.4	51.37	-14.8	21.49	-68.1	.7	.57	-18.5	.21	70.0
Stirling Engine	3.3	2.85	-13.6	1.96	-40.6	10.9	9.64	-11.5	6.56	39.8
Advanced FGD	235.5	193.61	-17.7	110.83	-52.9	-105.6	-86.78	+17.8	49.68	52.9
Organic Rankine Cycle ²	.8	.8	0.0	.8	0.0	7.3	7.3	0.0	7.3	0.0
Coal-Oil Mixtures ²	19.3	19.3	0.0	19.3	0.0	-15.7	-15.7	0.0	-15.7	0.0
Open Cycle Gas Turbine	5.9	.97	-83.5	.27	-95.4	-25.7	-4.27	+83.3	-1.21	95.2
Closed Cycle Gas Turbine	19.7	17.34	-11.9	8.15	-58.6	-9.3	-7.24	+22.1	-2.16	76.7
Adv. Gas Turbine (RALFE)	24.62	21.76	-11.6	9.14	-62.8	-26.4	-23.34	11.5	-9.82	62.8
TEC (plant with topping)	53.9	27.36	-49.2	10.09	-81.2	-356.9	-181.27	49.2	-66.85	81.2

¹ All results are for the enhanced funding level

² ORC and COM are retrofit technologies not affected by growth rate.

Table 2

Project Ratings and Ranks for Alternative Growth Rates

PROJECT ¹	BASE CASE (Avg. 5% growth)		3% GROWTH		0% GROWTH	
	RATING	RANK	RATING	RANK	RATING	RANK
Reliable Lime/Limestone	1.23	1	1.14	1	0.78	1
PFB-Utility	0.76	2	0.65	2	0.53	2
AFB-Utility	0.62	3	0.60	3	0.51	3
AFB-Industrial	0.54	4	0.53	4	0.50	4
Phosphoric Acid	0.47	5	0.46	5	0.44	5
Molten Carbonate	0.44	6	0.38	7	0.34	8
Adv. Flue Gas Cleanup	0.40	7	0.39	6	0.35	6
Adv. Diesel (DARE)	0.40	8	0.36	8	0.35	7
Stirling Engine	0.34	9	0.32	9	0.28	10
Advanced FGD	0.29	10	0.30	10	0.31	9
Organic Rankine Cycle	0.26	11	0.26	11	0.26	11
Coal-Oil Mixtures	0.24	12	0.24	12	0.24	12
Open Cycle Gas Turbine	0.17	13	0.21	13	0.21	13
Closed Cycle Gas Turbine	0.03	14	0.03	14	0.04	15
Adv. Gas Turbine (RALFE)	-0.07	15	-0.04	15	0.04	16
TEC (plant with topping)	-0.60	16	-0.11	16	0.08	14

¹Results for enhanced funding

- The average changes in both quads supplied and cumulative consumer savings were: 21.3 percent decrease from the base case to the 3 percent growth case; 53.5 percent decrease from the base case to the 0 percent growth case.
- For Molten Carbonate and Open Cycle Gas Turbine, the difference between the base case and the "no growth" case is quite large. The only units installed for the "no growth" case are due to replacement of retiring plants. For Molten Carbonate, both quads supplied and cumulative consumer savings decrease by 87.2 percent. The corresponding difference between base case and "no growth" case for Open Cycle Gas Turbine is 95.2 percent.

Although dramatic changes in quads supplied and cumulative consumer savings occur with changes in the market potential growth rate, the impact of different growth rates on project ratings is small. Furthermore, the impact on the rank-order of projects is minimal. Table 2 shows that ratings decline by an average of 5 percent in going from the base case to the 3 percent growth case. (A few projects -- Advanced Flue Gas Desulphurization, Open Cycle Gas Turbine, RALFE, and TEC -- have increasing ratings due to an increase in consumer savings due to negative cost savings). The average decline from base case to "no growth" ratings is 7 percent. Only one change in the rank-order occurs in the 3 percent growth scenario (ranks 6 and 7 switch) and only 3 rank changes (of at most 2 places) occur in the no growth scenario.

The results reflect significant changes in ratings and small changes in rank for only three technologies:

- Molten Carbonate
- Stirling Engines
- TEC (Plant with thermionic topping cycle).

In general the results indicate that overall project ratings and ranks are relatively insensitive to changes in the assumed growth rate. This point tends to validate the methodology and provides some justification for computing project ratings and ranks. However, the significant changes in quads supplied and consumer savings should not be overlooked. These results are fairly sensitive to changes in the market potential growth rate.

B. MARKET SCORE WEIGHTS

Market score weights have an indirect effect on the determination of final appraisal outputs: quads supplied, cumulative consumer savings, and project ratings. The weights are used to compute market scores which are in turn used to allocate a given market among competing technologies. This nominal -- or theoretical -- allocation is then used as the basis for generating estimates of actual effective market penetration.² These estimates are then used to compute quads supplied and cumulative consumer savings which contribute to calculation of project ratings.

The analysis undertaken in this task is designed to answer the questions:

- How sensitive are market scores to moderate changes in the weights?
- Does the change in weights cause any significant change in effective market penetration?
- What changes occur in final results when the weights are changed?

There are 7 market score weights which correspond to the 7 evaluation criteria: (1) total operating cost, (2) procurement cost, (3) lead time, (4) plant life, (5) reliability, (6) efficiency, and (7) capacity utilization. The

²For a complete discussion of the allocation procedure, see the Market Penetration Handbook, Santa Fe Corporation, February 1979, pp. 16-22.

base case weights and alternative weights for these 7 criteria are provided in Table 3. In the base case, highest priority is placed on the total operating cost and procurement costs criteria, high priority on reliability, lower priority on lead time and efficiency, and lowest priority on plant life and capacity utilization. Alternative set 1 treats all criteria as equal priorities (except that plant life is given a slightly lower priority).

The second set of alternative weights affects the relative priorities of total operating costs and procurement costs; the weight for the former is raised (from 0.25 to 0.30) while the latter weight is reduced (to 0.20). Alternative set 2 reflects the notion that total operating cost is the overriding factor in choice of a new technology.

The analysis of alternative market score weights was performed for a sample of division projects in two major markets: baseload utilities and industrial cogeneration. The technologies chosen are:

Baseload Utilities

Molten Carbonate Fuel Cell
Reliable Lime/Limestone
AFB-Utility
PFB-Utility
Open Cycle Gas Turbine

Industrial Cogeneration

Advanced Gas Turbine (RALFE)
Advanced Diesel (DARE)
Stirling Engine

Table 3

Market Score Criteria and Weights

MARKET SCORE CRITERION	MARKET SCORE WEIGHTS		
	BASE CASE	ALTERNATIVE SET 1	ALTERNATIVE SET 2
TOTAL OPERATING COST (\$/YEAR)	0.25	0.15	0.30
PROCUREMENT COST (\$ in YEAR 1)	0.25	0.15	0.20
LEAD TIME (YEARS)	0.10	0.15	0.10
PLANT LIFE (YEARS)	0.05	0.10	0.05
RELIABILITY (%)	0.20	0.15	0.20
EFFICIENCY (%)	0.10	0.15	0.10
CAPACITY UTILIZA- TION (%)	0.05	0.15	0.05
TOTAL:	1.00	1.00	1.00

Results of the analysis are provided in Tables 4, 5, and 6 in terms of responses, respectively, to each of the three questions posed earlier. Table 4 presents market scores for the base case and two alternative sets of weights. From Table 4 it can be seen that no change in ranks of market scores occur for the industrial cogeneration projects. Hence there will be no change in effective penetration for these projects³ and the results in Table 5 and Table 6 are given only for the baseload utility projects which do evidence change. Since for each project in Table 4 the market scores of alternative set 2 is less than the market score of alternative set 1 (i.e., alternative set 2 market scores lie closer to the base case), alternative set 1 represents the scenario causing the greater deviation from the base case. Hence, the results in Table 5 and Table 6 are given for the base case and the alternative set 1 case only. Results for alternative set 2 are roughly the same as the base case for Open Cycle Gas Turbine, Molten Carbonate, and Reliable Lime/Limestone. For AFB-Utility and PFB-Utility, the alternative set 2 results fall closer to the alternative set 1 results.

Effective market penetration for the base case and for alternative weights set 1 is presented in Table 5. Changes in penetration are not large because they have been dampened by factors other than the rank of market scores including:

- Penetration Delay--Introduction of a new technology occurs gradually because of reluctance to accept a new technology at first. This reluctance decreases gradually as the number of years after commercialization increases.

³See Market Penetration Handbook. The scheme used for allocation of markets depends on the rank of scores, not the actual scores.

Table 4

Effects of Alternative Weights on Market Scores

	Project	Base Case		Alternative Weights - Set 1 Scenario		Alternative Weights - Set 2 Scenario	
		Market Score	Rank of Score	Market Score	Rank of Score	Market Score	Rank of Score
Baseload Utilities	Open Cycle Gas Turbine	1.12	1	1.13	2	1.10	1
	Molten Carbonate	1.08	2	1.14	1	1.09	2
	AFB-Utility	1.068	3	1.09	4	1.066	4
	PFB-Utility	1.067	4	1.10	3	1.07	3
	Reliable Lime/Limestone	1.03	5	1.07	5	1.03	5
Indus. Cogen.	Adv. Gas Turbine (RALFE)	1.11	1	1.14	1	1.13	1
	Stirling Engine	0.94	2	1.03	2	1.01	2
	Adv. Diesel (DARE)	0.87	3	0.99	3	0.92	3

Table 5

Comparison of Effective Market Penetration: Base Case to Alternative Market Score Weights Scenario
(Alternative Set 1 Used for Comparison)¹

Project ²	Scenario	Projected Effective Market Penetration (1000 MWs Installed Capacity)																			
		1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Reliable Lime/ Limestone	Base Case	0	0	0	2.9	12.3	32.4	45.2	46.7	45.0	38.4	8.7	0	0	0	0	0	0	0	0	0
	Alt. Weights	0	0	0	2.9	12.3	32.7	45.2	47.4	45.7	39.1	9.2	0	0	0	0	0	0	0	0	0
Molten Carbonate	Base Case	0	0	0	0	0	0	0	0	0	1.5	5.9	15.5	21.5	22.0	32.1	38.6	50.9	59.0	66.6	66.7
	Alt. Weights	0	0	0	0	0	0	0	0	0	2.3	7.7	17.4	23.4	24.0	34.2	40.8	53.4	61.8	69.6	69.8
PFB- Utility	Base Case	0	0	0	0	0	0	0	0	2.5	24.5	24.3	29.0	31.5	35.3	34.7	34.8	35.2	35.8	36.3	37.4
	Alt. Weight	0	0	0	0	0	0	0	0	2.7	24.9	24.6	29.4	32.0	35.7	35.2	34.8	35.2	35.8	36.3	37.4
AFB- Utility	Base Case	0	0	0	0	0	2.2	21.7	35.5	41.0	47.1	33.0	28.3	17.1	10.6	5.2	0	0	0	0	0
	Alt. Weight	0	0	0	0	0	1.9	21.7	34.8	40.6	46.0	32.2	27.9	16.7	10.1	4.7	0	0	0	0	0
Open Cycle Gas Turbine	Base Case	0	0	0	0	0	0	0	0	0.5	2.4	6.9	10.9	14.8	18.2	20.4	22.8	24.6	26.4	28.2	30.0
	Alt. Weight	0	0	0	0	0	0	0	0	0	1.6	5.1	9.0	12.8	16.3	18.3	20.6	22.1	23.6	25.2	26.9
Total (Baseload Utility Market Excluding Other Technol- ogies	Base Case	0	0	0	2.9	12.3	34.6	66.9	82.2	89.0	113.9	78.8	83.7	84.9	86.1	92.4	96.2	110.7	121.2	131.1	134.1
	Alt. Weight	0	0	0	2.9	12.3	34.6	66.9	82.2	89.0	113.9	78.8	83.7	84.9	86.1	92.4	96.2	110.7	121.2	131.1	134.1

¹ See Table 3 for weights and the criteria they are associated with.

² Results for enhanced funding

- Maximum Market Fraction--No new technology can penetrate more than a certain maximum amount defined by reliability, environmental, fuels availability, and/or other constraints.

The cumulative effective penetration of the 5 technologies in Table 5 represents a constant sum for any given year. The change in market scores causes a shift in the portion of this total captured by each of these 5 technologies but not in the total itself. The total does not include other division projects' shares or the shares going to other technologies (e.g., conventional technologies).

Table 6 summarizes the impact of alternative market scores weights on final results. Three projects have increased quads supplied and consumer savings for the alternative weights: Molten Carbonate, PFB-Utility, and Reliable Lime/Limestone. The average increase is 5.4 percent for both outputs. The average decrease for the other two projects -- Open Cycle Gas Turbine and AFB-Utility -- is 8.1 percent. The change in ratings is relatively small: an average change of 2.8 percent.

In summary, the two sets of market score weights tested did not cause significant impact in market scores, effective penetration, or final results. Since only a small sample of projects is used for the analysis, it cannot be concluded that the weights are unimportant. However, the results seem to indicate that exact values of the weights are not of the utmost importance.

Table 6

Effects of Alternative Market Score Weights on Final Output

PROJECT ¹	QUADS SUPPLIED (1981-2000)		CUMULATIVE CONSUMER SAVINGS (1981-2000) (Billion 1978\$)		PROJECT RATING	
	Base Case Case	Alternative Set 1	Base Case	Alternative Set 1	Base Case	Alternative Set 1
Open Cycle Gas Turbine	5.9	5.0	-25.7	-22.1	0.17	0.18
Molten Carbonate	76.1	82.4	66.0	71.5	0.44	0.45
AFB-Utility	217.8	215.7	80.0	79.2	0.62	0.62
PFB-Utility	155.9	157.6	103.8	105.0	0.76	0.76
Reliable Lime/ Limestone	251.6	268.7	5.0	5.3	1.23	1.30

¹Enhanced funding

C. ENERGY BENEFITS

Two energy benefits scenarios are analyzed: (a) the case where all energy benefits weights are set equal to one which is run for all 16 division projects, and (b) a comparison of the base case to a change in benefits type. There are three benefits types: coal use, alternative fuels use, and efficiency improvement in oil and natural gas use. A change in type from coal use to efficiency improvement is analyzed for selected technologies that may burn either oil or coal-derived liquids.

1. Analysis of Energy Benefits Weights

A set of weights is used for the calculation of project ratings to reflect the priorities of DOE objectives as shown in Table 7. Figure 1 lists the rank-order of priorities from which the weights in Table 7 were derived. The analysis consists of setting all energy benefits weights equal to one so as to compare the impact of having weights to the impact of having "no weights." There is no impact on absolute results -- quads supplied and consumer savings -- since these quantities are computed without weights. The benefits weights figure into calculation of overall project ratings. The impact of the weights versus no weights (all equal one) scenario is summarized in Table 8.

Table 7

Energy Benefits Weighting Factors

TIME PERIOD (t)	WEIGHTING FACTORS		
	COAL USE	ALTERNATIVE FUELS USE	MORE EFFICIENT OIL AND GAS USE
	W_c	W_a	W_e
1981-1990	1.0	0.5	0.2
1991-2000	0.8	0.4	0.1

Figure 1

Project Appraisal Energy Benefits Priorities

HIGHEST PRIORITY

LOWEST PRIORITY

ENERGY SUPPLIED THROUGH COAL USE BY 1990
 ENERGY SUPPLIED THROUGH COAL USE BY 2000
 ENERGY SUPPLIED THROUGH ALTERNATIVE FUELS USE
 BY 1990
 ENERGY SUPPLIED THROUGH ALTERNATIVE FUELS USE
 BY 2000
 IMPROVED EFFICIENCY OF OIL AND GAS BY 1990
 IMPROVED EFFICIENCY OF OIL AND GAS BY 2000

Table 8

Comparison of Base Case to No Energy Benefits Weights Case

Project ¹	Base Case (Weights in Table 7 Used)		No Weights Case (All Weights Equal to One)	
	Rating	Rank	Rating	Rank
Reliable Lime/Limestone	1.23	1	1.41	1
PFB-Utility	0.76	2	0.79	2
AFB-Utility	0.62	3	0.65	3
AFB-Industrial	0.54	4	0.56	4
Phosphoric Acid	0.47	5	0.50	5
Molten Carbonate	0.44	6	0.45	6
Adv. Flue Gas Cleanup	0.40	7	0.42	8
Adv. Diesel (DARE)	0.40	8	0.44	7
Stirling Engine	0.34	9	0.35	10
Advanced FGD	0.29	10	0.38	9
Organic Rankine Cycle	0.26	11	0.27	11
Coal-Oil Mixtures	0.24	12	0.26	12
Open Cycle Gas Turbine	0.17	13	0.18	13
Closed Cycle Gas Turbine	0.03	14	0.04	14
Adv. Gas Turbine (RALFE)	-0.07	15	-0.03	15
TEC (plant with topping)	-0.60	16	-0.36	16

¹Results for the enhanced funding level

Table 8 shows that removing weights (i.e., setting them all equal to one) has only a small effect on project ratings -- an average increase of 11 percent (excluding RALFE and TEC which have negative ratings) -- and almost no effect on the rank-order of projects. Advanced Flue Gas Cleanup and DARE (ranks 7 and 8) switch positions because of the following: (a) the former is a coal-using technology exclusively while DARE will use residual oil until coal-derived liquids are fully developed and available, and (b) by setting the lower weights on DARE's benefits due to efficiency improvement in oil use equal to the coal use weights, the DARE projects score higher than the Advanced Flue Gas Cleanup project. One other switch in the rank-order takes place: Advanced FGD and Stirling Engine switch places for ranks 9 and 10. This switch occurs for a different reason from the DARE/Advanced Flue Gas Cleanup switch. While the DARE/Advanced Flue Gas Cleanup switch occurred because of a difference in fuel type, the Advanced FGD/Stirling Engine switch occurs because of difference in the time frame weights. Advanced FGD commercializes early and has a large number of units installed by 1990 (end of the "near term"). These units accrue significant benefits in the 1990 through 2000 period while the Stirling Engine is just beginning to accrue benefits in this "long term" period. Hence, when the lower "long-term" weights are removed (set equal to one) the increase in project rating for Advanced FGD is significantly greater than the corresponding increase in the Stirling Engine rating.

In summary, the comparison of the base case to the "no weights" case evidences two changes in project ranks: one resulting from a difference in fuel type, and the other resulting from a difference in commercialization date (that is, a time frame difference). However, these two changes are of only one position each so that the overall impact of the different weights cases is small.

2. Analysis of Energy Benefits Type

Three projects were selected for sensitivity analysis of the energy benefits type:

- Advanced Diesel (DARE)
- Advanced Gas Turbine (RALFE)
- Stirling Engine

Each of these three projects is a multi-fuel technology: it is forecast that they will use residual oil as a fuel until liquefaction (coal-derived liquids) is available in the early 1990s. Hence, the base case energy benefits type is a mixture (approximately 50 percent each) of coal use and efficiency improvement on oil use. The analysis consists of changing this mixed type to all efficiency improvement. This scenario reflects two issues: (1) the possibility that liquefaction will not become a reality (either due to technological problems or economics), and (2) the potential environmental and health harm associated with coal-derived liquids which may hinder use of liquefaction.⁴

By changing the energy benefits type from a coal use/efficiency improvement mix to all efficiency improvement, the measure of quads supplied is reduced and there is some impact on project ratings. Quads supplied by efficiency improvement is the increment between quads supplied by the new technology and quads supplied by the conventional technology for a given fuel input. These increments are a small amount compared to the total quads supplied. Table 9 presents the changes in quads supplied and project ratings for DARE, RALFE, and Stirling Engine. The results show a significant change in quads supplied for DARE and RALFE: decreases of 33 percent and 42 percent, respectively. The change is not extreme because these technologies are considered partially "efficiency improvement" projects in the base case.

⁴Between the time of performing this analysis and writing this report, President Carter has expressed a desire for a sizeable synfuels capacity by 1990.

Table 9

Impact of Changing Energy Benefits Type

PROJECT ¹	BASE CASE: COAL USE/ EFFICIENCY IMPROVEMENT MIX		ALL BENEFITS: EFFICIENCY IMPROVEMENT	
	QUADS SUPPLIED	RATING	QUADS SUPPLIED	RATING
Advanced Diesel (DARE)	7.2	0.40	4.8	0.35
Advanced Gas Turbine (RALFE)	24.6	-0.07	14.3	-0.13
Stirling Engine	3.3	0.26	3.2	0.26

¹Results for enhanced funding

This point applies most directly to the Stirling Engine project which is considered an efficiency improvement technology in two markets and a mixture of coal-use and efficiency improvement in a third market (industry) for the base case. Hence changing this third market to all efficiency improvement only has a small effect (decrease of 3 percent) on the overall quads supplied. The changes in benefits type does not change the Stirling Engine rating and only moves the DARE and RALFE ratings by 0.05 and 0.06 respectively. In conclusion, the changing of energy benefits type on projects with a base case mixture of types has a small to moderate effect on quads supplied and only a minor impact on project ratings. Changing a project from all coal use to all efficiency improvement would, however, have a significantly larger impact.

SECTION III - COMPOSITE SCENARIOS

Various combinations of changes in project appraisal variables and results of selected combinations are presented in this section. These combinations of changes in variables are called composite scenarios. The project scenarios presented in Section II of this report and in Volume I pertain to changes in only one appraisal variable at a time. The composite scenarios discussed in this section involve concurrent changes in more than one variable. Possible combinations of scenarios presented in Volume I and Section II of this volume are discussed and two specific composite scenarios are analyzed.

A. BACKGROUND

As stated above, all the analysis performed up to this point has involved changes in only one project appraisal variable at a time. By performing this analysis it has been possible to isolate the effect of changes in these variables. That is, by comparing results for a single change to the base case (no change), it has been possible to determine the sensitivity of results to changes in each "key" and "additional" appraisal input. Now that this sensitivity information has been acquired, the impact of selected combinations of variable changes will be examined.

Two specific composite scenarios have been chosen by the Division of Fossil Fuel Utilization to obtain meaningful alternatives to the base case results. These two chosen composites represent the division's best judgment as to what combination of scenarios will provide equitable and realistic results. These composite scenarios and the results they yield are discussed below.

B. COMPOSITE SCENARIO ANALYSIS

The two sets of appraisal variable changes discussed in this section will be referred to as COMPOSITE I and COMPOSITE II. These two composite scenarios are similar in that they incorporate some of the same variable changes. A few of the variable changes differ between these two composites; but in general, the two composite scenarios presented below are close enough to be somewhat comparable and equally valid alternatives to the base case.

1. The COMPOSITE I Scenario

COMPOSITE I consists of changes in four project appraisal variables:

- Cost of Energy (COE)
- Market Potential/Growth Rate
- Effects and Impacts Score (EIS) Values
- Data Tolerance Factor (D_T)

The changes made in each of these four variables correspond to changes in each of the corresponding scenarios for these variables -- that is, COMPOSITE I is a simple combination of scenarios discussed in Volume I and Section II of this volume.¹ A summary of the changes to each variable are given in Table 10. Actual changes in the variables for COMPOSITE I are given in Tables 11 through 13. The base case and ECAS cost of energy values along with base case and ECAS D_T values are given in Table 11, while the base case and revised EIS values are listed in Table 12, and finally, the base case and alternative D_T values for ORC, DARE, and Stirling Engine are presented in Table 13. The other variable change in COMPOSITE I -- change in growth rate -- is an across-the-board 3 percent growth in market potential.

¹The complete set of project scenarios (other than COMPOSITE I and II) is given in Sensitivity Analysis of Project Appraisal Variables, Volume I: Key Variables, Santa Fe Corporation, June 1979, Tables 1-16.

Table 10

COMPOSITE I: Changes to Appraisal Variables

APPRAISAL VARIABLE	VARIABLE CHANGE	PROJECTS TO WHICH CHANGES APPLY
Cost of Energy (COE)	The ECAS ² COE value was used instead of the base case value.	ECAS projects: Molten Carbonate, AFB-Utility, PFB-Utility, Open Cycle Gas Turbine, and RALFE
Market Potential Growth Rate	The growth rate of 3 percent was applied to all markets.	All 16 division projects
Effects and Impacts Score (EIS)	Revised EIS values determined by Systems Integrators were used.	All 16 division projects
Data Tolerance Factor (D_T)	D_T values derived from ECAS were used and other D_T values were slightly reduced.	ECAS projects (see above) and ORC, DARE, and Stirling Engine

Table 11

Base Case and COMPOSITE I Inputs: COE and D_T Values for ECAS Projects

Project	Cost of Energy (mills/kwh)		Data Tolerance Factor (D_T)	
	Base Case	COMPOSITE I (ECAS)	Base Case	COMPOSITE I (ECAS)
Molten Carbonate	32.5	30.2	0.8	0.75
AFB-Utility	34.0	32.5	0.98	0.9
PFB-Utility	31.7	34.5	0.9	0.92
Open Cycle Gas Turbine	40.6	36.1	0.9	0.85
Adv. Gas Turbine (RALFE)	39.4	32.6	0.85	0.7

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

Table 12

Base Case and COMPOSITE I Inputs: EIS Values

PROJECT	UNNORMALIZED EIS		NORMALIZED EIS ¹	
	Base Case	Composite I	Base Case	Composite I
Reliable Lime/ Limestone	8	2	0.64	0.50
Advanced FGD	8	2	0.64	0.50
Adv. Flue Gas Cleanup	8	2	0.64	0.50
Molten Carbonate	10	2	0.80	0.50
Phosphoric Acid	12	4	0.96	1.00
TEC (plant with thermionic topping cycle)	6	1	0.48	0.26
AFB-Utility	11	1	0.88	0.26
AFB-Industrial	11	1	0.88	0.26
PFB-Utility	12.5	2	1.00	0.50
Coal-Oil Mixtures	9	1	0.72	0.25
Organic Rankine Cycle	2	0	0.16	0.00
Open Cycle Gas Turbine	6	-1	0.48	-0.26
Stirling Engine	5.7	1	0.46	0.26
Adv. Diesel (DARE)	3.3	0	0.26	0.00
Adv. Gas Turbine (RALFE)	2.9	-1	0.24	-0.26
Closed Cycle Gas Turbine	1.0	-2	0.08	-0.50

¹Normalized values are obtained by dividing each EIS by the maximum EIS. This procedure puts all EIS values on a common -1 to +1 scale for comparison.

Table 13

Base Case and COMPOSITE I Inputs: Alternatives D_T Values

PROJECT	Base Case D _T	Composite I D _T
Organic Rankine Cycle	0.75	0.6
Adv. Diesel (DARE)	0.85	0.8
Stirling Engine	0.8	0.6

Results for the use of COMPOSITE I input values and the comparison to the base case are given in Table 14. The comparison indicates several kinds of changes:

- In general, quads supplied are reduced by an average 21 percent with the exception of Coal-Oil Mixtures and Organic Rankine Cycle which are retrofit technologies not affected by a change in growth rates.
- Consumer savings decrease for non-ECAS projects because of the use of 3 percent growth rate in COMPOSITE I which is lower than the base case growth rate. Three of the five ECAS projects (AFB-Utility, Open Cycle Gas Turbine, and RALFE) have increased consumer savings in COMPOSITE I, in spite of the lower growth rate, due to the lower ECAS cost of energy values (a lower COE means higher consumer savings).
- All ECAS projects receive lower ratings in COMPOSITE I with the exception of RALFE. The implication is that changes in market growth, EIS values, and D_T values override the positive consumer savings changes for AFB-Utility and Open Cycle Gas Turbine while the sizeable consumer savings increase for RALFE dominates the other changes.
- The combination of EIS revisions, D_T changes, and reduced market growth yields lower ratings for all non-ECAS projects except Phosphoric Acid. The revised Phosphoric Acid EIS is more favorable in COMPOSITE I resulting in a small project rating increase.

The effect of COMPOSITE I changes on project ranks is summarized in Figure 2. Three significant changes occur: Coal-Oil Mixtures picks up 5 positions in rank because it is not affected by the reduction in growth rate, Advanced Flue Gas Cleanup picks up 4 positions because it is only slightly affected by the growth rate reduction, and AFB-Industrial loses 6 positions because of a significantly reduced EIS in the revised (COMPOSITE I) scenario. More than half of the 16 projects exhibit minimal or no change (0, +1, or -1 position) and 13 of the 16 projects exhibit at most "moderate" change in rank

Table 14

Comparison of the COMPOSITE I Scenario to the Base Case

PROJECT	QUADS SUPPLIED (1981-2000)		CUMULATIVE CONSUMER SAVINGS (1981-2000)--(BILLION 1978\$)		PROJECT RATING		PROJECT RANK	
	BASE CASE	COMPOSITE I	BASE CASE	COMPOSITE I	BASE CASE	COMPOSITE I	BASE CASE	COMPOSITE I
Reliable Lime/Limestone	251.6	227.8	5.0	4.5	1.23	1.08	1	1
Advanced FGD	235.5	193.6	-105.6	-86.8	0.29	0.23	10	9
Adv. Flue Gas Cleanup	67.4	57.4	0.7	0.6	0.40	0.32	7	4
Molten Carbonate	76.1	37.6	66.0	48.8	0.44	0.26	6	6
Phosphoric Acid	13.9	9.5	10.0	6.8	0.47	0.48	5	2
TEC (plant with thermionic topping cycle)	53.9	27.4	-356.9	-181.3	-0.60	-0.20	16	16
AFB-Utility	217.8	191.2	80.0	100.3	0.62	0.30	3	5
AFB-Industrial	16.7	14.6	0.0	0.0	0.54	0.22	4	10
PFB-Utility	155.9	139.7	103.8	48.2	0.76	0.43	2	3
Coal-Oil Mixtures	19.3	19.3	-15.7	-15.7	0.24	0.24	12	7
Organic Rankine Cycle	0.8	0.8	7.3	7.3	0.26	0.17	11	12
Open Cycle Gas Turbine	5.9	1.0	-25.7	1.9	0.17	-0.10	13	14
Stirling Engine	3.3	2.9	10.9	9.6	0.34	0.18	9	11
Adv. Diesel (DARE)	7.2	6.4	8.5	7.5	0.40	0.24	8	8
Adv. Gas Turbine (RALFE)	24.6	21.8	-26.4	18.3	-0.07	0.09	15	13
Closed Cycle Gas Turbine	19.7	17.3	-9.3	-7.2	0.03	-0.12	14	15

¹ Results for enhanced funding

Figure 2

Changes in Ranks: COMPOSITE I Scenario
Compared to Base Case

Rank Change: Number of Positions	Projects	Category of Change
+6	--	Significant Change
+5	Coal-Oil Mixtures	
+4	Advanced Flue Gas Cleanup	
<hr/>		
+3	Phosphoric Acid	Moderate Change
+2	RALFE	
<hr/>		
+1	Advanced FGD	Minimal or No Change
0	Reliable Lime/Limestone, Molten Carbonate, TEC	
-1	PFB-Utility, ORC, Open Cycle Gas Turbine, DARE, and Closed Cycle Gas Turbine	
<hr/>		
-2	AFB-Utility, Stirling Engine	Moderate Change
-3	--	
<hr/>		
-4	--	Significant Change
-5	--	
-6	AFB-Industrial	

(less than or equal to 3 positions up or down). In summary, the base case and COMPOSITE I rankings are somewhat different but the difference is not overwhelming.

2. The COMPOSITE II Scenario

COMPOSITE II consists of 2 sets of changes identical to COMPOSITE I:

- Use of ECAS cost of energy and D_T values for ECAS projects
- Use of 3 percent market growth rate

and 2 other sets of changes not included in COMPOSITE I:

- Revised formula for computing project ratings
- Alternative D_T values (different from COMPOSITE I alternative values) for selected non-ECAS projects.

The ECAS cost of energy and D_T values were given in Table 11. The original (base case) formula for project ratings is :

$$\text{Base Case formula: } R = [FOM_n + (0.5 \times EIS_n) + PS_n] \times D_T \quad (1)$$

where:

R = project rating

FOM_n = normalized Figure of Merit (FOM)

EIS_n = normalized Effects and Impacts Score (EIS)

PS_n = normalized Public Savings (PS)

D_T = Data Tolerance Factor

FOM_n, EIS_n, and PS_n are computed by dividing each FOM, EIS, and PS by the maximum FOM, maximum EIS, and maximum PS respectively. This process puts all terms on a common scale of -1 to +1. Furthermore,

$$FOM = \frac{\text{Weighted Quads Supplied (1981-2000)}}{\text{R\&D Cost to Completion}}$$

EIS = sum of scores for environmental, social, legal, and institutional effects and impacts (each of these four scores is on a scale of -5 to +5)

$$PS = \frac{\text{Cumulative Consumer Savings (1981-2000)}}{\text{R\&D Cost to Completion}}$$

The revision to the above formula for ratings used in COMPOSITE II is given by equation (2):

$$\text{COMPOSITE II formula: } R = [FOM_n + (0.5 \times EIS_n) + CCS_n] \times D_T \quad (2)$$

where CSS_n is normalized cumulative consumer savings which is equivalent to setting R&D cost equal to one in the PS_n computation. The revised formula--equation (2)--takes the approach that absolute consumer savings (represented by CCS_n) is perhaps a more meaningful contributor to ratings than the benefit/cost ratio of cumulative consumer savings divided by R&D cost (PS_n).

The changes in non-ECAS project data tolerance factors for COMPOSITE II are given in Table 15. These values are lower than the changes made to the same projects in COMPOSITE I (see Table 13).

Table 15

Alternative D_T Values for COMPOSITE II (Selected Non-ECAS Projects)

PROJECT	BASE CASE D_T	COMPOSITE II D_T
Organic Rankine Cycle	0.75	0.4
Adv. Diesel (DARE)	0.85	0.6
Stirling Engine	0.8	0.4

Because COMPOSITE I and COMPOSITE II use equal growth rate and COE values, they exhibit the same quads supplied and consumer savings values. Hence, quads supplied and consumer savings in Table 14 apply to COMPOSITE II as well. The differences between the impact of the two composite scenarios occurs in the project ratings. COMPOSITE II uses an alternate ratings formula (Equation (2)), the original EIS values (whereas COMPOSITE I uses revised values), and three lower alternative D_T values (for ORC, DARE, and Stirling Engine). Comparison of ratings for COMPOSITE II to both COMPOSITE I and the base case is provided in Table 16. Since the two composite scenarios have certain changes in appraisal variables in common (3 percent growth, ECAS cost of energy, and ECAS D_T values) it is obvious that the differences in ratings are primarily due to the revised EIS values and project rating formula. The other difference between COMPOSITE I and II -- alternative D_T values -- also has some impact. The comparison of project ratings indicates that COMPOSITE II ratings are generally closer to the base case than the COMPOSITE I ratings are. In addition, COMPOSITE I ratings are closer to the base case than to COMPOSITE II.

Table 16

Comparison of Project Ratings: Base Case,
COMPOSITE I, and COMPOSITE II Scenarios

Project ¹	Project Rating		
	Base Case	COMPOSITE I	COMPOSITE II
Reliable Lime/Limestone	1.23	1.08	1.12
Advanced FGD	0.29	0.23	0.17
Advanced Flue Gas Cleanup	0.40	0.32	0.39
Molten Carbonate	0.44	0.26	0.52
Phosphoric Acid	0.47	0.48	0.47
TEC (plant with therm- ionic topping cycle)	-0.60	-0.20	-0.61
AFB-Utility	0.62	0.30	0.97
AFB-Industrial	0.54	0.22	0.53
PFB-Utility	0.76	0.43	0.81
Coal-Oil Mixtures	0.24	0.24	0.24
Organic Rankine Cycle	0.26	0.17	0.05
Open Cycle Gas Turbine	0.17	-0.10	0.21
Stirling Engine	0.34	0.18	0.25
Adv. Diesel (DARE)	0.40	0.24	0.09
Adv. Gas Turbine (RALFE)	-0.07	0.09	0.20
Closed Cycle Gas Turbine	0.03	0.12	0.10

¹Results for Enhanced funding.

These observations are summarized with the use of correlation coefficients in Table 17. The correlation coefficient is a measure of "closeness" for two sets of data with an absolute range of 0 to 1. The lower end, 0, corresponds to "no correlation" while 1 corresponds to "perfect correlation."

Table 17

Correlation Between Project Ratings: Base Case
COMPOSITE I, and COMPOSITE II

Comparison ¹	Correlation Coefficient
Base Case to COMPOSITE I	0.89
Base Case to COMPOSITE II	0.92
COMPOSITE I to COMPOSITE II	0.79

¹For enhanced funding

Figure 3 summarizes the changes in project ranks between the base case and COMPOSITE II. There are 3 significant rank changes: (1) RALFE increases by 4 positions because of higher consumer savings using ECAS cost of energy; (2) ORC and (3) DARE drop in rank by 4 and 7 positions respectively. The reasons for these changes are the use of low D_T values (lower than base case and COMPOSITE I) and the relatively low consumer savings of these projects. Although other projects have low consumer savings, ORC and DARE also have relatively low quads supplied and EIS values so the use of the revised rating formula which stresses absolute consumer savings (instead of a savings/cost ratio) lower these two projects' ratings more than others. The COMPOSITE II comparison has 10 of 16 projects in the "Minimal or No Change" rank category.

Figure 3

Changes in Ranks: COMPOSITE II Scenario
Compared to Base Case

Rank Changes: Number of Positions	Projects	Category of Change
+5	--	Significant Change
+4	RALFE	
<hr/>		
+3	Open Cycle Gas Turbine, Coal-Oil Mixtures	Moderate Change
+2	--	
<hr/>		
+1	Adv. Flue Gas Cleanup, Molten Carbonate, AFB-Utility, Stirling Engine and Closed Cycle Gas Turbine	Minimal or No Change
0	Reliable Lime/Limestone, TEC, AFB-Industrial	
-1	Phosphoric Acid, PFB-Utility	
<hr/>		
-2	Advanced FGD	Moderate Change
-3	--	
<hr/>		
-4	ORC	Significant Change
↓	--	
-7	DARE	

3. Summary

The two composite scenarios presented above give the viable alternatives to the base case. Comparison of the base case to each composite scenario was performed to help explain differences between them. More important than these differences though, is the fact that the base case and the two composite scenarios yield a reasonable range of values for inputs, quads supplied and consumer savings. This range can be used in several ways. The lower end of the range can be used as a "low" or "pessimistic" estimate for each project's outputs and the higher end of the range defined by the 3 scenarios represents a "high" or "optimistic" estimate for the same outputs. One may also use this range to select specific values -- either high, low, or some sort of average -- for each project. Management can thus rely on the ranges to compensate for uncertainty in inputs or select specific values in an attempt to obtain an optimal or "most realistic" set of output. Much judgment is -- and should be -- involved in this process. Only by combining quantitative results with judgment can appropriate planning and budget decisions be made. The two composite scenarios with the base case also provide a range of project ranks. However, it should be noted that this range incorporates two alternative ratings formulas and not simply differences in project data. Hence the comparison of ratings and ranks must be performed with caution.

SECTION IV - ECONOMIC COMPARISON OF DIVISION PROJECTS TO SYNFUELS

All results presented up to this point refer solely to the division projects or to conventional technologies. This section introduces another relevant comparison: division projects' cost of energy as compared to that of technologies using advanced coal synfuels. These synfuels include coal refined into either more efficient coal solids or coal-derived liquids. Using the same economic ground rules as used elsewhere in this report for the calculation of cost of energy (COE) values,¹ the following values were computed for the synfuels technologies:

Cost of Fuel (\$/MMBtu) --1978 dollars--	Computed COE (mills/kwh) --1978 dollars--	
	36% Efficiency	34% Efficiency
3	51.3	53.0
4	60.8	63.1
5	70.3	73.1

The three fuel costs estimates (3, 4, 5 dollars per million Btus) provide a realistic range of the probable synfuel costs.

The synfuels COE values given above represent an increase of 37 to 95 percent (depending on efficiency and fuel cost values chosen) above the conventional utility technology² COE which is 37.5 mills per kwh. In addition, these estimates are significantly higher than the COE values for all division projects; many of which have COE values lower than the conventional technology value of 37.5 mills per kwh.³ Hence, an economic comparison of division projects to

¹See Volume I, Appendix A of this report.

²Pulverized coal with scrubber plant.

³This is true of both computed and ECAS COE values.

technologies using these more costly synfuels indicates that the former are significantly more desirable. Even with the high efficiency (0.36) and low fuel cost (\$3/MMBtu) estimates, the computed COE for synfuels refined from coal (51.3 mills/kwh) is significantly higher than most division projects' COE -- by as much as 50 percent higher. These results, which use the same economic ground rules, for all computations, indicate that the synfuels technologies are not competitive with technologies being developed by the Division of Fossil Fuel Utilization.

SECTION V - CONCLUSIONS

This section recapitulates the results obtained in Volume I and the previous sections of this volume and draws a set of conclusions from the results. The following section presents a set of recommended next steps in the continuation of project appraisal efforts. It is important to document the conclusions of this task in a way which leads naturally to future appraisal efforts. By taking this approach, the success of future methodology refinement, data collection, and appraisal implementation is assured.

A. SUMMARY OF RESULTS

The sensitivity analysis task consisted of analysis of nine project appraisal variables. These variables were chosen as the most important inputs to the project appraisal methodology implementation. The task was designed to assess the sensitivity of appraisal results to changes in each of these nine variables so as to:

- Revise the final results of 1979 project appraisal and present alternative results constituting a range of output.
- Explain the differences between computed ranks and professional judgment ranks.
- Provide the first inputs to refinement of the appraisal methodology for future applications.

This report accomplishes all three of the above objectives. The base case scenario results give finalized quads supplied, consumer savings, and project ratings.¹ The combination of alternative scenarios and the two composite scenarios

¹The finalized results given as base case constitute a refinement of the previously documented output given in Results of FY 1979 Project Appraisal, Santa Fe Corporation, April 1979.

provide a range of data inputs and outputs for each project. Individual scenarios can be used to explain differences between computed and judgmental ranks.

In general, the sensitivity analysis results indicate that both quads supplied and consumer savings do not vary considerably with changes in most of the "key variables." Changes in "additional variables" also do not effect major changes with the exception of the "no growth" market potential scenario. The impact of changes in all variables (both "key" and "additional") on project ratings is less than the impact on the computed quads supplied and consumer savings outputs. Furthermore, the results show an even smaller--almost insignificant--impact on the overall rank-order of projects derived from ratings. There are a few exceptions to this statement: projects with large difference between base case and ECAS cost of energy (e.g., RALFE) can change rank by a significant amount. In summary, the results of this study indicate that the Project Appraisal Methodology (PAM) is relatively insensitive to small changes in input values. This confirms the validity of PAM's structure.

The results also help to explain the differences between computed and judgmental ranks by pinpointing the particular variables responsible for those differences. For example, many division projects with negative consumer savings received relatively high judgmental ranks. When the consumer savings is recalculated using a lower cost of energy (e.g., the ECAS estimate when it is lower than the base case) a project's rank can increase significantly, bringing it somewhat closer to its judgmental rank. Several of the differences in ranks occur because the judgmental rank takes into consideration criteria not explicitly incorporated into the project appraisal methodology. However, the sensitivity analysis is able to identify those variables which best explain the differences between computed and judgmental ranks. Detailed explanations appear in the conclusions sections of Volume I and in the appraisal results report.² A summary of these explanations is

² Results of FY 1979 Project Appraisal, Santa Fe Corporation, April 1979.

provided as Table 18. Three categories of difference in ranks are used: small, moderate, and large. Small differences between computed and judgmental rank are relatively insignificant and require no explanation. For moderate and large differences, the variable(s) which cause the differences are summarized.

Table 18

Explanation of Differences Between Computed and Judgmental Ranks

PROJECT	DIFFERENCE IN RANK	VARIABLE(S) WHICH CAUSE THE DIFFERENCE IN RANK
Reliable Lime/Limestone	Moderate	Market potential, maximum market fraction
Advanced FGD	Moderate	COE
Advanced Flue Gas Cleanup	Large	Market potential, maximum market fraction
Molten Carbonate	Small	--
Phosphoric Acid	Small	--
TEC (plant with therm- ionic topping cycle)	Small	--
AFB-Utility	Moderate	D_T , EIS
AFB-Industrial	Moderate	COE
PFB-Utility	Moderate	EIS, COE
Coal-Oil Mixtures	Large	COE
Organic Ranking Cycle	Moderate	D_T , EIS, early commercial- ization
Open Cycle Gas Turbine	Moderate	COE, EIS
Stirling Engine	Moderate	Commercialization date, D_T
Advanced Diesel (DARE)	Moderate	Market potential, maximum market fraction
Advanced Gas Turbine (RALFE)	Large	COE
Closed Cycle Gas Turbine	Small	--

B. OBSERVATIONS

The analysis presented in Volume I and the preceding sections of this volume provides a set of observations on the appraisal data, project ranks, the appraisal exercise as a whole, and the methodology used for project appraisal. These observations, listed below, are derived directly from one or more of the project scenario analyses or the composite scenarios, and are a straightforward extension of the results summarized above.

1. Project Data

- In general, the results indicate that project appraisal input data is reasonably consistent and hence provided meaningful results.
- The analysis shows a moderate sensitivity of results to data inputs so that future efforts should emphasize the importance of obtaining the best data possible.
- The largest impact on results caused by a data input change occurs in the scenarios which use alternative cost of energy values. This implies that it is of utmost importance that cost of energy information is as accurate as possible.

2. Project Ranks

- Although several scenarios cause significant changes in computed results (e.g., quads supplied, consumer savings), there is at most a moderate impact of these scenarios on project ranks. This fact indicates that the set of project ranks is a fairly stable, and hence believable ordering of projects. However, the ranking should never be the only input to planning and budget decisions. The rank-order must be used as a guideline in conjunction with the computed quads supplied and cumulative consumer savings results.
- The largest effect on project ranks stems from changes in several variables at a time. That is, the use of composite scenarios alters the project rank-order more than any single variable change (i.e., a "regular" project scenario).

3. The Appraisal Exercise

- Sensitivity analysis is useful in explaining project merits and differences between project ranks.
- The use of an appraisal panel helped to generate several of the scenarios for sensitivity analysis. The panel's conclusions are an important part of the project appraisal exercise.
- The sensitivity analysis uncovered a few uncertainties and discrepancies associated with project data and data manipulation by program proponents. This result indicates that more careful attention should be paid to procedures for data collection and manipulation in future applications of project appraisal.

4. The Project Appraisal Methodology

- The stability of project ranks and the relatively moderate impact of variable changes on all outputs tends to validate the correctness and robustness of the project appraisal methodology.
- The usefulness of alternative data inputs and the consequent range of results derived from the methodology indicates that it can be an effective tool in post-appraisal analysis in addition to the actual appraisal exercise (i.e., obtaining base case results).
- The appraisal variables which indicate the most sensitivity of results to input are:

--Planning Horizon: Extending the planning horizon beyond 2000 has the biggest impact by significantly affecting all outputs.

--Cost of Energy: The cost of energy has a direct impact on consumer savings and an indirect impact on project ratings. Because consumer savings can change from positive to negative for relatively moderate changes in this variable, cost of energy is an important input.

Because these two variables have the greatest impact on results, future refinement of the methodology should address each of them attentively.

- Several of the appraisal variables exhibit a very minor impact on results when changed by a moderate amount but exhibit a major impact when changed significantly. These variables are:

--Market Potential: Reducing the growth rate from the base case average of five percent to three percent has a small to moderate impact on results while a decrease to zero percent (no growth, just conversions and replacements) has a major impact.

--Commercialization Date: Postponing the commercialization date by one year has a minimal effect on results for most projects while a three year postponement causes very significant changes in results.

--Data Tolerance Factor (D_T): Small changes in the data tolerance factor do not affect project ranks but a sizeable change can cause a significant rank shift.

Careful attention should therefore be paid to ensure that the best data is used for each of these variables.

SECTION VI - NEXT STEPS

A number of improvements in the annual project appraisal exercise have been made in 1979. These improvements were the result of past years' sensitivity analysis, recommendations from the division's interactive planning workshops, and other post-appraisal analyses. Further refinements to the appraisal methodology and the overall appraisal exercise can be made now that a thorough analysis of the 1979 appraisal results has been performed. This section presents recommended refinements and new directions related to project appraisal which could benefit the division's overall planning and budgeting effectiveness.

A. DATA BANK DEVELOPMENT AND INTERACTIVE PLANNING

The analysis presented in this two-volume report provides several benefits:

- It summarizes 1979 project appraisal data and presents appraisal results in a more complete manner by providing a range of information for each project.
- It focuses attention on the problems of uncertainty and potential inconsistency in current data.
- It provides a starting point for full-scale development of a project appraisal data bank which will resolve inconsistencies and mitigate most of the uncertainty associated with the data.

The third of these--a starting point for data bank development--leads naturally from the first two. The sensitivity analysis has helped to pinpoint potential or present problems with the FY 1979 appraisal data. From this starting point, a resolution and/or prevention of problems can be achieved by a concentrated effort on data bank development for the purpose of serving multiple functions:

¹The original base case results are presented in Results of FY 1979 Project Appraisal without comparison to any alternative scenario results.

- Making future appraisal exercises more credible and meaningful
- Making future appraisal exercises easier to implement in a constrained timeframe
- Providing data input to control of decentralized projects
- Providing a wholly consistent source of easily accessed data for all phases of the budget and planning cycle.

A data bank development task would systematically perform the following steps:

1. Identify markets, market subsectors, and subsector applications for all division projects resolving current questions as to which sectors, subsectors, and application areas actually do apply.
2. Identify competing technologies as a function of time in each market (to the level of subsector).
3. Identify all system characteristics fully:
 - efficiency
 - costs (capital, fuel, etc.)
 - reliability
 - pollution burden
 - other
4. Quantify all information in common (comparable) terms and tie into existing data banks where possible.
5. Develop a computerized management information system containing the above information.
6. Implement the information system in an interactive mode for easy access and use.

By performing the above steps with FY 1979 data and documented references as a starting point to actual data bank development, the implementation of the project appraisal methodology in future years can be assured of greater success, real time assessment of projects, and more credible and justifiable appraisal results. As noted above, the development of an appraisal data bank will also benefit other

phases of the division planning and budgeting process. Taken together, these benefits constitute a potentially substantial increase in the overall effectiveness of division management.

B. INFORMATION SYSTEMS AND DECENTRALIZATION

The project information collected during the annual appraisal exercise can be used in the guidance of other division operations such as the control of decentralized projects. The project appraisal methodology could contribute in this area by providing a system for incorporating project data on a timely basis from the field. Such a system could cause the project managers to maintain current files on all on-going field projects related to the decentralization effort. Using this data in real time application of the project appraisal methodology would help division management to summarize field data, plan future decentralization tasks, and coordinate field operations with the project appraisal/budgeting exercise.

C. MARKET PENETRATION ANALYSIS AND MODEL COORDINATION

Perhaps the most important part of the appraisal exercise is assessment of a project's market potential and the estimated penetration into the market of interest. In 1979, a major step towards achievement of realistic market assessment information was taken with the implementation of a systematic market penetration analysis methodology.² The use of this methodology provided generally consistent and useful input to the project appraisal exercise. The next step is to refine the market assessment of division projects by incorporating more relevant detail and revised data into the analysis and computerizing the market penetration methodology for consistent results and real time interactive use.

²Market Penetration Handbook, Santa Fe Corporation, February 1979.

Past analyses³ have shown that the market penetration inputs are the most critical variables in the project appraisal methodology. Hence it is of prime importance and great potential benefit to the division to have a refined market assessment tool with a real time capability. Furthermore, such a system could be used in conjunction with other division models presently in use or planned for future use -- utility sector models, process analysis and technical evaluation models, etc. -- to provide a greater degree of coordination and increased analytical power.

D. REFINEMENT OF PROJECT APPRAISAL METHODOLOGY

In addition to the above tasks it is important to maintain relevance by incorporating sensitivity analysis results and the next steps into refinement of the project appraisal methodology. For example, several possible refinements to the methodology include:

1. Extending the timeframe horizon from the year 2000 to 2010
2. Clarifying definitions of R&D funding levels and guidelines for obtaining preferred (judgmental) ranks.
3. Developing specific means of rating supportive technologies (e.g., cleanup) and means of evaluating multi-market technologies more comprehensively (e.g., Heat engines).
4. Incorporating the use of data ranges into the appraisal analysis.
5. Converting the market penetration and project appraisal methodologies to real time interactive systems.

³These analyses include this Sensitivity Analysis report (Vols. I and II) and the previous year's report, Sensitivity Analysis for Project Appraisal, Santa Fe Corporation, August 1978.

The last of these refinements includes incorporation of the project appraisal methodology (PAM) into a unified system of technology assessment and budget allocation as shown in Figure 4. This unified framework can be achieved with the use of various economic and engineering process models. The key to the framework is a linking of these models with the methodology presented in the Market Penetration Handbook and PAM. Adding to human interaction via PAM allows for the explicit incorporation of important judgmental input by using a scoring approach. Finally, this framework of links allows for feedback from human interaction via PAM to both the economic and process assessment models.

The economic assessment model can be industry specific (e.g., utilities) and/or regional. It should include standard econometric capabilities to forecast supply, demand, and other price characteristics. The process assessment model provides the ability to quantify material inputs such as labor, capital, and environmental impacts by using engineering information. These two assessment models feed into the market penetration analysis which incorporates both engineering (process) information and economic projections into an estimation of effective penetration for each technology (project) evaluated. There are also feedbacks from the penetration analysis to insure consistency in the assessment and economic equilibrium.

Once a market penetration analysis is performed, the results feed into the exercise of the project appraisal methodology (PAM) which calculates and displays relevant absolutes and formulates useful benefit/cost ratios and project scores. The latter two outputs allow for the use of professional judgment in R&D planning and budget allocation. Finally, the intrinsic link between PAM and division management insures successful coordination of all

Figure 4

A Unified Framework for Technology Assessment and R&D Budget Allocation

models and decisions involved. This unified framework is ideally suited to the real time use of the market penetration and project appraisal methodologies which the Division of Fossil Fuel Utilization has developed and successfully implemented. Future use of these tools will be most beneficial if they are combined with the available assessment models in a framework such as that given in Figure 4.

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