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MASTER

PROJECT APPRAISAL METHODOLOGY
SENSITIVITY ANALYSIS

D R A F T

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SECTION I - INTRODUCTION

The purpose of this report is to provide the Division of Fossil Fuel Utilization of the U.S. Department of Energy (DOE) with an analysis of the results of exercising the Division's project appraisal methodology during FY 1978. These results will be used to determine priorities for making further adjustments and refinements in the methodology in subsequent fiscal years.

The division uses the project appraisal methodology (PAM) to make decisions about how to allocate federal funds to candidate R&D projects. The division is responsible for over 30 research and development (R&D) projects. Due to the large number of projects and the great variety in projects, funding decisions would be difficult without a methodology.

The methodology scores R&D projects according to the following eight criteria:

- Energy savings
- Technical risk
- Cost
- Commercial potential
- Uniqueness
- Resource availability
- Environmental impact
- Legal, social, and institutional effects.

Projects with high scores are deemed more favorable for funding than projects with low scores.

Using this methodology, the Division of Fossil Fuel Utilization conducted a project appraisal session in the early part of 1978. The results of this session were then used to prepare the division's FY 1980 budget submission.¹ Since the appraisal was conducted, two issues have been raised concerning the methodology. The first issue relates to the question: how accurate must project data be in order to make a reasonably sound assessment of a project's merit relative to other candidate projects? Improving the accuracy of data such as market potential and market penetration would require considerable effort on the part of program managers. Moreover appraisal panel members need to know what data should be validated. What the division wanted to know was which data inputs have the greatest impact on project scores. An understanding of the sensitivity of scores to data inputs would enable the division to set priorities for refining and validating data inputs.

The second issue pertains to the question: which elements of the methodology should be altered to reflect changes in the division's mission? New guidance was provided recently to the division establishing a set of program priorities. Furthermore, the division's mission has been changing rapidly over the last two years as a result of reorganization and evolution of energy policy. Further changes in the division's mission are anticipated in the future. Thus, it was determined that a sensitivity analysis also should be conducted on the energy savings weighting factors. These factors are the elements of the methodology, as it is currently structured, which measure the alignment of projects with the division's mission.

¹U.S. Department of Energy, Division of Power Systems, FY 1978 Project Appraisal Application and Results (DOE/ET-0057) (Springfield, VA: NTIS, 1978).

This report presents the results of the sensitivity analysis, in an effort to address the above issues. Section II, Analysis of the Project Appraisal Methodology, summarizes the characteristics of the variables analyzed and assesses their impact on Figures of Merit. Section III, Results and Conclusions, is a discussion of conclusions and recommendations for altering the methodology and improving data inputs. The Appendix, Unweighted Project Energy Savings, presents yearly and cumulative project energy savings for the years 1980-2000.

SECTION II - ANALYSIS OF THE PROJECT APPRAISAL METHODOLOGY

A. CHARACTERISTICS OF THE METHODOLOGY

The project appraisal methodology employed by the Division of Fossil Fuel Utilization is a scoring model whereby points are awarded to candidate R&D projects as a measure of their relative potential for achieving a stated set of energy goals. Project scores are used to ascertain which projects should be funded and at what levels.²

The methodology combines both a Figure of Merit (FOM) and a Subjective Assessment (S) into an overall project score. This overall score is calculated by first normalizing both components, then multiplying the normalized Subjective Assessment by 0.15, and finally adding the two components together. This process is shown below:

$$FOM_N + 0.15S_N = \text{OVERALL PROJECT SCORE}$$

Projects are then ranked according to their overall score, with projects having the highest score at the top of the list.

In this study the attributes of the variables in the Figure of Merit were examined. The Figure of Merit is composed of two numerics: energy savings and project cost. Together, they formulate the Figure of Merit in the following fashion:

$$\text{FIGURE OF MERIT} = \frac{\text{CUMULATIVE ENERGY SAVINGS (1980-2000)}}{1980 \text{ FEDERAL R\&D COST}}$$

The denominator of the Figure of Merit expresses the 1980 dollar cost to the federal government of the R&D project. Three dollar figures are

² U.S. Department of Energy, Division of Power Systems, "Project Appraisal Methodology," January 1978.

used, one for each of the following funding levels: minimum, current, and enhanced. The numerator, on the other hand, is composed of many elements, including:

- Energy savings per unit per year
- Energy savings weighting factors
- Market potential
- Market penetration

Mathematically, the numerator of the Figure of Merit is arrived at in the following manner:

$$(1) \quad \begin{array}{l} \text{Cumulative} \\ \text{Energy} \\ \text{Savings} \end{array} = \sum_{t=1980}^{2000} \left(\frac{\text{Energy Savings}}{\text{Unit-Year}} \times \text{Cumulative Unit-Years} \right)$$

$$(2) \quad \sum_{t=1980}^{2000} \left[ES_a(t) \times CUI(t) \right]$$

where

$ES_a(t)$ = Adjusted energy savings per unit during year t (energy savings are adjusted by weighting factors)

$CUI(t)$ = Cumulative number of units installed through year t , or unit-years.

Taking each of the two components of the numerator of equation (2) separately, we have

$$(3) \quad ES_a(t) = W_p \times ES_p(t) + W_g \times ES_g(t) + W_o \times ES_o(t)$$

where

ES_p = energy savings, petroleum (quads/unit/year)

ES_g = energy savings, gas (quads/unit/year)

ES_o = energy savings, other resources (quads/unit/year)

W_p = weighting factor for petroleum savings

W_g = weighting factor of gas savings

W_o = weighting factor for other savings

Similarly,

$$(4) \quad CUI(t) \approx \sum_{t'=1980}^t \left\{ UI(t') \times [P_i(t') - P_o(t')] \right\}$$

where

$UI(t')$ = maximum potential units installed in year t'

$P_i(t')$ = percent of market penetrated at the i^{th} funding level in year t'

$P_o(t')$ = percent of market penetrated with no government funding in year t' .

For the conduct of the project appraisal in FY 1978, energy savings weighting factors were assigned the following values:

	1980-1985	1986-2000
PETROLEUM SAVINGS	2.0	0.6
GAS SAVINGS	1.5	0.6
OTHER SAVINGS	0.1	0.2

B. SENSITIVITY ANALYSIS

The sensitivity analysis was conducted to evaluate the effect of variables on a project's Figure of Merit. In particular, this was accomplished by holding all of the variables constant, except for the variable

being studied. The variable under examination was then increased and decreased by 100 percent. The impact of this variable on the Figure of Merit was then measured by calculating the percentage change in the Figure of Merit attributable to an equivalent percentage change in the variable. The analytic process is graphically displayed below:

If a change in the Figure of Merit was greater than or equal to 100 percent for a 100 percent change in the variable being studied, it was deemed the variable had a major impact on the Figure of Merit. A change in the Figure of Merit of less than 10 percent for a 100 percent change in the variable being studied was interpreted as a minor impact on the Figure of Merit. A variable which, when changed 100 percent, resulted in a change of between 11 and 99 percent in the Figure of Merit was deemed to have a moderate impact.

The data base chosen for the analysis was purposely selected to reflect accurate, real-world project scores. Consequently, data was used for 11 of the 27 projects scored in the recently concluded FY 1978 project appraisal session. Each of these 11 projects was reviewed by the appraisal panel and

thus have updated and agreed upon data. In addition, the selected projects encompass all four of the division's activity areas and involve a broad range of technologies. Data from the following projects were used in the analysis:

ACTIVITY	PROJECT
FUEL CELLS	MOLTEN CARBONATE FUEL CELL ON-SITE INTEGRATED ENERGY SYSTEM 4.8 MW FUEL CELL
ADVANCED ENVIRONMENTAL CONTROL TECHNOLOGY	LIME/LIMESTONE ADVANCED CLEANUP
HEAT ENGINES	DIRECTLY FIRED HEAT CYCLES HIGH-GRADE HEAT OPEN-CYCLE GAS TURBINES
COMBUSTION SYSTEMS	PRESSURIZED FLUIDIZED-BED - UTILITIES ATMOSPHERIC-PRESSURE FLUIDIZED-BED - ENGINE COMBUSTION TECHNOLOGIES

For each of these projects, the following variables were analyzed:

- Energy savings weighting factors
- Market potential and market penetration
- Project cost

1. Energy Savings Weighting Factors

The first set of variables examined was the energy savings weighting factors. These weighting factors are multipliers of the true energy savings for any given R&D project and, in general, will increase the scores of those projects which result in savings during the 1980 to 1985 time frame while penalizing projects which result in energy savings only during the

1986 to 2000 time frame. Based on the National Energy Plan to "provide for energy conservation by 1985," the weighting factors are structurally designed to score favorably those projects that meet this goal. Thus, as shown below, petroleum savings in the 1980 to 1985 time frame are doubled, while petroleum savings in the 1986 to 2000 time frame are valued at only 60 percent of their true worth.

	1980-1985	1986-2000
PETROLEUM	2.0	0.6
NATURAL GAS	1.5	0.6
OTHER	0.1	0.2

ENERGY SAVINGS WEIGHTING FACTORS

To see how changes in weighting factors affect Figures of Merit, each was increased and decreased 100 percent, using incremental steps of 50 percent, while all other variables were held constant. This analysis was performed for each of 11 projects. The degree of the changes in Figures of Merit, averaged over the 11 projects, are summarized below:

	1980-1985	1986-2000
PETROLEUM	MINOR	MAJOR
NATURAL GAS	MINOR	MINOR
OTHER	MINOR	MODERATE

Overall, changing energy savings weighting factors in the 1980-1985 time frame has little or no impact on Figures of Merit. In all cases this result is traceable to a singular trait: the division's existing R&D projects provide virtually no early energy savings. Even at the enhanced level of funding,

only 1 percent of total energy savings are realized for all projects prior to 1986; the remaining 99 percent accrue after 1985. Consequently, altering the weighting factors yields only negligible effects on overall project scores.

Each of three weighting factors in the 1986 to 2000 time frame affects the Figures of Merit differently. The most dominant variable of the three is the petroleum savings weighting factor. Increasing this factor by 100 percent doubles the Figures of Merit. It is evident the major portion of energy savings during this time period are in petroleum; thus the savings fall into and are greatly affected by the domain of this one variable.

The second variable in the 1986 to 2000 time frame, the weighting factor for natural gas savings, plays a minor role in determining overall project scores. As in the case of the 1980 to 1985 weighting variables, this is because few gas savings accrue between 1986 and 2000, not because of the value of the weighting factor.

The weighting factor for other savings, the third variable in the 1986 to 2000 time frame, is the most interesting of the three in that it can affect project scores negatively. That is, as the weighting factor increases in value, the Figure of Merit decreases, and vice versa. This result is brought about because it is possible for projects that use other resources to have negative energy savings. For example, projects that switch from oil to coal would have positive oil savings and negative coal savings. In the majority of the projects used for this analysis, this was the case. Overall, in addition to affecting project scores negatively, this weighting factor,

when varied, affects the Figure of Merit moderately. This is because of the moderate presence of other energy savings during this time frame.

The complete range of changes in Figures of Merit attributable to changes of $\pm$ 100 percent in each of these six weighting factor variables is shown in Figures II-1 through II-6.

2. Market Potential and Market Penetration Variables

The Figure of Merit varies directly with changes in market potential and market penetration variables (see equation (4)) and with a 1:1 correspondence to changes in each of these two variables. If, for example, the market potential estimates for any given project are doubled, the total energy savings for that particular project are doubled, and consequently the Figure of Merit for that project is doubled. The same is true for market penetration estimates. Thus both of these variables have a major impact on the Figure of Merit. The results of this finding are graphically displayed in Figures II-7 through II-8. Because of the 1:1 correspondence, the slope of the curves is unity.

3. Project Cost Variables

A project's cost is inversely related to its Figure of Merit, where the Figure of Merit approaches infinity as the cost approaches zero. Thus, Figures of Merit are more sensitive to decreases in project costs than to increases. In other words, a decrease in cost causes a greater rate of change in the Figure of Merit than an equivalent increase in cost. Further, a decrease in cost results in a positive change while an increase in cost results in a negative change. This is true for all projects, irrespective of the funding level specified, whether minimum, current, or enhanced. The results are shown in Figure II-9.

% CHANGE IN
FIGURE OF MERIT

FIGURE II-1. SENSITIVITY OF FIGURE OF MERIT TO PETROLEUM SAVINGS (1980-1985) WEIGHTING FACTOR

FIGURE II-2. SENSITIVITY OF FIGURE OF MERIT TO NATURAL GAS SAVINGS (1980-1985) WEIGHTING FACTOR

FIGURE II-4. SENSITIVITY OF FIGURE OF MERIT TO PETROLEUM SAVINGS (1986-2000) WEIGHTING FACTOR

FIGURE II-5. SENSITIVITY OF FIGURE OF MERIT TO NATURAL GAS SAVINGS (1986-2000) WEIGHTING FACTOR

FIGURE II-6. SENSITIVITY TO FIGURE OF MERIT TO OTHER SAVINGS
(1986-2000) WEIGHTING FACTOR

FIGURE II-7. SENSITIVITY OF FIGURE OF MERIT TO MARKET POTENTIAL

FIGURE II-8. SENSITIVITY OF FIGURE OF MERIT TO MARKET PENETRATION

MINIMUM
CURRENT
ENHANCED } FUNDING LEVEL

% CHANGE IN
FIGURE OF MERIT

% CHANGE IN
PROJECT
COST

% CHANGE IN
PROJECT
COST

MINIMUM
CURRENT
ENHANCED

FUNDING LEVEL

% CHANGE IN
FIGURE OF MERIT

FIGURE II-9. SENSITIVITY OF FIGURE OF MERIT TO PROJECT COST

C. EFFECTS OF SUBSTITUTING TOTAL PROJECT COSTS FOR CURRENT PROJECT COSTS

During the conduct of the FY 1978 project appraisal, a decision was made to use only FY 1980 project cost, as opposed to total cost or a fixed percentage of total dollars required over a project's life. Although adopting this policy simplifies data requirements, it brings into play a potentially serious drawback--yearly fluctuations in a project cost could cause major changes in Figures of Merit and project rankings. For example, if a project's cost is halved, its Figure of Merit doubles and, if a project's cost is doubled, its Figure of Merit is halved. Consequently, it is conceivable that a project could experience a high ranking one year and a low ranking the next, solely because of yearly deviations in cost.

To ascertain whether or not this problem may have affected project ranks this year, Figures of Merit were computed for the 11 projects using total project costs. Both sets of Figures of Merit were then ranked from 1 to 21, and the difference between the two ranks was calculated. This difference was then used to determine how closely the rankings based on FY 1980 project costs compared with the rankings on total project costs. This comparison revealed a positive 0.92 correlation by computing Spearman's Rank correlation coefficient. This decidedly high correlation coefficient indicates virtual sameness between the two sets of rankings. Thus, no significant problem currently exists, although it may in future years.

Changes in the rankings of Figures of Merit are shown in Table II-1.

TABLE II-1. RANKINGS OF FOM'S: 1980 PROJECT COSTS VERSUS TOTAL PROJECT COSTS

PROJECT (ACTIVITY)	FUNDING LEVEL	FIGURE OF MERIT BASED ON 1980 COSTS	FOM'S RANK	FIGURE OF MERIT BASED ON TOTAL COST	FOM'S RANK	CHANGE IN FOM'S RANK
MOLTEN CARB (FC)	CURR	0.1085	17	0.0056	17	0
	ENH	0.1677	14	0.0090	15	-1
O/S IES (FC)	CURR	1.3801	5	0.3167	6	-1
	ENH	2.0209	2	0.4507	5	-3
4.8MW (FC)	CURR	0.3055	13	0.0925	10	+3
	ENH	0.3160	12	0.1539	8	+4
LIME/LIMESTONE (ADV)	CURR	--	--	--	--	--
	ENH	1.0986	7	0.2510	7	0
ADVANCED CLEANUP (ADV)	CURR	0.1182	15	0.0025	21	-6
	ENH	0.1081	18	0.0094	14	+4
DIRECTLY FIRED HEAT (HE)	CURR	0.7737	10	0.0763	11	-1
	ENH	0.7762	9	0.1159	9	0
HIGH GRADE HEAT (HE)	CURR	0.7894	8	0.0419	12	-4
	ENH	0.5365	11	0.0290	13	-2
OPEN CYCLE GAS TUR (HE)	CURR	0.1032	19	0.0029	19	0
	ENH	0.0991	20	0.0028	20	0
PFB UTILITY (CS)	CURR	0.0775	21	0.0053	18	+3
	ENH	0.1112	16	0.0069	16	0
AFB INDUSTRIAL (CS)	CURR	1.8795	4	6.0771	1	+3
	ENH	1.1359	6	1.0068	4	+2
ENGINE COMBUS TECH (CS)	CURR	1.9239	3	2.4946	3	0
	ENH	2.0897	1	3.3886	2	-1

CURR=CURRENT ENH=ENHANCED FC=FUEL CELLS ADV=ADVANCED ENVIRONMENTAL CONTROL TECHNOLOGY
 HE=HEAT ENGINES CS=COMBUSTION SYSTEMS

D. MARGINAL RETURNS ANALYSIS

Figures of Merit, in absolute terms, indicate a project's benefit to cost ratio at three distinct funding levels. But it does not indicate the rate of change in benefits when funding is increased from the minimum level to the current level and to the enhanced level. It is important to ascertain the rate of change because incremental funding does not always result in proportionally more benefits. Thus, calculating marginal returns indicates whether a project would be funded past the point of diminishing return if a higher funding level were selected.

Marginal returns denotes the added benefit of investing additional funds beyond the minimum funding level. The measure is derived by dividing marginal benefits (energy savings) by marginal cost. Marginal benefits (∂B) equals the difference between the adjusted energy savings of a project funded at a given level and the savings that would result if the project were funded at the next higher level. The difference may be either positive or negative. Marginal cost (∂S) equals the difference between a given funding level and the next higher funding level; for example, the dollar difference between the minimum funding level and the current funding level. Table II-2 shows the calculations of marginal returns for each of 11 projects. The marginal returns of the Engine Combustion Technology Project, for example, are relatively high (5.8) when funding is increased from the minimum level to the current level. The marginal returns are lower (2.5), however, when funding is increased further to the enhanced level.

To ascertain changes in rates of return when funding is increased from the minimum level to the enhanced level, marginal returns ($\partial B / \partial S$) are plotted against R&D costs in Figures II-10 through II-13. Figure II-10,

for example, plots the rate of return for the On-Site Integrated Energy Systems Fuel Cell Project. A marginal return of 1.2 is plotted for the minimum funding level of \$11.5 million, and a return of 8.0 is plotted for the enhanced funding level of \$15.5 million. The steep positive slope of the line connecting these two points indicates that a high rate of return would result if funding for this project were increased from the minimum level to the enhanced level. On the other hand, the Engine Combustion Technology Project demonstrates a decline in the rate of return if funding were increased to the enhanced level. This decline is shown in Figure II-13. A marginal return of 5.8 is plotted for the minimum funding level of \$2.5 million and a return of 2.5 is plotted for the enhanced level of \$4.5 million. The negative slope of the line indicates that although returns are relatively high when funding is increased from the minimum to the current level, the rate of return diminishes when funding is increased to the enhanced level.

Of the 11 projects, only 3 showed an increasing rate of return when funding is increased for the minimum level to the enhanced level. These three projects are On-Site Integrated Energy Systems, Molten Carbonate, and 4.8 MW; all are in the fuel cell activity area. The other 8 projects showed either no additional or decreasing rates of return.

The analysis of marginal returns indicates that while a project may rank higher than another at the enhanced funding level, the actual rate of return may be lower. For example, the Engine Combustion Technology Project ranked 2.09 while the On-Site Integrated Energy System Project ranked 2.02 at the enhanced funding level. Yet, the rate of return from increased funding of the On-Site Integrated Energy Systems Project is much higher than that of the Engine Combustion Technology Project, as indicated by the differences in the slopes of the lines for these two projects in Figures II-10 and II-13.

TABLE II-2. MARGINAL RETURNS OF PROJECTS

PROJECT (ACTIVITY)	FUNDING LEVEL DIFFERENCES	MARGINAL BENEFITS (∂B)	MARGINAL COSTS ($\partial \$/$)	MARGINAL RETURNS ($\partial B/\partial \$/$)
MOLTEN CARBONATE (FC)	CURR-MIN	1.3	7.0	0.2
	ENH-CURR	1.7	4.0	0.4
O/S IES (FC)	CURR-MIN	3.1	2.5	1.2
	ENH-CURR	12.0	1.5	8.0
4.8MW (FC)	CURR-MIN	1.7	10.0	0.2
	ENH-CURR	5.0	15.0	0.3
LIME/LIMESTONE (ADV)	CURR-MIN	--	-5.0	--
	ENH-CURR	--	13.0	--
ADVANCED CLEANUP (ADV)	CURR-MIN	-0.3	-5.0	0.1
	ENH-CURR	1.1	19.9	0.1
DIRECTLY FIRED HEAT (HE)	CURR-MIN	6.6	3.0	2.2
	ENH-CURR	6.0	7.7	0.8
HIGH GRADE HEAT (HE)	CURR-MIN	9.4	6.8	1.4
	ENH-CURR	-2.8	2.4	-1.2
OPEN CYCLE GAS (HE)	CURR-MIN	2.8	7.5	0.4
	ENH-CURR	0.9	10.7	0.1
PFB UTILITY (CS)	CURR-MIN	1.7	1.0	1.7
	ENH-CURR	1.9	9.0	0.2
AFB INDUSTRIAL (CS)	CURR-MIN	27.9	1.0	27.9
	ENH-CURR	4.0	9.8	0.4
ENGINE COMBUSTION TECH (CS)	CURR-MIN	4.6	0.8	5.8
	ENH-CURR	3.0	1.2	2.5

MIN=MINIMUM FUNDING

CURR=CURRENT FUNDING

ENH=ENHANCED FUNDING

FIGURE. II-10. RATE OF CHANGE IN MARGINAL RETURNS AT MINIMUM AND ENHANCED FUNDING LEVELS: FUEL CELL PROJECTS

FIGURE II-11. RATE OF CHANGE IN MARGINAL RETURNS AT MINIMUM AND ENHANCED FUNDING LEVELS: ADVANCED ENVIRONMENTAL CONTROL TECHNOLOGY PROJECTS

FIGURE II-12. RATE OF CHANGE IN MARGINAL RETURNS AT MINIMUM AND ENHANCED FUNDING LEVELS: HEAT ENGINE PROJECTS

FIGURE II-13. RATE OF CHANGE IN MARGINAL RETURNS AT MINIMUM AND ENHANCED FUNDING LEVELS: COMBUSTION SYSTEM PROJECTS

SECTION III - RESULTS AND CONCLUSIONS

A. CONSIDERATIONS IN USING THE METHODOLOGY

The findings of this study raise several concerns that should be considered when applying the methodology. Those having the greatest implications for future refinements of the appraisal process are discussed below.

The first concern is that projects are ranked relative only to the other projects appraised that year. The PAM is designed to produce overall project scores which can be used directly to rank a given set of projects. This ranking indicates a project's potential for achieving a stated set of objectives relative to the other projects ranked. Consequently, no one knows for sure if the totality of projects being ranked is good, bad, or indifferent. In essence, there is no established standard against which to compare rankings from one year to the next. For example, the highest ranked project for any given year has a normalized Figure of Merit of 1.0. However, the unnormalized Figure of Merit for the highest ranked project may vary greatly from year to year. At present this information is not utilized in the appraisal process. The danger in not having these reference points is that one may unknowingly fund marginal or mediocre projects.

The second concern relates to the environment in which the methodology is used. The PAM works most effectively in a competitive environment. At present this is the case; four different technological arenas, or activities, are competing for the same research and development dollars. Thus, an activity manager must seek out the "best" projects for appraisal in order to maintain or increase his or her share of the R&D funds available to the division. Should the PAM be used in a non competitive environment, it is conceivable that there would be no incentive to seek out the "best" projects.

The third concern is the need for the PAM to be updated continuously. Conceived to reflect National Energy Plan goals and the division's mission by weighting project energy savings according to a set of priorities, the appraisal methodology needs to be periodically reviewed and updated to ensure that alignment with the division's mission is maintained and that changes in energy policy are reflected in Figures of Merit.

The fourth concern relates to the need for accurate project data if the PAM is to provide accurate project rankings. Not all data contributes equally to a project's Figure of Merit; thus, accuracy is more important for some data inputs than for others. Understandably, it is important to know which variables require the most and least accurate data and to ensure that data is improved where accuracy is important.

B. CONCLUSIONS

There is a real need to focus attention during future project appraisal sessions on data that is most likely to influence Figures of Merit. In addition to facilitating an efficient and smoothly run review of projects, this directed emphasis on accuracy adds to the integrity of using the PAM as a management tool.

The analysis indicated that Figures of Merit are highly sensitive to data on market potential and market penetration and that their impact is equally strong. Therefore, improvements in the accuracy of these data inputs would contribute substantially to the validity of project rankings.

The sensitivity of Figures of Merit to weighting factors varied considerably. The six weighting factors are listed below according to the degree of impact each had on the Figures of Merit:

WEIGHTING FACTORSENSITIVITY OF FOM

1. Petroleum savings (1986-2000)	HIGH
2. Other savings (1986-2000)	MODERATE
3. Natural gas savings (1986-2000)	LOW
4. Petroleum savings (1980-1985)	↓
5. Natural gas savings (1980-1985)	
6. Other savings (1980-1985)	LOWEST

Although Figures of Merit exhibited a low sensitivity to the bottom four weighting factors, the degree of impact varied for each.

Only two of the weighting factors impact significantly on the Figures of Merit because the projects save little energy during the period 1980 to 1985. In other words projects only had substantial savings of oil and other resources and only during the period 1986 to 2000. Thus, changes to the weighting factors for the 1980 to 1985 period will not significantly affect Figures of Merit, nor will changing the gas savings weighting factor for the period 1986 to 2000.

A major concern indicated by this list is the relatively high ranking of the other savings weighting factor for the period 1986 to 2000. This variable acted negatively on Figures of Merit by decreasing the savings of projects aimed at fuel switching to coal. If this factor were not ranked so high, there would be little need for alarm. However, because of its high ranking, it appears the methodology is somewhat inconsistent with division's energy savings goals. These goals call for the following priorities:

HIGHEST PRIORITY

LOWEST PRIORITY

OIL SAVINGS BY 1985
OIL-TO-COAL SWITCHING BY 1985
GAS SAVINGS BY 1985
GAS-TO-COAL SWITCHING BY 1985
OIL OR GAS SAVINGS BY 2000
OIL-TO-COAL OR GAS-TO-COAL SWITCHING
BY 2000
COAL SAVINGS BY 2000
COAL SAVINGS BY 1985

Fuel switching ranks second, fourth, and sixth in importance. Consequently, to accommodate these priorities, the methodology may need some minor adjustments to add rather than deduct points from fuel switching projects.

Recognizing the dangers present in calculating Figures of Merit using project costs for only the current year, a comparison was made to determine the effect of substituting total project costs to calculate Figures of Merit. The results showed little change in project rankings. This correlation, however, may be due solely to the fact that the current year's project costs are proportional to total project costs. If next year's project costs are non-proportional to total project costs, significant reversals in project ranks may occur.

It also appears that there is merit in supplementing the methodology with other analyses during the project appraisal process. A type of analysis that might be utilized in this context is the calculation of the marginal returns. This analysis, which measures the added benefits obtained by increasing funding levels, would help in making decisions as to whether or not a particular project warrants a higher funding level.

C. RECOMMENDATIONS

The sensitivity analysis has examined the interplay of variables that make up a project's Figure of Merit. In addition, other factors affecting the application of the methodology have been addressed, such as the competitive nature of the environment in which the methodology should be used. In this section, the findings of this study are formulated into a set of recommendations for enhancing future refinement and use of the project appraisal methodology. It is recommended that the division should:

1. Provide for a yearly review of the methodology to ensure that it is aligned with national energy policy and the division's goals and mission. This review is particularly important because of the speed at which the division's goals and mission seem to be evolving. In particular, the methodology should be adjusted so that projects involving fuel switching, presently a high priority, are not penalized.
2. Emphasize the need, in future project appraisal sessions, for accurate data on market potential and market penetration variables which impact highly on Figures of Merit. For example, a handbook for preparing market penetration data should be prepared. In addition, the appraisal panel should be instructed to direct their attention to validating data for variables that most impact the Figures of Merit.

3. Consider supplementing the PAM with additional types of analysis, such as the calculation of marginal returns, to derive for each project the additional benefits obtainable through increased funding. This factor could be decisive in choosing between two seemingly equal projects.
4. Consider using total project cost in the methodology instead of cost for a single year. This replacement would provide more stability in the Figures of Merit of a given project from one year to the next.
5. Develop a data base of unnormalized Figures of Merit and unadjusted energy savings for comparison of projects on a year to year basis. This data base should be used to ensure that the quality of the newer projects at least matches the standards established by previously funded projects.
6. Ensure the project appraisal process remains competitive. Several activity managers should be encouraged to compete for research and development funds, thereby forcing them to submit high quality projects for appraisal.

APPENDIX - UNWEIGHTED ENERGY SAVINGS

Presented in the appendix are graphs showing the accumulated unweighted energy savings (1980-2000) for the 11 projects used in the sensitivity analysis. In addition, tables showing the unweighted energy savings on a yearly basis and a cumulative basis for the years 1980-2000, are also presented for these 11 projects.

FIGURE A-1

MOLTEN CARBONATE (FC)

	MINIMUM FUNDING		CURRENT FUNDING		ENHANCED FUNDING	
	SAVINGS		SAVINGS		SAVINGS	
YEAR	YEARLY	CUMULATIVE	YEARLY	CUMULATIVE	YEARLY	CUMULATIVE
1980	0	0	0	0	0	0
81	0	0	0	0	0	0
82	0	0	0	0	0	0
83	0	0	0	0	0	0
84	0	0	0	0	0	0
1985	0	0	0	0	0	0
1986	0	0	0	0	0	0
87	0	0	0	0	0	0
88	0	0	0	0	0	0
89	0	0	0	0	0	0
1990	0	0	0	0	0	0
1991	0	0	0	0	0	0
92	0	0	0	0	0	0
93	0	0	0	0	0.05	0.05
94	0	0	0.03	0.03	0.15	0.20
1995	0	0	0.10	0.13	0.31	0.51
1996	0.01	0.01	0.20	0.33	0.50	1.01
97	0.05	0.06	0.34	0.67	0.74	1.75
98	0.11	0.17	0.53	1.20	1.00	2.75
99	0.22	0.39	0.75	1.95	1.31	4.06
2000	0.36	0.75	1.00	2.95	1.65	5.71

ENERGY SAVINGS ATTRIBUTABLE TO GOVERNMENT SPENDING (QUADS)

TABLE A-1

CUMULATIVE ENERGY SAVINGS (QUADS) ATTRIBUTABLE TO GOVERNMENT
SPENDING

FIGURE A-2

ON-SITE INTEGRATED ENERGY SYSTEM (FC)

	MINIMUM FUNDING		CURRENT FUNDING		ENHANCED FUNDING	
	SAVINGS		SAVINGS		SAVINGS	
YEAR	YEARLY	CUMULATIVE	YEARLY	CUMULATIVE	YEARLY	CUMULATIVE
1980	0	0	0	0	0	0
81	0	0	0	0	0	0
82	0	0	0	0	0.01	0.01
83	0	0	0.01	0.01	0.03	0.04
84	.01	0.01	0.03	0.04	0.06	0.10
1985	.02	0.03	0.07	0.11	0.14	0.24
1986	0.06	0.09	0.14	0.25	0.26	0.50
87	0.10	0.19	0.22	0.47	0.40	0.90
88	0.16	0.35	0.36	0.83	0.60	1.50
89	0.29	0.64	0.54	1.37	0.85	2.35
1990	0.47	1.11	0.77	2.14	1.21	3.56
1991	0.70	1.81	1.02	3.16	1.72	5.28
92	0.98	2.79	1.33	4.49	2.27	7.55
93	1.32	4.11	1.69	6.18	2.87	10.42
94	1.71	5.82	2.10	8.28	3.52	13.94
1995	2.15	7.97	2.57	10.85	4.22	18.16
1996	2.66	10.63	3.08	13.93	4.98	23.14
97	3.20	13.83	3.61	17.54	5.79	28.93
98	3.76	17.59	4.18	21.72	6.65	35.58
99	4.37	21.97	4.79	26.51	7.55	43.13
2000	5.01	26.98	5.43	31.94	8.52	51.65

ENERGY SAVINGS ATTRIBUTABLE TO GOVERNMENT SPENDING (QUADS)

4.8 M.W. ELEC POWER PLANTS (FC)

CUMULATIVE ENERGY SAVINGS (QUADS) ATTRIBUTABLE TO GOVERNMENT SPENDING

FIGURE A-3 .

4.8 MW ELECTRIC POWER PLANTS (FC)

YEAR	MINIMUM FUNDING		CURRENT FUNDING		ENHANCED FUNDING	
	SAVINGS		SAVINGS		SAVINGS	
	YEARLY	CUMULATIVE	YEARLY	CUMULATIVE	YEARLY	CUMULATIVE
1980	0.00	0.00	0.00	0.00	0.02	0.02
81	0.00	0.00	0.01	0.01	0.04	0.06
82	0.00	0.00	0.02	0.02	0.08	0.14
83	0.01	0.01	0.03	0.05	0.14	0.28
84	0.02	0.03	0.05	0.10	0.21	0.49
1985	0.04	0.07	0.09	0.19	0.30	0.79
1986	0.06	0.13	0.12	0.31	0.34	1.13
87	0.11	0.24	0.18	0.50	0.45	1.58
88	0.16	0.40	0.23	0.72	0.53	2.11
89	0.23	0.62	0.32	1.04	0.67	2.77
1990	0.29	0.90	0.40	1.44	0.78	3.55
1991	0.36	1.26	0.51	1.95	0.91	4.46
92	0.44	1.70	0.61	2.56	1.03	5.49
93	0.52	2.22	0.72	3.28	1.15	6.44
94	0.61	2.83	0.82	4.11	1.28	7.92
1995	0.72	3.55	0.93	5.04	1.40	9.32
1996	0.82	4.37	1.04	6.07	1.52	10.85
97	0.93	5.30	1.14	7.21	1.65	12.50
98	1.03	6.34	1.25	8.46	1.77	14.26
99	1.14	7.47	1.35	9.81	1.89	16.15
2000	1.25	8.72	1.46	11.27	2.02	18.17

ENERGY SAVINGS ATTRIBUTABLE TO GOVERNMENT SPENDING (QUADS)

TABLE A-3

LIME/LIMESTONE (ADV)

CUMULATIVE ENERGY SAVINGS (QUADS) ATTRIBUTABLE TO GOVERNMENT SPENDING

FIGURE A-4

LIME/LIMESTONE (ADV)

YEAR	MINIMUM FUNDING		CURRENT FUNDING		ENHANCED FUNDING	
	SAVINGS		SAVINGS		SAVINGS	
	YEARLY	CUMULATIVE	YEARLY	CUMULATIVE	YEARLY	CUMULATIVE
1980	0	0	0	0	0	0
81	0	0	0	0	0	0
82	0	0	0	0	0	0
83	0	0	0	0	-.01	-.01
84	0	0	0	0	-.01	-.02
1985	0	0	0	0	-.04	-.06
1986	0	0	0	0	-.05	-.11
87	-.02	-.02	0	0	-.08	-.19
88	-.02	-.04	0	0	-.09	-.28
89	-.04	-.08	0	0	-.11	-.39
1990	-.05	-.13	0	0	-.12	-.51
1991	-.05	-.18	0	0	-.13	-.64
92	-.06	-.24	0	0	-.13	-.77
93	-.06	-.30	0	0	-.13	-.90
94	-.05	-.35	0	0	-.13	-1.03
1995	-.06	-.41	0	0	-.14	-1.17
1996	-.06	-.47	0	0	-.14	-1.31
97	-.05	-.52	0	0	-.14	-1.45
98	-.06	-.58	0	0	-.14	-1.59
99	-.06	-.63	0	0	-.14	-1.73
2000	-.06	-.69	0	0	-.14	-1.87

ENERGY SAVINGS ATTRIBUTABLE TO GOVERNMENT SPENDING (QUADS)

TABLE A-4

ADVANCED CLEANUP (ADV)

CUMULATIVE ENERGY SAVINGS (QUADS) ATTRIBUTABLE TO GOVERNMENT
SPENDING

FIGURE A-5

ADVANCED CLEANUP (ADV)

	M I N I M U M F U N D I N G		C U R R E N T F U N D I N G		E N H A N C E D F U N D I N G	
	S A V I N G S		S A V I N G S		S A V I N G S	
YEAR	YEARLY	CUMULATIVE	YEARLY	CUMULATIVE	YEARLY	CUMULATIVE
1980	0	0	0	0	0	0
81	0	0	0	0	0	0
82	0	0	0	0	0	0
83	0	0	0	0	0	0
84	0	0	0	0	0	0
1985	0	0	0	0	0	0
1986	0	0	0	0	0	0
87	0	0	0	0	0	0
88	0	0	0	0	0	0
89	0	0	0	0	0	0
1990	0	0	0	0	0	0
1991	0	0	0	0	0.01	0.01
92	0	0	0	0	0.01	0.02
93	0.01	0.01	0	0	0.02	0.04
94	0.01	0.02	0	0	0.03	0.07
1995	0.01	0.03	0	0	0.03	0.10
1996	0.01	0.04	0.01	0.01	0.04	0.14
97	0.02	0.06	0.01	0.02	0.05	0.19
98	0.03	0.09	0.02	0.04	0.06	0.25
99	0.04	0.13	0.02	0.06	0.07	0.32
2000	0.05	0.18	0.03	0.09	0.09	0.41

ENERGY SAVINGS ATTRIBUTABLE TO GOVERNMENT SPENDING (QUADS)

TABLE A-5

CUMULATIVE ENERGY SAVINGS (QUADS) ATTRIBUTABLE TO GOVERNMENT SPENDING

FIGURE A-6

DIRECTLY FIRED HEAT CYCLES (HE)

	MINIMUM FUNDING		CURRENT FUNDING		ENHANCED FUNDING	
	SAVINGS		SAVINGS		SAVINGS	
YEAR	YEARLY	CUMULATIVE	YEARLY	CUMULATIVE	YEARLY	CUMULATIVE
1980	0	0	0	0	0	0
81	0	0	0	0	0	0
82	0	0	0	0	0	0
83	0	0	0	0	0	0
84	0	0	0	0	0	0
1985	0	0	0	0	0	0
1986	0	0	0	0	0.02	0.02
87	0	0	0	0	0.04	0.06
88	0	0	0.01	0.01	0.07	0.13
89	0	0	0.01	0.02	0.12	0.25
1990	0	0	0.02	0.04	0.19	0.44
1991	0	0	0.06	0.10	0.27	0.71
92	0.01	0.01	0.10	0.20	0.37	1.07
93	0.01	0.02	0.18	0.38	0.48	1.55
94	0.03	0.05	0.27	0.65	0.59	2.14
1995	0.04	0.09	0.37	1.02	0.71	2.85
1996	0.07	0.16	0.50	1.52	0.84	3.69
97	0.13	0.29	0.64	2.16	0.98	4.67
98	0.19	0.48	0.79	2.95	1.12	5.79
99	0.26	0.74	0.93	3.88	1.27	7.06
2000	0.33	1.07	1.08	4.96	1.42	8.48

ENERGY SAVINGS ATTRIBUTABLE TO GOVERNMENT SPENDING (QUADS)

TABLE A-6

CUMULATIVE ENERGY SAVINGS (QUADS) ATTRIBUTABLE TO GOVERNMENT SPENDING

FIGURE A-7

HIGH GRADE HEAT (HE)

YEAR	MINIMUM FUNDING		CURRENT FUNDING		ENHANCED FUNDING	
	SAVINGS		SAVINGS		SAVINGS	
	YEARLY	CUMULATIVE	YEARLY	CUMULATIVE	YEARLY	CUMULATIVE
1980	0	0	0	0	0	0
81	0	0	0	0	0	0
82	0	0	0	0	0	0
83	0	0	0	0	0	0
84	0	0	0	0	0	0
1985	0	0	0	0	0	0
1986	0	0	0	0	0	0
87	0	0	0	0	0	0
88	0	0	0	0	0	0
89	0	0	0	0	0	0
1990	0	0	0	0	0	0
1991	0	0	0	0	0	0
92	0	0	0	0	0	0
93	0	0	0	0	0	0
94	0	0	0.25	0.25	0.12	0.12
1995	0	0	0.76	1.01	0.38	0.50
1996	0	0	1.55	2.56	0.91	1.41
97	0.28	0.28	2.65	5.21	1.73	3.14
98	0.85	1.13	3.90	9.11	2.88	6.02
99	1.74	2.87	5.31	14.42	4.38	10.40
2000	2.75	5.62	6.86	21.28	6.23	16.63

ENERGY SAVINGS ATTRIBUTABLE TO GOVERNMENT SPENDING (QUADS)

TABLE A-7

OPEN CYCLE GAS TURBINES (HE)

CUMULATIVE ENERGY SAVINGS (QUADS) ATTRIBUTABLE TO GOVERNMENT SPENDING

FIGURE A-8

OPEN CYCLE GAS TURBINES (HE)

YEAR	MINIMUM FUNDING		CURRENT FUNDING		ENHANCED FUNDING	
	SAVINGS		SAVINGS		SAVINGS	
	YEARLY	CUMULATIVE	YEARLY	CUMULATIVE	YEARLY	CUMULATIVE
1980	0	0	0	0	0	0
81	0	0	0	0	0	0
82	0	0	0	0	0	0
83	0	0	0	0	0	0
84	0	0	0	0	0	0
1985	0	0	0	0	0	0
1986	0	0	0	0	0	0
87	0	0	0	0	0	0
88	0	0	0	0	0	0
89	0	0	0	0	0	0
1990	0	0	0	0	0	0
1991	0	0	0	0	0	0
92	0	0	0	0	0	0
93	0	0	0	0	0	0
94	0	0	0	0	0.05	0.05
1995	0	0	0	0	0.15	0.20
1996	0	0	0.10	0.10	0.39	0.59
97	0	0	0.29	0.39	0.72	1.31
98	0	0	0.78	1.17	1.21	2.52
99	0	0	1.45	2.62	1.72	4.24
2000	0.36	0.36	2.33	4.95	2.28	6.52

ENERGY SAVINGS ATTRIBUTABLE TO GOVERNMENT SPENDING (QUADS)

TABLE A-8

PRESSURIZED FLUIDIZED BEDS FOR UTILITIES (CS)

FIGURE A-9

PRESSURIZED FLUIDIZED BEDS FOR UTILITIES (CS)

YEAR	MINIMUM FUNDING		CURRENT FUNDING		ENHANCED FUNDING	
	SAVINGS		SAVINGS		SAVINGS	
	YEARLY	CUMULATIVE	YEARLY	CUMULATIVE	YEARLY	CUMULATIVE
1980	0	0	0	0	0	0
81	0	0	0	0	0	0
82	0	0	0	0	0	0
83	0	0	0	0	0	0
84	0	0	0	0	0	0
1985	0	0	0	0	0	0
1986	0	0	0	0	0	0
87	0	0	0	0	0	0
88	0	0	0	0	0	0
89	0	0	0	0	0	0
1990	0	0	0	0	0	0
1991	0	0	0.01	0.01	0.03	0.03
92	0	0	0.03	0.04	0.06	0.09
93	0	0	0.05	0.09	0.10	0.19
94	0	0	0.06	0.15	0.13	0.32
1995	0	0	0.08	0.23	0.17	0.49
1996	0.01	0.01	0.13	0.36	0.25	0.74
97	0.02	0.03	0.17	0.53	0.34	1.08
98	0.03	0.06	0.22	0.75	0.43	1.51
99	0.03	0.09	0.28	1.03	0.53	2.04
2000	0.05	0.14	0.34	1.37	0.63	2.67

ENERGY SAVINGS ATTRIBUTABLE TO GOVERNMENT SPENDING (QUADS)

TABLE A-9

ATMOSPHERIC-PRESSURE FLUIDIZED BEDS FOR INDUSTRY (CS)

CUMULATIVE ENERGY SAVINGS (QUADS) ATTRIBUTABLE TO GOVERNMENT SPENDING

FIGURE A-10

ATMOSPHERIC-PRESSURE FLUIDIZED BEDS FOR INDUSTRY (CS)

	MINIMUM FUNDING		CURRENT FUNDING		ENHANCED FUNDING	
	SAVINGS		SAVINGS		SAVINGS	
YEAR	YEARLY	CUMULATIVE	YEARLY	CUMULATIVE	YEARLY	CUMULATIVE
1980	0	0	0	0	0	0
81	0	0	0	0	0	0
82	0	0	0	0	0	0
83	0	0	0	0	0	0
84	0	0	0	0	0	0
1985	0	0	0	0	0	0
1986	0	0	0	0	0	0
87	0	0	0	0	0	0
88	0	0	0	0	0	0
89	0	0	0	0	0	0
1990	0	0	0	0	0	0
1991	0	0	0	0	0	0
92	0	0	0	0	0	0
93	0	0	0	0	0	0
94	0	0	0	0	0	0
1995	0	0	0	0	0	0
1996	0	0	0	0	0	0
97	0	0	0	0	0	0
98	0	0	0	0	0	0
99	0	0	0	0	0	0
2000	0	0	0	0	0	0

ENERGY SAVINGS ATTRIBUTABLE TO GOVERNMENT SPENDING (QUADS)

TABLE A-10

ENGINE COMBUSTION TECHNOLOGIES (CS)

CUMULATIVE ENERGY SAVINGS (QUADS) ATTRIBUTABLE TO GOVERNMENT SPENDING

FIGURE A-11

ENGINE COMBUSTION TECHNOLOGIES (CS)

YEAR	MINIMUM FUNDING		CURRENT FUNDING		ENHANCED FUNDING	
	SAVINGS		SAVINGS		SAVINGS	
	YEARLY	CUMULATIVE	YEARLY	CUMULATIVE	YEARLY	CUMULATIVE
1980	0	0	0	0	0	0
81	0	0	0	0	0	0
82	0	0	0	0	0	0
83	0	0	0	0	0.04	0.04
84	0	0	0	0	0.09	0.13
1985	0	0	0.04	0.04	0.16	0.29
1986	0	0	0.09	0.13	0.27	0.56
87	0	0	0.18	0.31	0.40	0.96
88	C.02	0.02	0.29	0.60	0.56	1.52
89	C.05	0.07	0.41	1.01	0.73	2.25
1990	C.08	0.15	0.54	1.55	0.87	3.12
1991	0.13	0.28	0.68	2.23	1.01	4.13
92	0.17	0.45	0.80	3.03	1.13	5.26
93	0.22	0.67	0.88	3.91	1.22	6.48
94	0.27	0.94	0.94	4.85	1.28	7.76
1995	0.30	1.24	0.97	5.82	1.32	9.08
1996	0.32	1.56	0.98	6.80	1.31	10.39
97	0.33	1.89	0.97	7.77	1.27	11.66
98	0.34	2.23	0.95	8.72	1.21	12.87
99	0.34	2.56	0.91	9.63	1.12	13.99
2000	0.35	2.91	0.87	10.50	1.00	14.99

ENERGY SAVINGS ATTRIBUTABLE TO GOVERNMENT SPENDING (QUADS)

TABLE A-11

SANTA FE CORPORATION
4660 KENMORE AVENUE
ALEXANDRIA · VIRGINIA 22304
TELEPHONE (703) 823-2233

SANTA FE CORPORATION