EVALUATION OF ALTERNATIVE USES OF COAL AND COAL-DERIVED FUELS - INDUSTRY, GOVERNMENT, AND PUBLIC VIEWPOINTS VOLUME I

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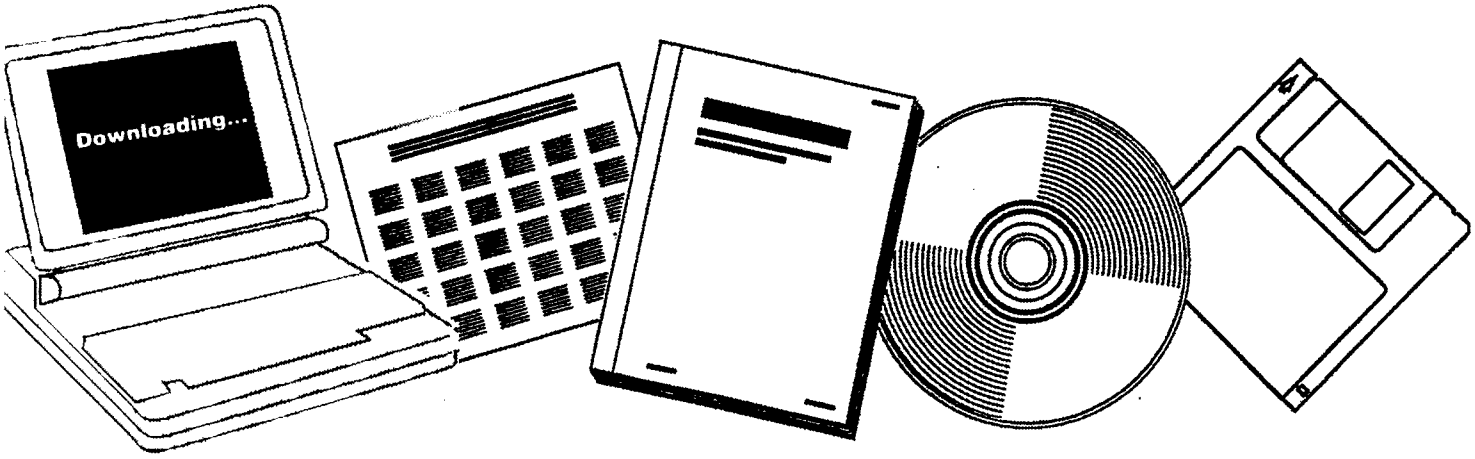

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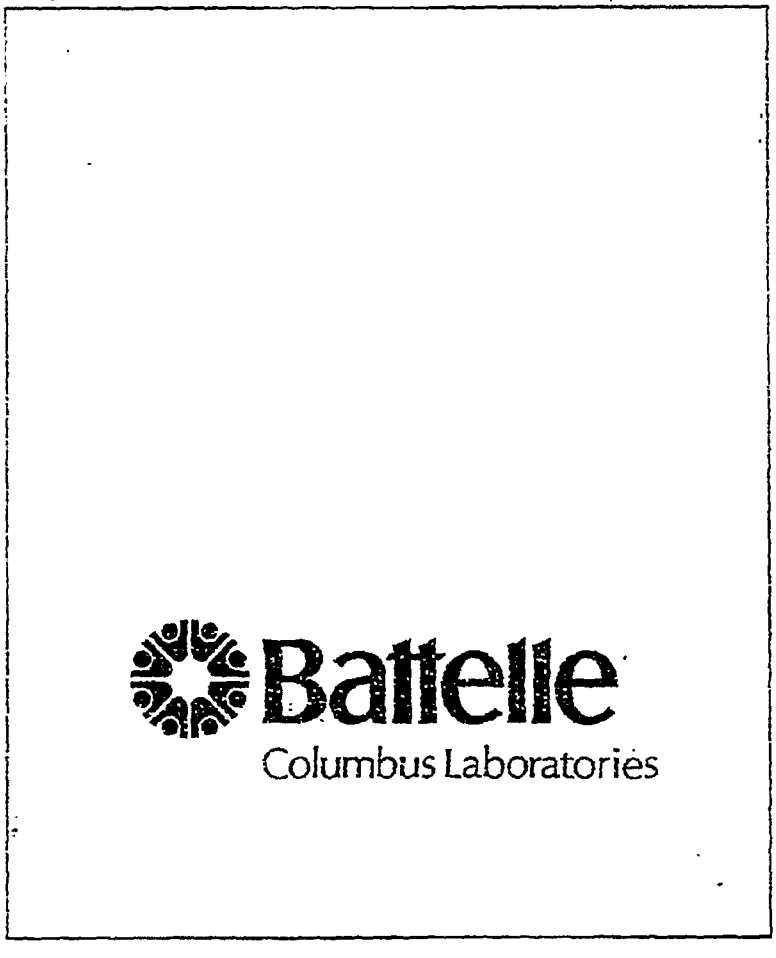

Battelle
Columbus Laboratories

RESEARCH REPORT

on

EVALUATION OF ALTERNATIVE USES OF COAL AND COAL-DERIVED FUELS — INDUSTRY, GOVERNMENT, AND PUBLIC VIEWPOINTS

Volume I

to

ENERGY RESEARCH & DEVELOPMENT ADMINISTRATION
Fossil Energy Department

November 17, 1975

by

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ABSTRACT

This report covers a study by Battelle's Columbus Laboratories to identify viewpoints representative of various interest groups on alternative uses of coal and coal-derived fuels. The study was conducted for the ERDA Fossil Energy Department to provide background inputs to the R&D planning process. A series of nine structured workshops was conducted with selected representatives of the various interest groups.

The individual workshops included representation of industrial and utility companies, state and federal governments, and public interest groups. Viewpoints were recorded on (1) the relative importance of five specific evaluation criteria, (2) the evaluation of seven fuel categories against the criteria, (3) a forecast of future fuel utilization by categories, and (4) suggested R&D emphasis for the fuel categories.

This report, Volume I, is a summary and appraisal of workshop results. Volume II contains appendices with more detailed records from the workshops.

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EVALUATION OF ALTERNATIVE USES OF COAL AND COAL-DERIVED FUELS — INDUSTRY, GOVERNMENT AND PUBLIC VIEWPOINTS

from

BATTELLE
Columbus Laboratories

SUMMARY

Alternative choices for the development of fossil fuels are viewed in different ways by different industries, by government agencies, and by other interest groups. This report is the result of a study in which Battelle's Columbus Laboratories organized selected workshop groups to assist the Energy Research and Development Administration in identifying views of different groups. Workshop participants evaluated the importance of criteria that could apply to energy planning and decision-making, and they evaluated alternative coal-derived fuels that could be used to meet the nation's energy needs. Profiles of these evaluations are synthesized and presented herein.

OBJECTIVES AND SCOPE

The primary objective of this study was to identify views representative of industries and other groups, to provide inputs to the Energy Research and Development Administration in the planning process for Federal R&D on coal and coal-derived fuels.

One-day workshop meetings were held with representatives of eight different interest groups, plus a composite group composed of recognized spokesmen for the individual groups. A total of 66 individuals participated in the workshops. The same workshop structure and definitions were used in developing and recording views of each group.

INTEREST GROUPS

Workshop groups were organized by interests with one group representing each of the interests shown in Table A.

TABLE A. INTEREST GROUPS COVERED IN WORKSHOPS

Industrial & Utilities	Public Interest & Government
• Coal Industry	• Public Interest Groups
• Oil & Chemical Industry	• State Governments
• Gas Industry	• Federal Government Agencies
• Electric Power Industry	
• Industrial Fuel Users	

• Composite Group
(with representation of each interest group)

Participants were selected with the intent of obtaining generally representative samples of the specific group viewpoints.

For the industrial representation, major industrial and utility companies were selected; most of the participants were high-level management representatives engaged in corporate planning or R&D planning. A spectrum of public-interest organizations was selected for that group. Energy planners from coal-producing and industrial states were selected for the State Government Group. The Federal Government Agencies were those that have principal responsibilities in energy research and policy or that use large quantities of fuel. The Composite Group included staff of energy trade associations and spokesmen for other groups. (Profiles of the groups are presented in the Appendix.)

APPROACH

The informal workshop sessions involved group discussion and structured evaluation activities. Participants were asked to rate seven fuel categories against five evaluation criteria, and then, to rate the relative importance of the criteria. This rating procedure was carried out three times with discussion between each, so that definitions and other aspects of the evaluation procedure were explored in open discussion prior to the final ratings. (The group ratings presented in this report are averages of the individual participant's final ratings for a given workshop group.)

The fuel ratings and the criteria ratings were combined in a weighted scoring procedure to yield a derived weighted score to establish a ranking for the fuel categories. The weighted scores can be interpreted as a measure of the relative degree to which the development or use of the various fuel categories should be encouraged.

Two supplemental workshop activities were developed at the request of participants: (1) a forecast of the mix of fuel utilization in the various categories for three different time frames, and (2) a recommendation of relative R&D emphasis for the fuel categories.

FUEL CATEGORIES AND EVALUATION CRITERIA

Evaluation criteria and fuel categories used as a basis for the workshop discussions and ratings are identified in Tables B and C.*

* Additional notes of explanation of these fuel categories and evaluation criteria are contained in Appendix A.

TABLE B. EVALUATION CRITERIA

Criteria	Definition
A. Energy Self-Sufficiency	Eliminate dependency on foreign energy sources
B. Extent of Technical Problems	State of development toward commercialization
C. Economics (cost aspects)	Capital and operating cost of fuel-production and use
D. Environmental Impacts	Impact on physical and biological environment (generally local)
E. Human Impacts	Impact on net "quality of life" (generally broad)

TABLE C. FUEL CATEGORIES

Category	Definition or Example
1. Coal, Direct-Fired, Unconstrained by SO_2 Emission Regulations	Where SO_2 regulations are waived or not applicable (including small equipment)
2. Low-Sulfur Coal, Direct-Fired	LS coal fired specifically to meet SO_2 regulations
3. Coal, Direct-Fired, with SO_2 Control Equipment	Includes stack-gas treatment or fluidized-bed combustion
4. Chemically Cleaned Coal	Solvent-refined coal (fired solid) or other chemically desulfurized coal
5. Synthetic Liquids	Fuels and feedstocks from coal liquefaction
6. Low and Intermediate-Btu Gas	Fuel gas ~100-500 Btu/cu ft, from on-site or near-site gasification
7. Pipeline-Quality Gas	SNG from coal ~1000 Btu/cu ft
8. Mixed Fuels	Mixture of pulverized coal + liquid, fired as a liquid

It should be noted that the first two categories are more practice oriented and do not call for the same type of R&D as do the other categories. Categories 4 through 7 are "clean fuels", and 5 through 7 are "synthetic fuels" derived from coal.

OVERVIEW OF RESULTS

Tables D, E, and F summarize the results of the criteria and fuel category ratings by the workshop groups.

Ratings of Evaluation Criteria

Table D presents the final ratings as to the importance of the evaluation criteria for all of the groups on a scale from 0 to 9. The principal group expressions as to the importance of the specific criteria were:

- Criteria considered important by most groups were energy self-sufficiency and economics (cost). The Public Interest Group viewed these criteria as less important than environmental or human impacts.
- The Coal Industry Group gave energy self-sufficiency an average rating of 8.1, the highest rating given any criterion by any group.
- The Gas Industry Group expressed a strong rating of importance for economics as a criterion, giving it an average rating of 8.0.
- The Oil and Chemical Industry Group also rated energy self-sufficiency and economics equally at 7.9.
- The Industrial Fuel Users Group also preferred energy self-sufficiency and economics as important criteria, rating them at 7.7 and 7.9, respectively.
- The Public Interest Group rated environmental impact and human impact high, at 7.6 and 7.7, respectively.

TABLE D. RATING OF CRITERIA BY WORKSHOP GROUPS
Ratings on a scale of 0 to 9.

Evaluation Criteria	Coal Industry	Oil and Chemical Industry	Gas Industry	Electric Power Industry	Industrial Fuel Users	Public Interest Groups	State Governments	Federal Government Agencies	Composite Group
A. Energy Self-Sufficiency	8.1	7.9	6.4	7.5	7.7	5.1	7.4	7.6	7.0
B. Extent of Technical Problems	6.5	6.4	6.1	7.4	4.9	3.4	6.1	6.9	6.2
C. Economics	6.4	7.9	8.0	7.4	7.9	3.9	6.4	6.7	7.3
D. Environmental Impacts	5.6	5.0	4.9	5.9	5.3	7.6	6.0	7.0	7.3
E. Human Impacts	6.0	5.1	6.0	6.0	5.0	7.7	5.8	6.7	5.3

TABLE E. WEIGHTED SCORES FOR FUEL CATEGORIES BY WORKSHOP GROUP
Maximum score is 10.0.

Fuel Categories									
1. Coal, fired unconstrained by SO_2 regulations	10.0	9.9	5.2	10.0	10.0	4.1	9.8	9.3	6.6
2. Low sulfur coal, fired to meet SO_2 regulations	9.4	10.0	6.0	8.9	9.8	10.0	10.0	10.0	8.6
3. Coal, fired with SO_2 control equipment	5.8	8.0	5.6	5.7	7.1	8.9	8.4	7.8	7.9
4. Chemically cleaned coal	6.1	5.3	4.3	6.1	7.2	8.5	7.0	7.0	6.3
5. Synthetic liquids	5.5	6.0	8.6	6.1	6.3	7.8	6.9	6.6	8.4
6. Low/intermediate Btu gas	6.2	7.9	8.6	7.8	8.4	8.5	8.1	7.7	10.0
7. Pipeline-quality gas	5.1	6.5	10.0	5.0	7.1	7.5	6.5	7.5	9.7
8. Mixed fuels	8.1								

- The Electric Power Industry rated energy self-sufficiency, extent of technical problems, and economics at 7.5, 7.4, 7.4, respectively.

- The lowest ratings were by the Public Interest Group for extent of technical problems at 3.4 and for economics at 3.9.

The ratings of the other three groups did not result in statistically significant discrimination among the criteria within each group.

Generally, the groups regarded each criterion as having importance. Average ratings were above 4.5, the midpoint of the scale, in all except the two cases cited.

In terms of ranges between high and low ratings, the two government groups discriminated least among the criteria of any groups. The Public Interest Group reflected the strongest discrimination; this group took the position that their primary area of competence was with respect to weighting of criteria, rather than their appraisal of individual fuel categories.

Evaluation of Fuel Categories

Weighted Scores. Table E presents a matrix of weighted scores for the fuel categories, derived by combining their evaluation ratings with the importance ratings of criteria in Table D.* The ratings of fuel categories represent the assessment by the workshop participants as to the ability of each of the fuel categories to satisfy a specified criterion. The highest score in any workshop group is 10.0, with the score being indicative of the relative degree to which the development and use of a fuel category should

* The scoring procedure, together with points of discussion and criticism by workshop participants, is discussed in the main body of this report under "Assessment of the Workshop Methodology".

TABLE F. RANKING OF FUEL CATEGORIES BY WORKSHOP GROUPS

Based on Weighted Scores

Fuel Category \ Group	Coal Industry	Oil and Chemical Industry	Gas Industry	Electric Power Industry	Industrial Fuel Users	Public Interest Groups	State Governments	Federal Government Agencies	Composite Group
1. Coal, fired unconstrained by SO_2 regulations	1		6	1		7			6
2. Low sulfur coal, fired to meet SO_2 regulations			4						
3. Coal, fired with SO_2 control equipment	6		5	6	5+				5
4. Chemically cleaned coal	5	7	7	4+	4		5	6	7
5. Synthetic liquids	7	6		4+	7	5	6	7	≈4
6. Low/intermediate Btu Gas	4	4					4	4	
7. Pipeline-quality gas	8	5		7	5+	6	7	5	
8. Mixed fuels									

be encouraged. The primary utility of the scoring and rank ordering is to provide an entry point for examination of the more detailed ratings against each criterion, as presented in the main body of this report.

Rankings. Table F presents the results in terms of the rankings by each workshop group, based on the weighted scores of Table E. (The fuel category having the highest weighted score for a given group ranks No. 1 for that group.) In Table F, the highest rankings have the darkest shading. Categories which ranked fourth, fifth, and sixth are shown by a single light shading; the lowest rankings have no shading.

Several fuel categories emerge as having relatively high overall rankings for several groups. These are low-sulfur coal, coal fired unconstrained by SO_2 regulations, and low/intermediate-Btu gas. Other observations follow.

- Low-sulfur coal was ranked first or second by 7 of the 9 groups. It was ranked highest by four groups: Oil and Chemical Group, Public Interest Group, State Government Groups, and Federal Agencies Group. (Practical limitations in availability of low-sulfur coal were recognized.)

- Coal, fired unconstrained by SO_2 regulations was ranked first or second (in terms of weight score) by 6 of the 9 groups. It was ranked first by the Coal Industry Group, Electric Power Industry Group and Industrial Fuel Users Group.

- Low/intermediate-Btu gas was ranked highest among the synthetic fuels categories by all except the Gas Industry Group, and was top ranked over all the fuel categories by the Composite Group. It was second ranked by one group and third ranked by three groups. All groups rated it no lower than fourth.

Other categories that were ranked first or second by at least one group are as follows:

- Coal, Fired with SO_2 Control Equipment (including both stack-gas control systems and fluidized-bed combustion). Four groups ranked this category moderate to high (ranking 2 or 3) in terms of the final weighted score: Public Interest Group, the two government groups, and the Oil and Chemical Industry Group.

- Synthetic Liquids. The highest ranking for synthetic liquids was by the Gas Industry Group (tying for second in terms of weighted scores). The Oil and Chemical Industry ranked this category sixth; however, the group observed that this ranking did not fully reflect the group's view of the long-term importance of this category.

- Pipeline-Quality Gas. The Gas Industry Group top ranked pipeline-quality gas or SNG. The Composite Group ranked this category second.

- Mixed Fuels. This fuel concept was ranked third by the Coal Industry Group, the only group that evaluated this category.

The remaining fuel category:

- Chemically Cleaned Coal was ranked third by the Public Interest Group and fourth by the Electric Power Industry Group.

Overall, the rankings appear to reflect group viewpoints in support of direct firing of solid coal; two of the highest ranking fuel categories involve direct firing.

Similarities of Rankings Among Groups. Several features are noted in Table F as to similarities in rankings of fuel categories among the various groups:

- The first four rankings were remarkably similar for the groups representing the Coal Industry, the Electric Power Industry, and Industrial Fuel Users.

- The first four rankings were identical for the Oil and Chemical Industry Group and the State Governments Group.

- The rankings by the Gas Industry Group and the Composite Group were generally similar, especially at the lower three rankings.

- The rankings by the Public Interest Group stood out as substantially different from the other groups, but were somewhat similar to those by the Composite Group.*

Forecast of Relative Mix of Fuels

Figure A-1 summarizes graphically the participants' forecast of the relative mix of the fuel categories in future years. This supplementary information was recorded at the request of the first group, due to the tendency to predict what will occur—as opposed to the thrust in the preceding ratings of what should be encouraged to occur to meet national interests. The length of the bars represent the combined forecast of all participants in terms of relative or percentage mix, rather than absolute energy units.

* It should be noted that two participants originally scheduled for the Composite Group workshop were unable to attend, and their intended viewpoints were missing; these were the representatives of the coal industry and of public interest groups.

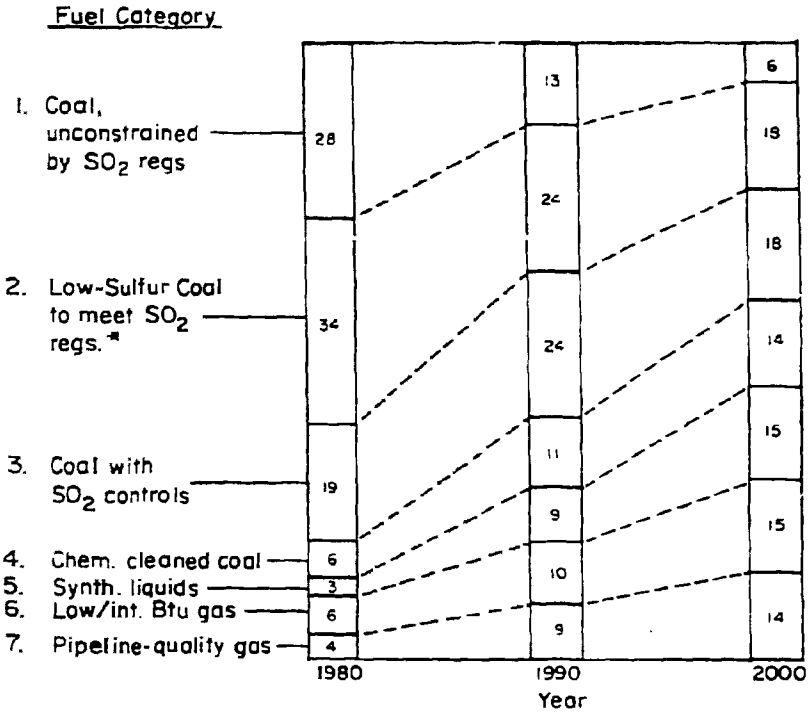

FIGURE A-1. FORECA T OF RELATIVE MIX OF FUELS AS A PERCENTAGE OF TOTAL COAL ENERGY UTILIZATION -- All Groups Combined

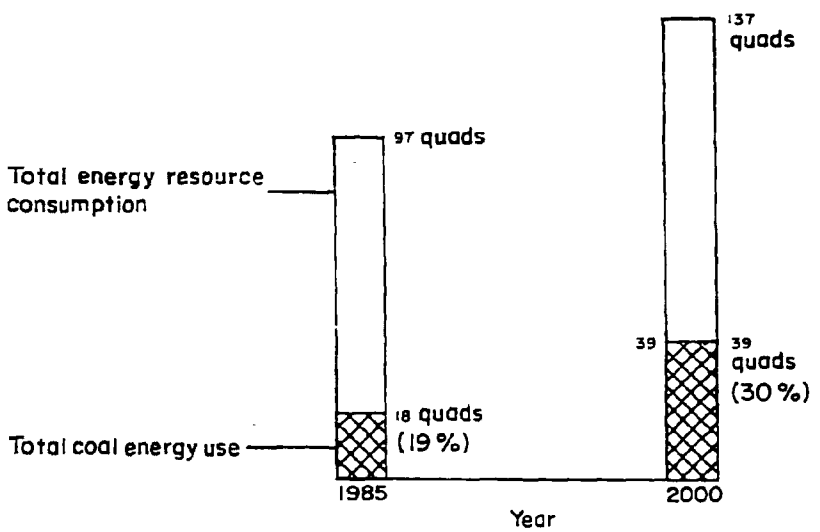

FIGURE A-2. ERDA FORECAST OF TOTAL COAL ENERGY UTILIZATION AND TOTAL ENERGY RESOURCE CONSUMPTION
From ERDA 48, Scenario V, Combination of all Technologies

Synthetic liquids and gaseous fuels were forecast to grow from 13 percent of energy originating from coal in 1980 to 44 percent by the year 2000. Thus, over half of the coal energy was expected to be utilized in solid or pulverized forms in the year 2000.

Figure A-2 provides a perspective of the expected growth of all coal energy utilization. This shows the forecasts of coal energy and total resource consumption that were made in ERDA-48* for the years 1985 and 2000 for Scenario V, Combination of All Technologies. An indication of total annual Btu utilization expected for each fuel category can be derived by combining the workshop forecasts on a percentage basis from Table A-1 with the ERDA forecasts of total coal energy utilization in Quads (10^{15} Btu) from Table A-2.

Forecasts by each of the groups are contained in the main body of this report. Some additional aspects of the group veiwpoints were:

- Several groups were optimistic with respect to the near-term growth of SO_2 control technology in Fuel Category 3. Five groups forecast a percentage growth in this category from 1980 to 1990, but none forecast that there would be continued growth to 2000. The Electric Power Industry Group were more pessimistic about SO_2 control technology and forecast a slight decline to 13 percent utilization in 2000; this group also forecast that 13 percent of coal energy still would be coal fired unconstrained by SO_2 controls in the year 2000.

- The Industrial Fuel Users Group and the Public Interest Groups expected chemically-refined coal to have a substantial future, growing to approximately 20 percent of the coal energy by 2000.

- The Oil and Chemical Industry Group and the Gas Industry Group were the most optimistic about the growth of synthetic liquids, forecasting 17 percent of coal energy by 2000.

* "A National Plan for Energy Research, Development, and Demonstration: Creating Energy Choices for the Future", ERDA-48, Volume I, The Energy Research and Development Administration (June, 1975).

- The Electric Power Industry Group and Industrial Fuel Users Group were the most optimistic groups concerning low and intermediate-Btu gas, forecasting about 20 percent by 2000.

- The Gas Industry Group forecast the penetration by pipeline-quality gas to be the highest of any group, 22 percent by 2000.

Although there were these differences in views among groups, each of the seven fuel categories was recognized as having a substantial role in meeting future energy needs.

Recommendations of Relative Emphasis for R&D Effort

Figure B presents graphically the combined input from the participants on their recommended emphasis of R&D effort. This additional information was obtained as a result of participant requests. A point recognized and

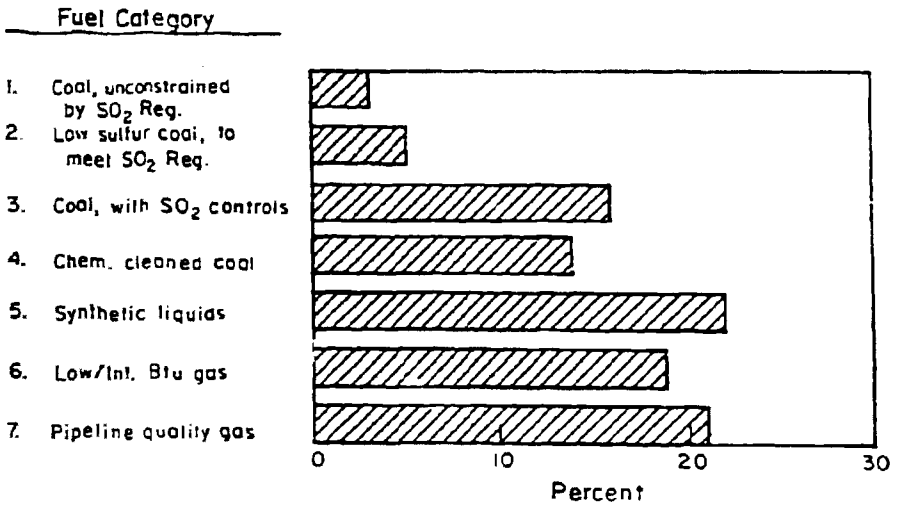

FIGURE B. RELATIVE R&D EMPHASIS IN PERCENT — ALL GROUPS COMBINED

discussed by most of the groups is that the fuel category ratings (of what should be encouraged on a priority basis) do not necessarily relate directly to the allocation of R&D needed to bring about commercialization. The groups cited that this depends on the state of the technology, the extent of technical problems, and relative R&D costs.

There were different views among the various groups, reflecting differences observed in the ratings. However, it is clear that the participants generally viewed that the greatest R&D efforts should be directed to synthetic liquids and to gasification. Substantial allocations were suggested for SO_2 control and for chemically refined coal. Viewpoints of the various groups expressed in workshop comments are outlined in the report.

Group Profiles

Figure C provides an overview of responses of each group on the fuel categories—summarizing top rankings by weighted scores, largest uses forecast for 1980 and for 2000, and principal R&D emphasis. The first listed fuel category in the ranking column is the top ranking; a second category having high scores is noted in some cases. The 1980 and 2000 columns denote, respectively, the category receiving the largest utilization forecast for the near-term and longer-term. Fuel categories with highest recommended R&D emphasis are listed in the last column.

The arrows in Figure C connect fuel categories in successive columns where a category is carried over to another column. Only the Gas Industry Group carried over their highest ranked category, Pipeline-Quality Gas (SNG), as far as the long-term forecast or the R&D emphasis column.

Further insight into the viewpoints of each of the groups can be gained from examining the principal results summarized by the various groups in the main body of this report.

FIGURE C. OVERVIEW OF WORKSHOP GROUP VIEWPOINTS ON FUEL CATEGORIES

Group	Top Ranked	Largest Use Forecast For 1980	Largest Use Forecast For 2000	Major R&D Emphasis
Coal Industry	Coal, no controls → Coal, no controls LS coal → LS coal . .	. . . .	. . Synth liquids → Synth liquids Low-Btu gas .	
Oil & Chemical	LS coal → LS coal Coal, no controls → Coal, no controls .	. . .	. . . Snyth liquids	
Gas Industry	SNG → SNG → SNG . Coal, no controls .	. .	. Coal, with controls .	
Electric Power	Coal, no controls → Coal, no controls .	. .	. Low-Btu gas → Low-Btu gas	
Industrial Fuel Users	Coal, no controls → Coal, no controls LS coal → LS coal	. . . .	. . Chem Cl Coal . Low-Btu gas . SNG → SNG	
Public Interest	LS coal → LS coal . Coal, with controls . .	. Coal, with controls .	. . . . . .	*
State Governments	LS coal → LS coal Coal, no control	. . . Coal, with controls → Coal, with controls → Coal, with controls		
Federal Agencies	LS coal → LS coal Coal, no controls → Coal, no controls . .	. . . . .	. . . . Coal, with controls .	*
Composite Group	Low-Btu gas . . SNG . . . Coal, no controls . LS coal . .	. . . . Coal, with controls .	. . . .	*

* Note: Little difference among responses by these groups on R&D emphasis for the highest 3 or 4 fuel categories.

OVERALL OBSERVATIONS

The approach used in this study was successful in capturing, in a consistent way, views of the various interest groups selected for participation in the workshops. There was sufficient interest in the approach that high-level people were willing to participate in the workshops.

Evaluation of the results, through specific feedback from the participants themselves, indicates that they regarded the ratings to be fairly representative of their interest group. The only exception was the State Governments Group. (These evaluations are outlined in this report in the section on assessment of methodology.) While the precision of the final ratings and other recorded viewpoints have recognized limitations (regarding sample size, subjectivity and overlap of criteria definitions, etc.), the results can provide useful inputs to ERDA in terms of general viewpoints that should be considered in the planning process for R&D on coal and coal-derived fuels.

An overall observation regarding group viewpoints, reflected in the ratings and forecasts of fuel categories, is the contined significance of direct firing of solid coal (fuel categories 1 through 4) as perceived by most interest groups. Even with the expected development and utilization of synthetic fuels, the total utilization of solid coal categories was forecast to exceed the total utilization of synthetic fuels from coal (fuel categories 5 through 7) in the year 2000.

Additional observations follow, based on discussion in the workshops.

- Regarding the extent of unsolved technical problems associated with the fuel categories, the point was emphasized by several groups that the technical feasibility of producing fuels for each of the categories has been demonstrated on some scale. However, the last five categories have not been demonstrated in a commercial way as fully meeting modern technological and economic needs.

- Philosophical questions related to short-term or long-term R&D were discussed by several groups. It was agreed that high-risk programs, in areas with many technical problems, could be justified where potential benefits are high and might never be developed without a continuing national program. At the same time, there were strong suggestions, in the light of urgent needs, to emphasize those developments "right on the threshold" in order to commercialize developments more quickly.

- The groups emphasized that ratings or scores in the evaluation did not necessarily imply a recommendation for R&D emphasis, due to differences in the extent of technical problems and the costs of needed R&D in the different areas. Also a distinction was recognized between action plans and R&D needs.

- In suggestions of R&D emphasis and in comments on R&D needs, the groups generally agreed to refer to the broad view of the federal role, rather than attempting to delineate the respective roles of ERDA and other agencies.

- Strong views were expressed by the industrial groups that uncertainties of government regulation and policy both at federal and local levels, has the effect of discouraging investment decisions by the private sector to undertake needed development on its own. Consistency of policy and regulations, and possibly federal incentives, were suggested.

- The Oil and Chemical Industry viewed synthetic liquids as having significant importance in the future (for transportation fuels, for home heating, and for use as feedstock). They urged major emphasis on federal R&D and demonstration to advance this technology.

- The Gas Industry Group expressed concern that federal policy or R&D decisions may tend to encourage electrification of the U.S. They cited that the nation cannot afford to underutilize or give up the efficient energy distribution system already in existence in the gas industry.

- The Electric Power Industry Group suggested that greater flexibility in utilization of the different fuel categories could be achieved if environmental protection regulations were based on controlling to ambient air-quality standards rather than on constant emission standards applying to point sources. This would allow for the use of higher sulfur fuels except during periods of adverse meteorological conditions. To aid in setting ambient air-quality standards on a cost-benefit basis, the group recommended additional research related to health effects of SO_2 and other pollutants.

- In considering aspects of environmental and human impacts in decisions related to fuels options, the Public Interest Group recommended that an attempt be made to internalize all social and environmental costs in considering fuel options.

- Several groups called attention to the fact that environmental issues, traditionally, had concentrated on SO_2, but other pollutants like sulfates and fine particulates are of concern.

- It was clear that the groups perceive that fuels in the various categories are capable of serving a variety of uses, and each form of fuel has applications that it will serve most effectively and/or competitively. This multiplicity of needs, both short-term and long-term, underscores the desirability of a balanced R&D program.

- Most groups expressed the philosophy that essentially all of the categories of coal and coal-derived fuels are expected to be important to the nation for some uses and should be encouraged as options within the framework of the criteria.*

In short, the various findings as presented in this report contribute useful background to the formulation of national energy policies and plans.

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* This is consistent with the ERDA Plan: "A National Plan for Energy Research, Development and Demonstration" (ERDA 48, Volume 1. June, 1975).

EVALUATION OF ALTERNATIVE USES OF COAL AND COAL-DERIVED FUELS — INDUSTRY, GOVERNMENT AND PUBLIC VIEWPOINTS

to

ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION
FOSSIL ENERGY DEPARTMENT

ERDA Contract No. W-7405-eng 92, Task 74

from

BATTELLE
Columbus Laboratories

November 15, 1975

INTRODUCTION AND APPROACH

BACKGROUND

In a previous contract with the Office of Coal Research, Battelle developed a methodology for evaluating and rank-ordering R&D activities*. It was recognized by planners in the Energy Research and Development Administration (ERDA) that the application of this particular methodology might provide an effective tool by which to identify and compare the viewpoints of special interest groups involved in the development and use of fossil fuels and their derivatives. This follow-on contract was initiated with the primary objective to identify views representative of industries and other groups to provide input to ERDA in the planning process for federal R&D on coal and coal-derived fuels. A subsidiary objective was the evaluation of the methodology as a decision-structuring tool.

WORKSHOP FORMAT AND PROCEDURES

This report presents the results from a sequence of nine structured workshops conducted with small groups of knowledgeable participants. The

* "Development of Alternative Paths for Clean Utilization of Coal as an Energy Source and Development of a Methodology for Decision Making", by D. W. Malone, E. H. Hall, K. Kawamura, and D. L. Morrison, Battelle-Columbus report to U.S. Department of the Interior, Contract No. 14-0001-1936 (December 20, 1974).

TABLE 1. COMPOSITION OF WORKSHOP GROUPS

- Coal Industry — (8)
  - Coal operators (2)
  - Coal operator/steel companies (2)
  - Manufacturer of coal preparation equipment
  - Energy company/developer of conversion processes
  - Railroad/minerals developer
  - Engineer-contractor firm in mining and conversion

- Oil and Chemical Industry — (8)
  - Integrated oil companies (international) (3)
  - Integrated oil companies (domestic) (2)
  - Chemical companies (2)
  - Engineer-construction firm specializing in oil and chemical processing

- Gas Industry — (8)
  - Integrated gas-distribution/transmission companies (2)
  - Gas-distribution companies (2)
  - Gas-transmission companies (2)
  - Gasification/utility company
  - Engineer-construction firm involved in gasification plants (1)

- Electric Power Industry — (8)
  - Large electrical utility systems (2)
  - Large electrical utility company
  - Utility boiler manufacturers (2)
  - Gas-turbine manufacturers (2)
  - Engineer-construction firm active in fuel burning equipment (1)

- Industrial Fuel Users — (7)
  - Manufacturers of industrial fuel burning equipment (2)
  - Worldwide automobile manufacturer
  - Electrical and electronics manufacturer
  - Integrated steel company
  - Glass and packaging company
  - Manufacturer of industrial air-pollution-control equipment

- Public Interest Groups — (7)
  - American Public Health Assn.
  - Common cause
  - League of Women Voters of the U.S.
  - National League of Cities
  - National Wildlife Federation
  - Public Interest Research Group
  - Smithsonian Institution

- State Governments -- (7)
  - Officials responsible for energy policy and planning:
    - Eastern and Appalachian states (3)
    - Midwestern states (1)
    - Western states (3)

- Federal Government Agencies — (7) *
  - Environmental Protection Agency
  - Federal Energy Administration
  - Federal Power Commission
  - General Services Administration
  - U. S. Department of the Interior
  - U. S. Department of Commerce
  - U. S. Department of Defense

- Composite Group — (6) *
  - American Gas Association
  - American Petroleum Institute
  - Bituminous Coal Research, Inc.**
  - Electric Power Research Institute
  - National Association of Manufacturers
  - National Governor's Conference
  - National Science Foundation

* Names and positions of workshop representatives of these groups are identified in Appendix C.

** Representative was unable to attend the workshop, but sent initial ratings and comments which are included in the Appendix.

groups ranged in size from six to eight individuals, and a total of 66 participants were involved in the nine workshops conducted during the period June, July, and August, 1975. This approach was chosen in lieu of the more commonly used "broad survey" strategy, in order to provide for discussion and strengthening of insights during the workshops. In considering the results of this study, the method by which information was obtained should be kept in mind to provide a perspective in interpreting the results.

Composition of Groups

The workshop sessions were organized around structured evaluation activities and group discussion. Each group was selected to be representative of a particular interest group concerned with energy supply or use.

Table 1 shows the composition of groups by identifying the types of organizations selected for each group*. For the industry groups, major companies in the respective industries were generally selected. For example, most of the industrial organizations were large companies listed in Fortune 500; several were from the 20 largest industrial companies.

The Public Interest Group was selected to represent a spectrum of public interest organizations, including several oriented to health and environmental aspects. The State Government Group was composed of energy planners or administrators in executive branches of major coal producing or consuming states. The Federal Government Agencies were selected as having principal responsibilities in energy research or policy or that use large quantities of fuel; the individual representatives from the agencies were designated by high-level officials having responsibility for fossil energy R&D or other energy issues. The Composite Group included staff of energy trade associations and spokesmen for other groups; they were not participants in the workshops for specific interest groups. Most of the participants were engaged in management level planning or R&D planning for their organizations.

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* Additional descriptive material on the composition of groups is contained in Appendix C.

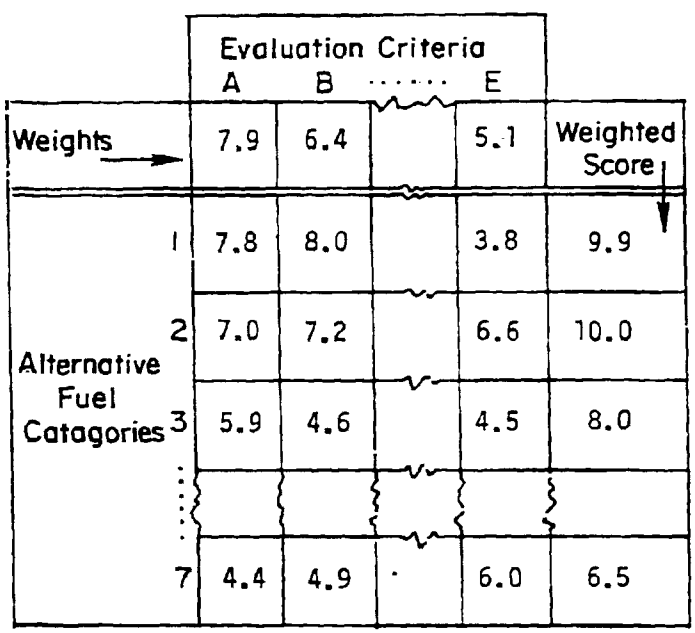

FIGURE 1. EVALUATION MATRIX AS BASIS FOR THE WORKSHOP STRUCTURE

Principal entries to the matrix are the average group ratings on a scale from 0 to 9. The "weighted score" is a derived figure; the highest score is 10.0.

In the interest of providing an environment for relaxed and objective discussion, industrial and utility companies were assured that these organizations would not be identified in the record. This policy was also found to be important in expediting the invitation and acceptance process in convening the groups, by avoiding the need for formal corporate or organization approval.

Basis for Workshop Structure

The conceptual basis for the workshop structure is illustrated in the "evaluation matrix" of Figure 1.

The workshop structure was based on a systematic and separate evaluation of first the fuel alternatives and then the criteria, using a rating scale from 0 to 9*. Given this basic input, it was possible to interpret the criteria ratings as weights and to compute a derived weighted score for each fuel category, which can be interpreted as an indicator of the relative degree to which the fuel categories should be encouraged.

Early in the workshop, the participants were asked to rate (1) the relative importance of the criteria, and (2) the relative ability of the various fuel categories to meet the specified criteria. The entire rating and scoring procedure was repeated two more times during the day, with ample time for group discussions between ratings to clarify definitions and to discuss the results of the previous ratings. Most of the results presented later in this report are taken from the third, and final, rating procedure. More information on the format of the workshops is contained in the section on "Assessment on the Methodology and Results". The advance materials and sample forms used during the workshop are included in Appendix A.

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* In all scale definitions, low ratings are "unfavorable" and high ratings are "favorable", i.e., a high rating for a fuel category on energy self-sufficiency means high contribution; a high rating on extent of technical problems means few problems; a high rating on economics means low cost; likewise, a high rating for environmental impacts and human impacts refers few adverse impacts.

Terminology Used in Presenting Results

It is appropriate to call the reader's special attention to aspects of terminology used in the workshops and the presentation of results. The term rating is used to refer to original votes generated as explicit responses by the participants on standardized forms. For the most part, only group average ratings of the third and final votes are presented in this report. The term weighted score is used to refer to a mathematical aggregation of the group average ratings for the various fuel categories, weighted by group average ratings of the evaluation criteria. The term ranking, or rank order position, refers to an ordinal number indicating the relative position of a fuel category as determined by the relative magnitude of the ratings or weighted scores.

There are many different ways in which the basic rating data can be aggregated. To keep the mathematical operations as simple as possible, the workshop plan called for aggregating over all five criteria. The weighted scores resulting from this aggregation, together with the rank-order positions based on the scores, should be used only as an overview for analyzing the more detailed evaluation ratings. Some of the participants in the workshops were emphatic in their concern that the aggregated scores not be misinterpreted. These and other points related to methods of scoring and additional information are discussed in the section on "Assessment of the Methodology and Results".

Supplementary Workshop Activities

In referring to the rank-order information, it is tempting to use the term preference. It is important to note, however, that there is not necessarily a one-to-one correspondence between derived weighted scores, interpreted as preferences, and the actual preferences which the groups would have expressed in response to a direct query as to what fuel categories should be encouraged. There was considerable discussion of this distinction among workshop participants. Because this concern was particularly pronounced

during the early sessions, two additional workshop exercises were introduced: (1) a forecast of the mix of fuel utilization in the various categories for three different future years, and (2) an expression of recommendations for relative R&D emphasis for the fuel categories.

DEFINITIONS OF EVALUATION CRITERIA AND FUEL CATEGORIES

Tables 2 and 3 contain brief abstracts defining the evaluation criteria and the fuel categories*:

Evaluation Criteria

A. Contribution to Energy Self-Sufficiency in the U.S.

B. Extent of Technical Problems

C. Economics (or cost)

D. Environmental Impacts

E. Human Impacts.

Fuel Categories

1. Coal as Mined, direct-fired, unconstrained by SO_2 emission regulations
2. Low-Sulfur Coal, direct-fired specifically to meet SO_2 emission regulations
3. Coal as Mined, direct-fired with SO_2 control equipment
4. Chemically Cleaned Coal
5. Synthetic Liquids
6. Low-Btu or Intermediate-Btu Gas
7. Pipeline-Quality Gas
8. Mixed Fuel (added by the Coal Industry Group to include pulverized-coal/oil slurries).

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* Additional detail relating to these definitions is contained in Appendix A.

TABLE 2. EVALUATION CRITERIA—ABSTRACTS OF DEFINITIONS

A. Contribution to Energy Self-Sufficiency in the U. S.

This criterion is based on consideration of the extent to which the U. S. can effectively utilize domestic coal and coal-derived fuels on a major scale to eliminate dependency on foreign energy sources as soon as possible. The criterion refers to the degree to which coal and coal-derived fuels can be used as substitutes for petroleum-based clean fuels to free them for high priority uses. The military preparedness aspect is also included in this criterion.

B. Extent of Technical Problems

This criterion refers mainly to the state of development of technology associated with the various conversion processes, and with the level of technical risk involved in the problems remaining to be solved. Of particular concern is the probability that the process can be developed to a commercial scale.

C. Economics (or Cost)

This criterion refers to the total cost of building and operating a system to produce, transport, store, and utilize a given coal-derived fuel product. This includes all of the tangible costs that must be incurred to realize full implementation of a given coal-derived fuel (e.g., RD&D, capital investment for plants and facilities, operation, transportation, and environmental controls).

D. Environmental Impacts

This criterion refers to the relative adverse impact on the physical and biological environment at the conversion site, at the point of use, and in transporting and storing the coal-derived fuel. It also refers to the adverse impact on all elements of the natural environment, mainly localized impacts.

E. Human Impacts

This criterion refers to the impact on the net "Quality of Life" of the overall population as a result of extensive use of the various fuels. Of concern are adverse impacts that might affect individuals, communities, or society in general. Also included are any significant cultural impacts or employment shifts resulting from the conversion processes and associated activities. Mainly, this criterion refers to overall impacts to the nation.

TABLE 3. FUEL CATEGORIES—ABSTRACTS OF DEFINITIONS

(1) Coal as Mined, Direct Fired, Unconstrained by SO_2 Emission Regulations

Includes coal, as mined, that is to be direct fired in equipment where SO_2 regulations are nonexistent, are waived, or will permit operation with it measures for SO_2 control--e.g. where SO_2 emission levels are not covered in Federal or local regulations, as for small equipment or older installations. (This category assumes no constraints as to emission regulations.)

(2) Low-Sulfur Coal, Direct Fired Specifically to Meet SO_2 Emission Regulations

Applies where coal, to be direct fired, is chosen (on the basis of its sulfur content) specifically for the purpose of meeting SO_2 emission regulations--whether it is low in sulfur by its natural sulfur content or with the aid of mechanical preparation and washing.

(3) Coal as Mined, Direct Fired with SO_2 Control Equipment

Applies to coal of any sulfur level, as mined, where this coal is to be direct fired in installations with SO_2 control equipment to meet regulations. This covers installations where SO_2 control is achieved either by (a) stack-gas treatment for downstream SO_2 control or (b) chemically active fluidized-bed combustion.

(4) Chemically-Cleaned Coal

Comprises solid coal that has been chemically treated to reduce sulfur content such that no other SO_2 control is needed. Ash may also be reduced, but particulate controls may still be needed in some installations. Examples are solvent-refined coal or other chemically-desulfurized coal that is fired conventionally as solid fuel.

(5) Synthetic Liquids

Fuels from coal liquefaction processes comprise this category, along with intermediate liquid products that can be used as feed-stocks for further refining to finished fuels or to chemicals. Sulfur levels of such finished fuels are expected to be low enough that SO_2 controls are not required.

(6) Low-Btu or Intermediate-Btu Gas

Covers fuel gas from coal gasification at the site of utilization, or piped for relatively short distances to the point of utilization, the energy value of fuel gas in this category is in the range from 100-500 Btu/cu ft, depending on the gasifier:

- Low-Btu gas (typically, 150 Btu/cu ft)
- Intermediate-Btu gas (typically, 300 Btu/cu ft).

Generally, sulfur and particulate are to be removed from the fuel gas prior to its utilization. (The Gas Industry Group and the Oil and Chemical Industry Group preferred to label this category "Industrial Fuel Gas" as encompassing the range 100-500 Btu/cu ft.)

(7) Pipeline-Quality Gas

Pipeline-quality gas, or high-Btu gas, from coal is intended to be essentially interchangeable with natural gas in transmission and utilization. It is frequently called "substitute natural gas" or "synthetic natural gas" (SNG), approximately 1000 Btu/cu ft.

(8) Mixed Fuels[a]

A colloidal product consisting of coal and a liquid that would have firing characteristics of a liquid rather than a solid. This product could be a mixture of coal and petroleum products or could also be a mixture of coal and a synthetic liquids (which would be coal-derived). The product has the potential of being distributed by existing methods, mainly pipeline distribution systems.

(a) This fuel category was proposed and rated by the Coal Industry Group. It was not included in the advance kit and was not rated by the other groups.

STRUCTURE OF THIS REPORT

The following provides an overview of the structure of the remainder of this report.

Principal Results and Assessment. The results of the various workshops are presented under this next section. These results are examined from several viewpoints:

- Importance of criteria
- Fuel category evaluation ratings and scores
- Forecast of relative mix of fuels and suggested relative emphasis for R&D
- Summary profiles of groups.

Assessment of the Workshop Methodology. Readers interested in details of the workshop procedures and evaluation are referred to this main section. It includes information on:

- Participant feedback
- Concepts and hypotheses
- Recommendations relating to the methodology.

Overall Observations. This section contains overall observations related to the success of the workshop approach and a summary of observations on key viewpoints of groups.

Appendix. Volume II contains additional detailed information as follows.

A. Materials Provided to Participants Before and During Workshops

B. Key Comments by Participants

C. Principal Records from Each Workshop

D. Additional Summaries of Results Across Groups

E. Statistical Analyses of Results.

PRINCIPAL RESULTS AND ASSESSMENTS

The principal results of the workshops are presented and assessed in this section, organized as follows:

- Modifications and Interpretations of Definitions
- Ratings Placed on Importance of Evaluation Criteria
- Summary by Fuel Categories
  - Ratings, rankings by weighted scores, and participant comments
- Evaluation Ratings of Fuel Categories Against Criteria
- Supplementary Information from Workshop Activities
  - Forecast of relative mix of fuels
  - Suggested relative emphasis for R&D
- Summary Profiles of Groups.

The material in this section constitutes a broad summary and assessment of results.

MODIFICATIONS AND INTERPRETATIONS OF DEFINITIONS BY GROUPS

The groups were free to alter the original definitions abstracted in Tables 2 and 3 or to clarify interpretations in order to make their responses more effective in expressing the viewpoint of their interest group. Those modifications are summarized in Table 4 and are also discussed as part of the workshop results. More detailed discussion of the modifications are contained in Appendix C.

These modifications should be kept in mind when examining the results and assessments presented in the figures and tables in this report.

TABLE 4. SUMMARY OF PRINCIPAL REDEFINITIONS AND INTERPRETATIONS BY GROUPS

- Coal Industry
  - Time Frame: Present to 1990
  - "Energy independence" means we can get along without critical shortages
  - Added eighth fuel category, labeled "mixed fuels", defined as a colloidal mix of pulverized coal and oil
- Oil and Chemical Industry
  - Time Frame: Midrange, 1985 to 2000
  - Criteria A, B, and C considered to be strongly interrelated
  - Category 5 relabeled as "synthetic liquid hydrocarbons"
  - Category 6 interpreted as "Industrial Fuel Gas"
- Gas Industry
  - Time Frame: Year 2000
  - "Eliminate dependency on foreign sources" when we have to
  - Extent of Technical Problems considered for new technologies in evaluating Categories 4-7
  - For economics, the total cost, from the ground to end use was considered
  - For Categories 1-4, "finished fuel" was interpreted to be electricity
  - Category 6 relabeled "Industrial Fuel Gas"
- Electric Power Industry
  - Time Frame: Technologies evaluated for contribution in the year 1990
  - For Category 1 consider constant emission standards removed, but ambient air quality standards retained
- Industrial Fuel Users
  - Time Frame: Present to 1990
  - Criterion A modified to include reducing foreign imports
  - Category 1 evaluated assuming modified air quality regulations--ambient standards retained, point source emission regulations removed, cost-benefit and synergism of pollutants considered in setting standards
  - Category 4 includes primarily coal that can be burned as a solid
  - Category 5 includes fuels primarily intended for higher valued end uses (e.g. transportation)
- Public Interest Groups
  - Time Frame: Not specified
  - Criterion C relabeled "Financing"
  - Include land use and productivity, weather impacts, human health effects, and mine site activities in Criterion D
  - Criterion E relabeled "Economic and Social Impact"
- State Governments
  - Time Frame: Present to 1990
  - "Energy independence" means the reduction of energy and economic vulnerability
- Federal Government Agencies
  - Time Frame: Left unspecified
  - Criterion A reoriented toward avoiding increase in dependency on foreign sources
  - For Category 1, ignoring SO_2 emission regulations is assumed to be legal
- Composite Group
  - Energy self-sufficiency considered to be an objective, the remaining four criteria interpreted as constraints

RATINGS PLACED ON IMPORTANCE OF EVALUATION CRITERIA

Figure 2 presents graphically the results of the criteria ratings by each group, as an indication of relative importance. These are final ratings on a scale from 0 to 9 averaged for all participants within the group.

Table 5 shows these same ratings for each criterion, with the groups listed in rank order of ratings.

The following are principal observations noted from the results of criteria rating:

- Criteria considered important by most groups were energy self-sufficiency and economics (cost). The Public Interest Group viewed these criteria as less important than environmental or human impacts.

- The Coal Industry Group gave energy self-sufficiency an average rating of 8.1, the highest rating given any criterion by any group.

- The Gas Industry Group expressed a strong rating of importance for economics as a criterion, giving it an average rating of 8.0.

- The Oil and Chemical Industry Group rated energy self-sufficiency and economics equally at 7.9.

- The Industrial Fuel Users Group also regarded energy self-sufficiency and economics as important criteria, rating them at 7.7 and 7.9, respectively.

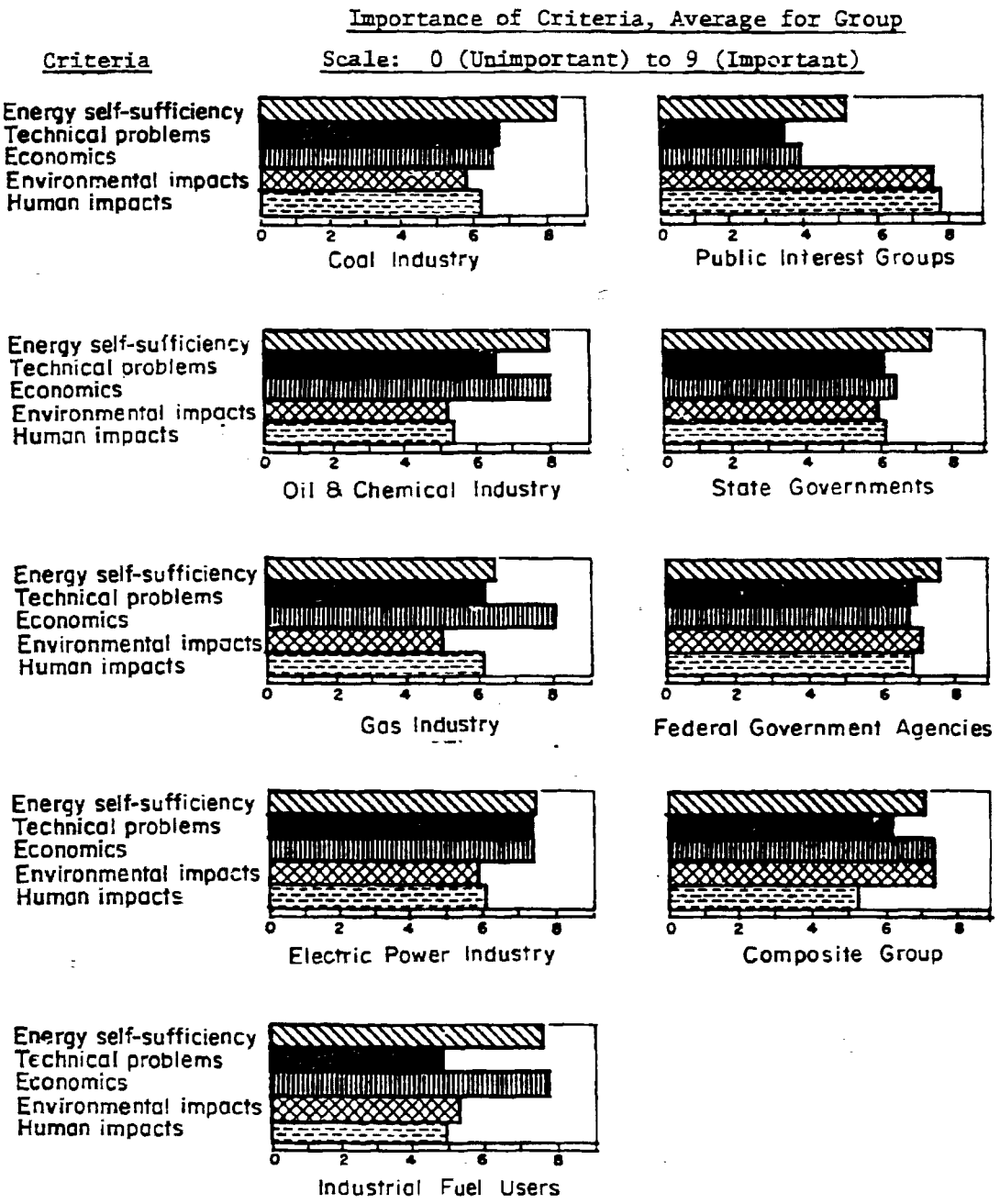


FIGURE 2. FINAL RATING OF EVALUATION CRITERIA BY GROUP

TABLE 5. RELATIVE IMPORTANCE PLACED ON EACH CRITERION

Average Rating on a Scale From 0 to 9

Criterion	Rating
Energy Self-Sufficiency	
Coal Industry	8.1
Oil and Chemical Industry	7.9
Industrial Fuel Users	7.7
Federal Government Agencies	7.6
Electric Power Industry	7.5
State Governments	7.4
Composite Group	7.0
Gas Industry	5.4
Public Interest Groups	5.1
Extent of Technical Problems	
Electric Power Industry	7.4
Federal Government Agencies	6.9
Coal Industry	6.5
Oil and Chemical Industry	6.4
Composite Group	6.2
Gas Industry	6.1
State Governments	6.1
Industrial Fuel Users	4.9
Public Interest Groups	3.4
Economics	
Gas Industry	8.0
Oil and Chemical Industry	7.9
Industrial Fuel Users	7.9
Electric Power Industry	7.4
Composite Group	7.3
Federal Government Agencies	6.7
Coal Industry	6.4
State Governments	6.4
Public Interest Groups	3.9
Environmental Impact	
Public Interest Groups	7.6
Composite Group	7.3
Federal Government Agencies	7.0
State Governments	6.0
Electric Power Industry	5.9
Coal Industry	5.6
Industrial Fuel Users	5.3
Oil and Chemical Industry	5.0
Gas Industry	4.9
Human Impact	
Public Interest Groups	7.7
Federal Government Agencies	6.7
Coal Industry	6.0
Gas Industry	6.0
Electric Power Industry	6.0
State Governments	5.8
Composite Group	5.3
Oil and Chemical Industry	5.1
Industrial Fuel Users	5.0

- The Public Interest Group rated environmental impact and human impact high, at 7.6 and 7.7, respectively.

- The Federal Government Agencies Group considered energy self-sufficiency as an important criterion, rating it at 7.6.

- The Electric Power Industry rated energy self-sufficiency, extent of technical problems, and economics at 7.5, 7.4, 7.4, respectively.

- The lowest ratings were by the Public Interest Group for extent of technical problems at 3.4 and for economics at 3.9.

Generally, the groups regarded all the criteria as having significant importance. Average ratings were above 4.5, the midpoint of the scale, in all except the two cases cited for the Public Interest Group.

An analysis of the variance (ANOVA) shows that there are statistically significant differences in the average rating of the five criteria by six of the nine groups. The groups whose average ratings of criteria are not statistically different within the group are: State Governments, Federal Government, and the Composite Group.

In terms of ranges between high and low ratings, the two government groups discriminated least among the criteria of any groups. The Public Interest Group reflected the strongest discrimination; this group took the position that their primary area of competence was with respect to weighting of criteria, rather than their appraisal of individual fuel categories with respect to criteria like extent of technical problem or economics.

EVALUATION RATINGS OF FUEL CATEGORIES AGAINST CRITERIA

The ratings of fuel categories are an expression by the workshop participants of the ability of each of the fuels to satisfy a specified criterion. In the scale definitions (on the scale from 0 to 9) low ratings are "unfavorable" and high ratings are "favorable", i.e., a high rating for a fuel category on energy self-sufficiency means high contribution; a high rating on extent of technical problems means few problems; a high rating on economics means low cost; a high rating for environmental impacts and human impacts means few adverse impacts.

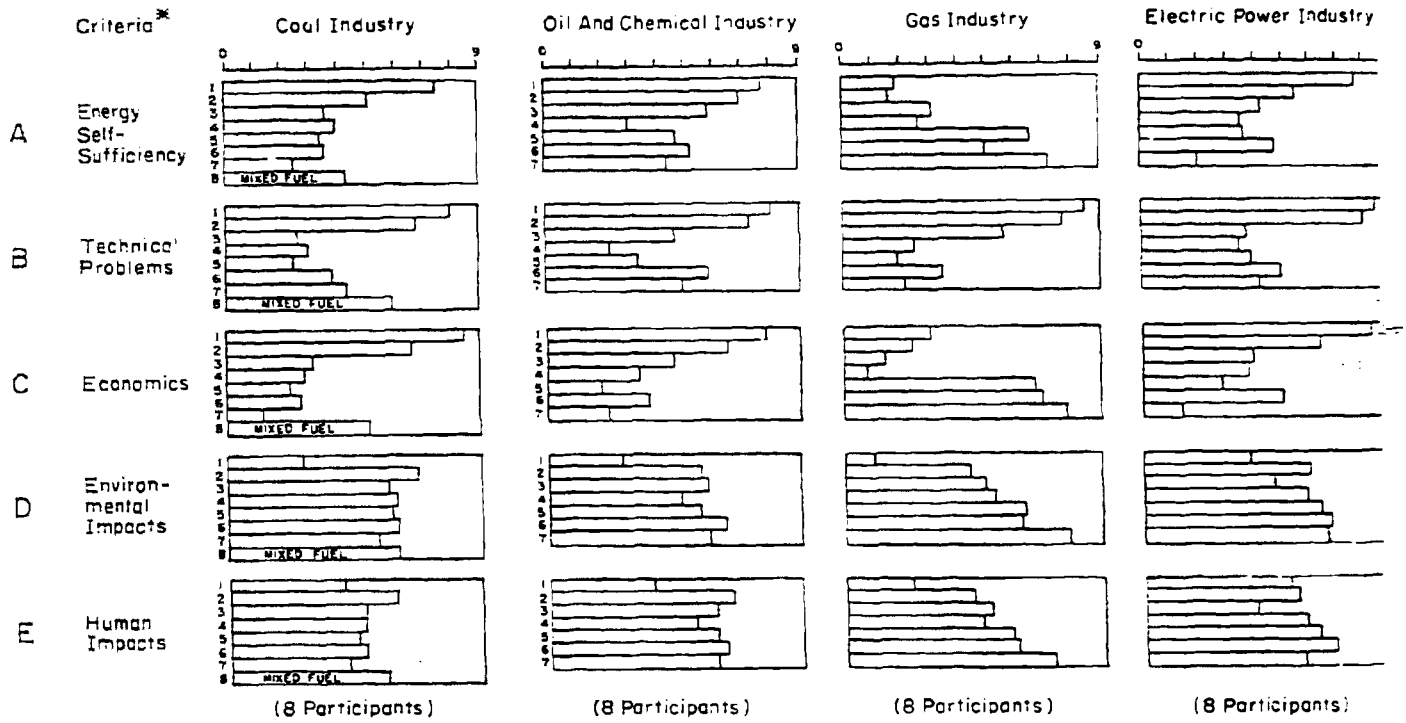
(As discussed previously, these ratings can be combined with the ratings given to the evaluation criteria, to derive overall weighted scores; these are presented in a subsequent section of this report.) The direct results of the workshop ratings of fuel categories are presented in the following figures and tables:

Figure 3. Ratings of Fuel Categories Against Each Criterion for all Interest Groups
(graphical presentation)

Table 6. Ratings of Each Fuel Category by Various Interest Groups
(separate tabular presentation for each criterion: Tables 6-a through 6-e).

In drawing comparisons from Figure 3 as to the viewpoints of the groups, it is suggested that the reader compare across the chart for a single criterion and note the profile of the fuel ratings. For example, to examine how the groups evaluated the fuel categories with respect to the extent of technical problems (i.e., where R&D might be most needed) read across Row B of Figure 3.

FIGURE 3. FINAL RATINGS OF FUEL CATEGORIES



1 Coal, fired unconstrained
2 Low sulfur coal
3 Coal, fired controlled
4 Chemically cleaned coal
5 Synthetic liquids
6 Low, int Btu gas
7 Pipeline-quality gas
8 Mixed fuel

* In all scale definitions low ratings are unfavorable and high ratings are favorable, i.e., a high rating on Energy-Self Sufficiency means high contribution; a high rating on Economics means low cost, a high rating on Extent of Technical Problem means few problems, likewise for Environmental and Human Impacts.

ES AGAINST EACH CRITERION FOR ALL INTEREST GROUPS

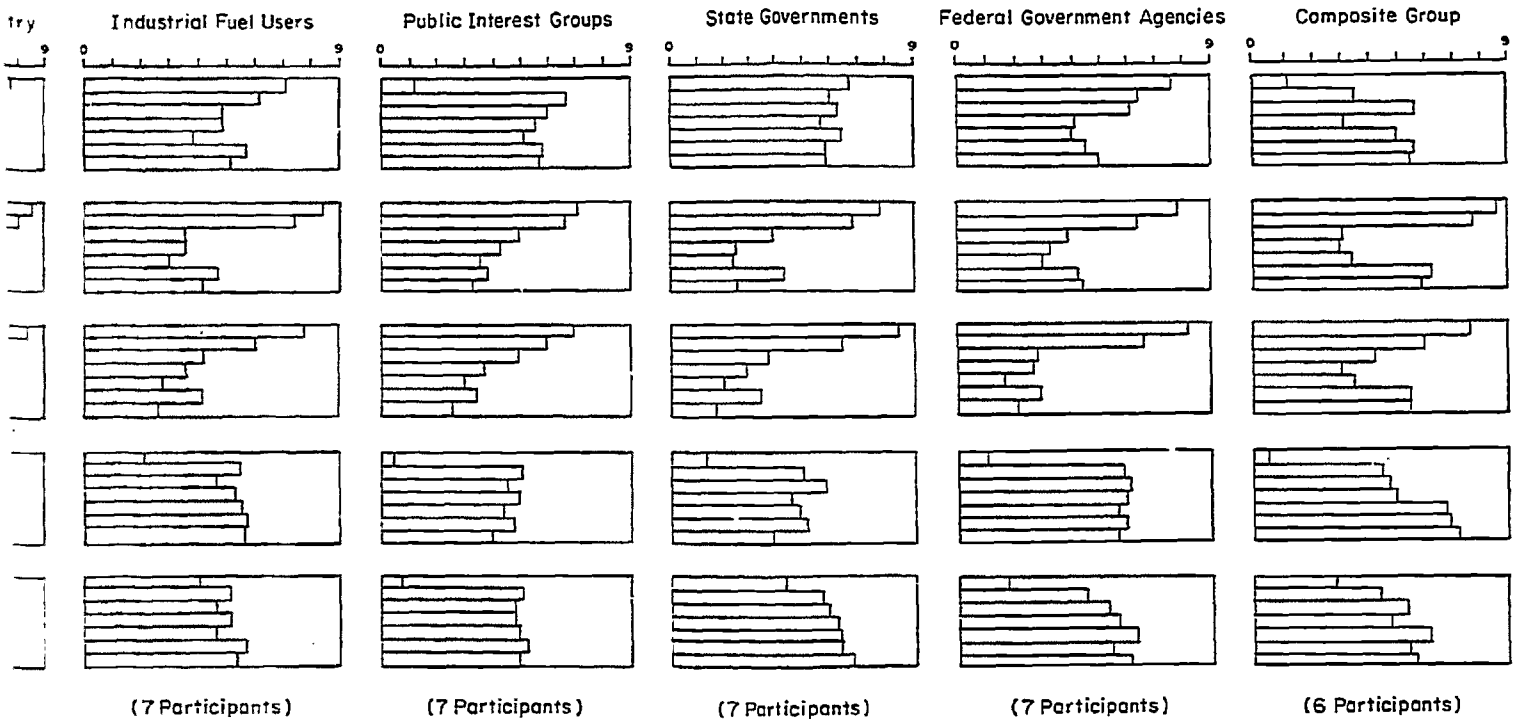


TABLE 6-a. RELATIVE EMPHASIS PLACED ON EACH FUEL CATEGORY BY VARIOUS INTEREST GROUPS

CRITERION A—ENERGY SELF SUFFICIENCY

Fuel Category	Rating
1) Coal, fired unconstrained by SO_2 regulations	
Oil and Chemical Industry	7.8
Electric Power Industry	7.8
Federal Government Agencies	7.6
Coal Industry	7.5
Industrial Fuel Users	7.1
State Governments	6.7
Gas Industry	1.9
Composite Group	1.2
Public Interest Groups	1.1
2) Low sulfur coal, fired to meet SO_2 regulations	
Oil and Chemical Industry	7.0
Public Interest Groups	6.7
Federal Government Agencies	6.4
Industrial Fuel Users	6.1
State Governments	6.0
Electric Power Industry	5.5
Coal Industry	5.1
Composite Group	3.5
Gas Industry	1.6
3) Coal, fired with SO_2 Control Equipment	
State Governments	6.3
Public Interest Groups	6.0
Federal Government Agencies	6.0
Oil and Chemical Industry	5.9
Composite Group	5.7
Industrial Fuel Users	4.9
Electric Power Industry	4.2
Coal Industry	3.6
Gas Industry	3.1
4) Chemically Cleaned Coal	
State Governments	5.7
Public Interest Groups	5.6
Industrial Fuel Users	4.9
Federal Government Agencies	4.1
Coal Industry	4.0
Electric Power Industry	3.5
Composite Group	3.2
Oil and Chemical Industry	3.0
Gas Industry	2.6

Fuel Category	Rating
5) Synthetic Liquids	
Gas Industry	6.6
State Governments	6.4
Public Interest Groups	5.1
Composite Group	5.0
Oil and Chemical Industry	4.8
Federal Government Agencies	4.0
Industrial Fuel Users	3.9
Electric Power Industry	3.6
Coal Industry	3.5
6) Low/Intermediate Btu Gas	
Public Interest Groups	5.9
State Governments	5.9
Industrial Fuel Users	5.7
Composite Group	5.7
Oil and Chemical Industry	5.2
Gas Industry	5.0
Electric Power Industry	4.8
Federal Government Agencies	4.6
Coal Industry	3.6
7) Pipeline-Quality Gas	
Gas Industry	7.2
State Governments	5.9
Composite Group	5.5
Public Interest Groups	5.4
Industrial Fuel Users	5.1
Federal Government Agencies	5.0
Oil and Chemical Industry	4.4
Coal Industry	2.5
Electric Power Industry	2.0
8) Mixed Fuels	
Coal	4.4

TABLE 6-b. RELATIVE EMPHASIS PLACED ON EACH FUEL CATEGORY BY VARIOUS INTEREST GROUPS.

CRITERION B—EXTENT OF TECHNICAL PROBLEMS

Fuel Category	Rating
1) Coal, fired unconstrained by SO_2 regulations	
Composite Group	8.7
Gas Industry	8.5
Electric Power Industry	8.5
Industrial Fuel Users	8.4
Coal Industry	8.0
Oil and Chemical Industry	8.0
Federal Government Agencies	7.9
State Governments	7.9
Public Interest Groups	7.1
2) Low sulfur coal, fired to meet SO_2 regulations	
Electric Power Industry	8.0
Gas Industry	7.8
Composite Group	7.8
Industrial Fuel Users	7.4
Oil and Chemical Industry	7.2
State Governments	6.9
Coal Industry	6.8
Public Interest Groups	6.7
Federal Government Agencies	6.4
3) Coal, fired with SO_2 control Equipment	
Gas Industry	5.6
Public Interest Groups	5.0
Oil and Chemical Industry	4.6
State Governments	4.0
Federal Government Agencies	3.9
Electric Power Industry	3.5
Industrial Fuel Users	3.4
Composite Group	3.2
Coal Industry	2.6
4) Chemically Cleaned Coal	
Public Interest Groups	4.3
Electric Power Industry	3.4
Industrial Fuel Users	3.4
Federal Government Agencies	3.3
Coal Industry	3.0
Composite Group	3.0
State Governments	2.6
Gas Industry	2.5
Oil and Chemical Industry	2.2

Fuel Category	Rating
5) Synthetic Liquids	
Electric Power Industry	3.8
Public Interest Groups	3.6
Composite Group	3.5
Oil and Chemical Industry	3.4
Industrial Fuel Users	3.0
Federal Government Agencies	3.0
Coal Industry	2.5
State Governments	2.4
Gas Industry	1.9
6) Low/Intermediate Btu Gas	
Composite Group	6.3
Oil and Chemical Industry	5.9
Electric Power Industry	4.9
Industrial Fuel Users	4.7
State Governments	4.4
Federal Government Agencies	4.3
Coal Industry	3.9
Public Interest Groups	3.9
Gas Industry	3.5
7) Pipeline-Quality Gas	
Composite Group	6.0
Oil and Chemical Industry	4.9
Coal Industry	4.4
Federal Government Agencies	4.4
Electric Power Industry	4.1
Industrial Fuel Users	4.1
Public Interest Groups	3.3
State Governments	2.6
Gas Industry	2.1
8) Mixed Fuels	
Coal Industry	5.9

TABLE 6-c. RELATIVE EMPHASIS PLACED ON EACH FUEL CATEGORY BY VARIOUS INTEREST GROUPS.

CRITERION C—ECONOMICS

Fuel Category	Rating
1) Coal, fired unconstrained by SO_2 regulations	
Coal Industry	8.5
Electric Power Industry	8.4
State Governments	8.4
Federal Government Agencies	8.3
Industrial Fuel Users	7.9
Oil and Chemical Industry	7.8
Composite Group	7.8
Public Interest Groups	7.0
Gas Industry	3.0
2) Low sulfur coal, fired to meet SO_2 regulations	
Federal Government Agencies	6.7
Coal Industry	6.6
Oil and Chemical Industry	6.4
Electric Power Industry	6.4
State Governments	6.4
Composite Group	6.2
Industrial Fuel Users	6.1
Public Interest Groups	6.0
Gas Industry	2.4
3) Coal, fired with SO_2 control equipment	
Public Interest Groups	5.0
Oil and Chemical Industry	4.5
Industrial Fuel Users	4.3
Composite Group	4.3
Electric Power Industry	3.9
State Governments	3.7
Coal Industry	3.1
Federal Government Agencies	2.9
Gas Industry	1.4
4) Chemically Cleaned Coal	
Electric Power Industry	3.8
Industrial Fuel Users	3.7
Public Interest Groups	3.7
Oil and Chemical Industry	3.2
Composite Group	3.2
Coal Industry	2.9
State Governments	2.9
Federal Government Agencies	2.7
Gas Industry	0.8

Fuel Category	Rating
5) Synthetic Liquids	
Gas Industry	6.8
Composite Group	3.7
Public Interest Groups	3.0
Industrial Fuel Users	2.9
Electric Power Industry	2.8
Coal Industry	2.4
State Governments	2.0
Oil and Chemical Industry	1.9
Federal Government Agencies	1.7
6) Low/Intermediate Btu Gas	
Gas Industry	7.0
Composite Group	5.7
Electric Power Industry	5.0
Industrial Fuel Users	4.3
Oil and Chemical Industry	3.6
Public Interest Groups	3.4
State Governments	3.4
Federal Government Agencies	3.0
Coal Industry	2.8
7) Pipeline-Quality Gas	
Gas Industry	7.9
Composite Group	4.8
Industrial Fuel Users	2.7
Public Interest Groups	2.6
Oil and Chemical Industry	2.1
Federal Government Agencies	2.1
State Governments	1.7
Coal Industry	1.4
Electric Power Industry	1.4
8) Mixed Fuels	
Coal Industry	5.1

TABLE 5-d. RELATIVE EMPHASIS PLACED ON EACH FUEL CATEGORY BY VARIOUS INTEREST GROUPS.

CRITERION D—ENVIRONMENTAL IMPACTS

Fuel Category	Rating
1) Coal, fired unconstrained by SO_2 regulations	
Electric Power Industry	3.8
Coal Industry	2.8
Oil and Chemical Industry	2.6
Industrial Fuel Users	2.1
State Governments	1.3
Federal Government Agencies	1.2
Gas Industry	1.0
Composite Group	0.5
Public Interest Groups	0.4
2) Low sulfur coal, fired to meet SO_2 regulations	
Coal Industry	6.9
Electric Power Industry	6.0
Federal Government Agencies	5.9
Industrial Fuel Users	5.6
Oil and Chemical Industry	5.5
Public Interest Groups	5.1
State Governments	5.0
Gas Industry	4.5
Composite Group	4.5
3) Coal, fired with SO_2 control equipment	
Federal Government Agencies	6.1
State Governments	5.9
Coal Industry	5.8
Oil and Chemical Industry	5.8
Gas Industry	5.0
Composite Group	4.8
Industrial Fuel Users	4.7
Electric Power Industry	4.6
Public Interest Groups	4.6
4) Chemically Cleaned Coal	
Coal Industry	6.0
Federal Government Agencies	6.0
Electric Power Industry	5.9
Gas Industry	5.4
Industrial Fuel Users	5.3
Public Interest Groups	5.0
Composite Group	5.0
Oil and Chemical Industry	4.8
State Governments	4.6

Fuel Category	Rating
5) Synthetic Liquids	
Composite Group	6.8
Gas Industry	6.4
Electric Power Industry	6.4
Coal Industry	5.9
Federal Government Agencies	5.7
Industrial Fuel Users	5.6
Oil and Chemical Industry	5.5
State Governments	4.9
Public Interest Groups	4.4
6) Low/Intermediate Btu Gas	
Composite Group	7.0
Electric Power Industry	6.8
Oil and Chemical Industry	6.4
Gas Industry	6.2
Coal Industry	6.1
Federal Government Agencies	6.0
Industrial Fuel Users	5.9
State Governments	5.1
Public Interest Groups	4.8
7) Pipeline-Quality Gas	
Gas Industry	8.0
Composite Group	7.3
Electric Power Industry	6.6
Oil and Chemical Industry	5.8
Industrial Fuel Users	5.7
Federal Government Agencies	5.7
Coal Industry	5.4
Public Interest Groups	4.0
State Governments	3.9
8) Mixed Fuels	
Coal Industry	6.1

TABLE 6-e. RELATIVE EMPHASIS PLACED ON EACH FUEL CATEGORY BY VARIOUS INTEREST GROUPS.

CRITERION E—HUMAN IMPACTS

Fuel Category	Rating
1) Coal, fired unconstrained by SO_2 regulations	
Electric Power Industry	5.1
State Governments	4.4
Coal Industry	4.1
Industrial Fuel Users	4.1
Oil and Chemical Industry	3.8
Composite Group	2.8
Gas Industry	2.4
Federal Government Agencies	2.0
Public Interest Groups	0.7
2) Low sulfur coal, fired to meet SO_2 regulations	
Oil and Chemical Industry	6.6
Coal Industry	6.0
State Governments	5.7
Electric Power Industry	5.5
Industrial Fuel Users	5.3
Public Interest Groups	5.1
Gas Industry	4.6
Federal Government Agencies	4.6
Composite Group	4.5
3) Coal, fired with SO_2 control equipment	
Oil and Chemical Industry	6.0
State Governments	6.0
Composite Group	5.5
Federal Government Agencies	5.3
Gas Industry	5.2
Coal Industry	4.9
Public Interest Groups	4.9
Industrial Fuel Users	4.7
Electric Power Industry	3.9.
4) Chemically Cleaned Coal	
State Governments	6.3
Electric Power Industry	5.8
Federal Government Agencies	5.7
Industrial Fuel Users	5.3
Oil and Chemical Industry	5.2
Coal Industry	4.9
Gas Industry	4.9
Public Interest Groups	4.9
Composite Group	4.8

Fuel Category	Rating
5) Synthetic Liquids	
State Governments	6.4
Federal Government Agencies	6.4
Composite Group	6.3
Electric Power Industry	6.2
Oil and Chemical Industry	6.0
Gas Industry	6.0
Public Interest Groups	5.0
Industrial Fuel Users	4.7
Coal Industry	4.6
6) Low/Intermediate Btu Gas	
Electric Power Industry	6.9
Oil and Chemical Industry	6.4
State Governments	6.4
Gas Industry	6.1
Federal Government Agencies	6.1
Industrial Fuel Users	5.9
Composite Group	5.5
Public Interest Groups	5.3
Coal Industry	4.9
7) Pipeline-Quality Gas	
Gas Industry	7.4
State Governments	6.9
Federal Government Agencies	6.1
Oil and Chemical Industry	6.0
Composite Group	5.8
Electric Power Industry	5.6
Industrial Fuel Users	5.4
Public Interest Groups	5.0
Coal Industry	4.2
8) Mixed Fuels	
Coal Industry	5.6

Overview of Fuel Categories Ratings

In assessing the results of the final rating of the fuel categories, summarized in Figure 3 and Tables 6-a through 6-e, several areas of general agreement and general disagreement stand out:

- As for general agreement, the ratings of the various fuels under extent of technical problems, environmental impact, and human impact revealed relatively small differences between the averages for the various groups. (For these three criteria the average difference between the high and low group averages for all fuel categories was on the order of 2.5 points on the rating scale.)

- The widest disagreement was observed in evaluating the fuel categories for contribution to energy self-sufficiency and economics, where the average range between the high and low group averages was 4.1 and 4.6, respectively. (Note especially the results for evaluation of coal, fired unconstrained for energy self-sufficiency, where two polar positions emerged: the Gas Industry Group, the Composite Group, and Public Interest Group combined to give a low average rating, and the remaining groups were in fairly close agreement with a high average rating.)

Other points of interest shown by the summaries:

- The absolute highest rating was for the extent of technical problems involved in burning coal, unconstrained by SO_2 regulations -- 8.7, by the Composite Group. That is, few technical problems are perceived.

- The closest agreement over all groups was for the environmental impact of chemically cleaned coal, with a high rating of 6.0 and a low rating of 4.6.

- Widest disagreement over all groups was recorded for energy self-sufficiency of burning coal, unconstrained by SO_2 regulations; ratings ranged from 1.1 to 7.8.

- Other areas of marked disagreement among groups were (1) the evaluations of pipeline quality gas relative to energy self-sufficiency and as to economics, and (2) the evaluation of synthetic liquids relative to economics. Differences between high and low were more than 5 points on the rating scale.

- The Gas Industry Group registered the most differences from the remaining groups:

  - For energy self-sufficiency, they rated all of the coal categories (1 through 4) low, giving the absolute lowest rating of all groups to coal categories 2, 3, and 4. Their rating of pipeline quality gas was significantly higher than all of the other groups.

  - For economics, the Gas Industry rated well below all other groups for coal categories 1 through 4 and well above all other groups for the synthetic categories 5, 6, and 7.

- The Public Interest Group stands out in their views toward burning of coal, unconstrained by SO_2 regulations. For this fuel category, they provided the absolute lowest average rating for three of the five criteria. (This

TABLE 7. WEIGHTED SCORES AND RANKINGS OF FUEL CATEGORIES

Maximum score is 10.0. Numbers in italics refer to rank order of scores within groups.

Fuel Category	Coal Industry	Oil and Chemical Industry	Gas Industry	Electric Power Industry	Industrial Fuel Users	Public Interest Groups	State Governments	Federal Government Agencies	Composite Group
1. Coal, fired unconstrained by SO_2 regulations	[illegible]	[illegible]	5.2 *6*	10.0 *1*	10.0 *1*	4.1 *7*	[illegible]	[illegible]	6.6 *6*
2. Low sulfur coal, fired to meet SO_2 regulations	[illegible]	10.0 *1*	6.0 *4*	[illegible]	[illegible]	10.0 *1*	10.0 *1*	10.0 *1*	[illegible]
3. Coal, fired with SO_2 control equipment	5.8 *6*	[illegible]	5.6 *5*	5.7 *6*	7.1 *5+*	[illegible]	[illegible]	[illegible]	7.9 *5*
4. Chemically cleaned coal	6.1 *5*	5.3 *7*	4.3 *7*	6.1 *4+*	7.2 *4*	[illegible]	7.0 *5*	7.0 *6*	6.3 *7*
5. Synthetic liquids	5.5 *7*	6.0 *6*	[illegible]	6.1 *4+*	6.3 *7*	7.8 *5*	6.9 *6*	6.6 *7*	8.4 *4*
6. Low/intermediate Btu gas	6.2 *4*	7.9 *4*	[illegible]	[illegible]	[illegible]	8.1 *4*	7.7 *4*	[illegible]	[illegible]
7. Pipeline-quality gas	5.1 *8*	6.5 *5*	10.0 *1*	5.0 *7*	7.1 *5+*	7.5 *6*	6.5 *7*	7.5 *5*	[illegible]
8. Mixed fuels	[illegible]								

* Maximum value of score is 10.0

group observed that their background of experience was relatively limited in evaluating the fuel categories with respect to technical problems and economics.

WEIGHTED SCORES FOR FUEL CATEGORIES

Table 7 presents a matrix of weighted scores for the fuel categories, derived by combining their evaluation ratings with the important ratings of criteria. The highest score in any workshop group is 10.0, with the score being indicative of the relative degree to which the development and use of a fuel category should be encouraged.

The shading of the blocks in Table 7 provides an indication of the ranking by each workshop group, as shown in the italicized numbers, the highest ranking having the darkest shading and the lowest ranking having no shading. (Categories which ranked fourth, fifth, and sixth are shown by a single light shading.)

Table 8 summarizes by fuel category the rank order position in which each workshop group scored the various fuel categories. A low ranking number reflects high scores of fuel preference. For example, the Composite Group ranked Fuel Category 6 (low/intermediate Btu gas) as their highest ranking fuel category as determined by weighted scores (No. 1 ranking).

Overall Observations on Fuel Category Rankings

Several fuel categories emerge from consideration of Tables 7 and 8 as having relatively high overall rankings, based on weighted scores. These are low-sulfur coal, coal fired without SO_2 controls, and low/intermediate-Btu gas. Detailed observations follow.

TABLE 8. RELATIVE EMPHASIS PLACED ON EACH FUEL CATEGORY BY VARIOUS INTEREST GROUPS. RANK ORDER POSITION OF WEIGHTED SCORES WITHIN GROUPS.

Fuel Category	Rank Order*
1. Coal, Fired Unconstrained by SO_2 Regulations	
Coal Industry	1
Electric Power Industry	1
Industrial Fuel Users	1
State Governments	2
Federal Government Agencies	2
Oil and Chemical Industry	2
Composite Group	6
Gas Industry	6
Public Interest Groups	7
2. Low Sulfur Coal, Fired to Meet SO_2 Regulations	
Oil and Chemical Industry	1
Public Interest Groups	1
Federal Government Agencies	1
State Governments	1
Industrial Fuel Users	2
Coal Industry	2
Electric Power Industry	2
Composite Group	3
Gas Industry	4
3. Coal, Fired with SO_2 Control Equipment	
Public Interest Groups	2
State Governments	3
Oil and Chemical Industry	3
Federal Government Agencies	3
Composite Group	5
Industrial Fuel Users	5
Gas Industry	5
Coal Industry	6
Electric Power Industry	6
4. Chemically Cleaned Coal	
Public Interest Groups	3
Industrial Fuel Users	4
Electric Power Industry	4
State Governments	5
Coal Industry	5
Federal Government Agencies	6
Composite Group	7
Oil and Chemical Industry	7
Gas Industry	7

Fuel Category	Rank Order*
5. Synthetic Liquids	
Gas Industry	2
Composite Group	4
Electric Power Industry	4
Public Interest Groups	5
State Governments	6
Oil and Chemical Industry	6
Federal Government Agencies	7
Industrial Fuel Users	7
Coal Industry	7
6. Low/Intermediate Btu Gas	
Composite Group	1
Gas Industry	2
Public Interest Groups	3
Industrial Fuel Users	3
Electric Power Industry	3
State Governments*	4
Oil and Chemical Industry	4
Federal Government Agencies	4
Coal Industry	4
7. Pipeline-Quality Gas	
Gas Industry	1
Composite Group	2
Federal Government Agencies	5
Industrial Fuel Users	5
Oil and Chemical Industry	5
Public Interest Groups	6
Electric Power Industry	7
State Governments	7
Coal Industry	8
8. Mixed Fuels	
Coal Industry	3

- Low-sulfur coal was ranked highest by four groups and second by three groups.

- Coal fired without SO_2 controls was ranked highest by three groups and second by three groups.

- Low/intermediate-Btu gas was ranked highest among the synthetic fuels categories by all except the Gas Industry Group and it was top ranked over all the fuel categories by one group, the Composite Group. It was second ranked by one group and third ranked by three groups. All groups rated it no lower than fourth.

- Other categories that were ranked first or second by at least one group were
  - Coal, fired with SO_2 controls (including both stack-gas control systems and fluidized-bed combustion)
  - Synthetic liquids
  - Pipeline quality gas.

These rankings can be viewed as group preferences for the fuel categories that should be encouraged. It should be noted that two of the highest ranking fuel categories are among those involving direct firing of solid coal.

Similarities Among Groups

Several striking features are noted in Tables 7 and 8 as to similarities in rankings of fuel categories among the various groups:

- The first four rankings were remarkably similar for the groups representing the Coal Industry, the Electric Power Industry, and Industrial Fuel Users. The first two rankings were identical and the third and fourth were very similar.

- The first four rankings were identical for the Oil and Chemical Industry Group and the State Governments Group.

- The rankings by the Gas Industry Group and the Composite Group were generally similar, especially at the lower three rankings.

- The rankings by the Public Interest Group stood out as substantially different than the other groups, but were somewhat similar to those by the Composite Group. (These scores for the Public Interest Group may have been influenced by their limited background in evaluating technical problems and economics, as noted previously.)

SUMMARY BY FUEL CATEGORIES—RATINGS, RANKING BY WEIGHTED SCORES, AND PARTICIPANT COMMENTS

In the eight numbered subsections which follow for each fuel category, both ratings and weighted scores are examined for each of the eight fuel categories. Where the groups made modifications or interpretations to fuel category definitions, these are noted in footnotes.

The first observation in each subsection relates to the ranking of the fuel category in terms of final weighted score. Other observations relate to ratings against the evaluation criteria.

Noted in italics for each fuel category are especially significant comments by participants during workshops. When a comment was expressed by an individual participant, as distinguished from a general position, this is noted by (IP) following the comment. (Additional key comments are contained in Appendix B.)

1. Coal, Fired Unconstrained by SO_2 Regulations*

Rankings

- This category was ranked first or second (in terms of weighted score) by 6 of the 9 groups. It was ranked first by the Coal Industry Group, Electric Power Industry Group* and Industrial Fuel Users Group. It was ranked low by the Public Interest Group.

Table 8

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* The Electric Power Industry Group established an interpretation on Fuel Category 1 that it refers to "unconstrained" by constant emission regulations, but with ambient air-quality standards maintained as established by proper cost-benefit analysis, and allowing for research and development by ERDA to make such analyses more meaningful.

Evaluation Ratings

- The contribution of this category to energy self-sufficiency was ranked highest by the industrial groups (except the Gas Industry Group) and by the Federal Government Group. The Public Interest Group, Composite Group, and Gas Industry Group rated it the lowest. Table 6-a

- As expected, few technical problems were perceived in firing coal without SO_2 control equipment. Table 6-b

- Economics of firing coal without controls were rated favorable by all groups except the Gas Industry Group. Table 6-c

- Extensive environmental impact was associated with this fuel use category by all groups; the most pessimistic was the Public Interest Group and the most optimistic was the Electric Power Industry Group. Human impacts were viewed similarly. Tables 6-c, d

Significant Comments in Workshops Regarding Firing Coal Unrestrained by SO_2 Regulations

- *The Coal Industry Group stated that there is a serious problem in converting many plants back to coal burning. The distribution system for coal would have to be completely rebuilt. In order to convert oil-designed boilers to solid coal firing, they would have to be derated, which is generally not feasible. Derating of 5 percent is usually unacceptable to a utility. Gas designed boilers cannot be converted.*

- *The Public Interest Group discussed the health effects of SO_2. Sulfate and particulate matter were mentioned as also being important, especially respirable particulates.*

- *The Federal Government Group indicated that there are many places where we could burn coal without SO_2 controls and still meet the ambient standards. (On the order of 50 percent of the coal-fired electric power plants presently violate some standards.) To solve our energy problems we will have to burn coal unconstrained by SO_2 regulations.*

2. Low-Sulfur Coal, Fired to Meet SO_2 Regulations

Rankings

- This fuel category was ranked first or second by 7 of the 9 groups (in terms of weighted scores). It was ranked highest by four groups: Oil and Chemical Group, Public Interest Group, State Governments Groups, and Federal Agencies Group. The lowest ranking was by the Gas Industry Group.

Evaluation Ratings

- The contribution of this fuel category to energy self-sufficiency was rated moderate to high by eight of the groups. Reservations were expressed by all groups as to the amount of low-sulfur coals that will be available and practical to transport to point of use.

- Few technical problems were perceived by the groups.

- Economics for the use of low-sulfur coal were judged favorably by eight groups. A pessimistic view was recorded by the Gas Industry Group.

- Environmental and human impacts of this category were judged generally to be equivalent to those for the synthetic fuels categories.

Significant Comments in Workshops Regarding Low Sulfur Coal

- *Several groups indicated that low-sulfur coal is a desirable answer but regarded the supply as limited, as confirmed by the Coal Industry Group. Others mentioned that transportation is a problem because the greatest need is in areas distant from low-sulfur coal deposits.*

3. Coal, Fired with SO_2 Control Equipment

This category was defined to include (1) stack-gas treatment, (2) chemically active fluidized-fuel combustion, or (3) any other systems where SO_2 control is combined with the combustion process.

Rankings

- Four groups ranked this category moderate to high (ranking 2 or 3) in terms of the final weighted score: Public Interest Group, the two government groups, and the Oil and Chemical Industry Group. It was ranked low by the other industry groups and lowest by the Electrical Power Industry Group and Coal Industry Group. Table 8

Evaluation Ratings

- The contribution of this fuel category to energy self-sufficiency was rated highest by the State and Federal Government Groups and Public Interest Groups. The industry groups rated the contribution of this fuel category as moderate to low. Table 6-a

- Many technical problems yet to be solved for this fuel category were perceived by all groups; the most pessimistic was the Coal Industry. Table 6-b

- The cost of SO_2 control equipment was rated relatively expensive by all industry groups. Table 6-c

- This fuel category compared favorably in ratings of environmental impacts to most of the other fuel categories but lower than the synthetic liquid and gaseous fuels. Human impacts were rated similarly, around mid range. Tables 6-d,e

Significant Comments in Workshops Regarding Coal, Fired with SO_2 Controls

- *A representative of the Government Group commented that stack-gas scrubbers do not work at the present time with the reliability needed. There is a need for a massive expansion of a new industry in order to make scrubbers viable. The capital cost of scrubbers is a real problem. (IP)* *

* View expressed by individual participant.

- *A representative from the Composite Group commented on fluidized combustion as being a very attractive technology under this fuel category. It may be most economical for retrofitting. However, there is high technical risk associated with atmospheric fluidized-bed combustion and a question of the availability of limestone at a reasonable cost. It was observed that this approach will not be used extensively in industrial boilers except for large industry. (IP)*

4. Chemically Cleaned Coal

This category was defined to include (1) solvent-refined coal or (2) other chemically desulfurized coal that is fired conventionally as a wolid fuel.*

Rankings

- Three groups ranked this use moderate to high in overall weighted score: the Public Interest Group (ranking 3), plus the Industrial Fuel Users and Electric Power Industry Group (ranking 4). Low preference was expressed by the other groups (ranking 5 to 7). Table 8

Evaluation Ratings

- The contribution of this fuel category to energy self-sufficiency was generally rated low to moderate. Table 6-a

* The Gas Industry Group interpreted "finished fuels" to be electricity in Fuel Categories 1, 2, 3, and 4.

- Many technical problems were perceived for chemical cleaning by all groups. The most pessimistic were the Gas Industry Group and the Oil and Chemical Industry Group. Table 6-b

- Costs of chemically cleaned coal were judged more expensive than the other fuel alternatives. The Oil and Chemical Industry Group was the most extreme of the groups in anticipating high costs. Table 6-c

- Environmental impacts associated with this fuel category compared favorably with those for the other direct solid-fuel fired uses and synthetic liquids. Human impacts were viewed similarly. Tables 6-d,e

Significant Comments in Workshops Regarding Chemically Cleaned Coal

- *Representatives of the Electric Industry Group suggested that the problem with solvent-refined coal is that it is neither coal (solid) nor oil (liquid); it is very difficult to store; it may be carcinogenic; and there are great materials handling problems.*

- *The recorded position by the Oil and Chemical Industry Group included this statement: "Important objective of sulfur removed from coal is depreciated in this rating by tying it to solvent-refined coal".*

5. Synthetic Liquids

This category includes liquid fuels from coal and intermediate liquids feedstocks for further refining to finished fuels or to chemicals*.

Rankings

- Rankings of overall preference for this fuel category were generally moderate to low. The highest ranking for synthetic liquids was by the Gas Industry Group (tying for second in terms of weighted scores). The Oil and Chemical Industry ranked this category sixth; however, the group observed that this ranking did not fully reflect the group's view of the long-term importance of this category. Table 8

Evaluation Ratings

- Contribution of this fuel category to energy self-sufficiency was rated from low to moderately high, with the Gas Industry Group recording the highest rating. The Oil and Chemical Industry Group's view was about average. (Rankings appeared to relate to differing views as to the role of synthetic liquids for feedstocks and for transportation fuels.) Table 6-a

- Many technical problems yet to be solved for synthetic liquid production were perceived by all groups. The most optimistic view was held by the Electric Power Industry Group. Table 6-b

* The Oil and Chemical Industry relabeled this category as "Synthetic Liquid Hydrocarbons", thus eliminating methanol.

- The costs associated with synthetic liquids were judged high by 8 of the groups. The Gas Industry Group was alone in estimating costs to be relatively favorable. Table 6-c

- Environmental impacts associated with synthetic liquids were judged to be moderate, roughly comparable to those for fuel categories 2, 3, and 4. The human impacts were judged similarly. (Potentially carcinogenic materials for synthetic liquid products and intermediates were mentioned by several groups.) Tables 6-d

Significant Comments in Workshops Regarding Synthetic Liquids

Several groups pointed out that the transportation sector is dependent on liquids. The following additional comments are from the statements by the Oil and Chemical Industry Group.

- *Technical and economic uncertainties produce an unjustified derating of synthetic liquids, producing a low ranking (6th).*

- *Suggest that synthetic liquids should be broken down to several categories--methanol, Fischer-Tropsch, hydrogenated syncrude, and lightly hydrogenated coal (which may be carcinogenic problems).*

- *The state of the art in synthetics is not good. Government action in R&D is needed.*

- *Liquid hydrocarbon has priority uses (e.g., transportation, engine fuels, and home heating oils). Coal can and should substitute for nonpriority uses. Long-term synthetic liquids will not displace existing high priority fuels, rather they should supplement them.*

- *Technology for production of methanol from coal is considerably more advanced than production of syncrude from coal.*

- *Aromatics for chemical use will come progressively more from coal as petroleum supplies decline.*

- *We have possibly overlooked processes which produce a combination of products.*

- *A practical problem to be faced is obtaining financing for synthetic fuels plants without certification that designs are based upon technology which has been demonstrated on a commercial scale.*

- *If this category is limited to "Synthetic Liquid Hydrocarbons" and if we concentrate on a time frame from 1985 to 2000, then "Synthetic Liquids" assume great significance. In particular, we believe they will be of increasing importance as transportation and space-heating fuels, and as chemical feedstocks, first to supplement petroleum and then to substitute for it.*

Significant Comments in Other Workshops Regarding Synthetic Liquids

- *The Electric Power Industry Group cited some experience with synthetic liquids "sludging out". Pyrolysis liquids have gummed up machines. There are a lot of problems yet in this area.*

- *The Federal Government Agency Group suggested that there is a strong suspicion of toxicity associated with liquid coal products.*

- *The Industrial Fuel User Group questioned the absence of oil shale in the list of fuel categories. This may be a lower cost alternative than synthetic liquids and may have resulted in some down rating of liquids from coal.*

6. Low and Intermediate-Btu Gas*

Rankings

- The Composite Group top ranked this fuel category in terms of weighted scores. The Gas Industry Group ranked it second. Three additional groups ranked it third: Public Interest Groups, Industrial Fuel Users, and Electric Power Industry. All groups except the Gas Industry Group noted it first among the synthetic fuels categories. Table 8

Evaluation Ratings

- The contribution of this fuel category to energy self-sufficiency was judged to be moderate. Table 6-a

* The Gas Industry and the Oil and Chemical Industry Group relabeled this category as "Industrial Fuel Gas" (100-500 Btu/cu ft).

- Many technical problems associated with this fuel category were perceived by seven of the groups with the Gas Industry Group the most pessimistic. The Composite Group and the Oil and Chemical Industry were relatively optimistic (rating 6.3 and 5.9, respectively). Table 6-b

- Wide differences in views of economics associated with this fuel category were recorded. Eight groups expected costs to be moderate to high. The Gas Industry Group considered costs to be favorable. Table 6-c

- Environmental impacts associated with this fuel category were judged to be moderate, with the Composite Group and Electric Power Industry Group recording the most favorable ratings. Human impacts were regarded similarly. Table 6-d,e

Significant Comments in Workshops Regarding Low/Intermediate Btu Gas

- *The Gas Industry Group commented that intermediate Btu gas is almost the same price as SNG. (Production of intermediate Btu gas is a basic step in production of pipeline quality gas.)*

- *A representative of the Oil and Chemical Industry Group preferred to separate low and intermediate Btu gas. The places for use of low Btu gas are limited, as retrofit possibilities for nitrogen-bearing gases are limited. (IP)*

- *The Federal Government Group pointed out that low Btu gas has potential for combined-cycle use with high efficiency. Much of the current thrust in low Btu gas is for combined-cycle use.*

- *There was a view expressed in the Federal Government Agencies Group that it would be inefficient, if by the year 2000, the predominant use of coal would be in boilers with sulfur-oxide controls. A more efficient use would be low Btu gasification, used in a combined-cycle system, or some equivalent system. (IP)*

- *A participant from the Industrial Fuel Group mentioned that there are different problems in transporting and storage and turndown in many industries that are not able to use low Btu gas around the clock. These are major technical, economic problems. (IP)*

Significant Comments by Composite Group Workshop Regarding Low/ Intermediate Btu Gas

- *A participant expressed the view that low/intermediate Btu gas has got to be the technology that ERDA should pursue. In making low Btu gas, the sulfur is converted to hydrogen sulfide, which can be removed from the gas stream. There is an excellent chance that we can ultimately generate power at a moderate decrease in cost over the conventional firing with stack-gas scrubbing. (IP)*

- *Low/intermediate Btu gas can also be used by industry. This probably will require an industrial complex with on-site gasification.*

- *Coal could be transported to the power generation plant which could be run by gas or electric utility industry, to keep the cost down. (IP)*

- *Low/intermediate Btu gas technology offers more benefits than any other technology. (IP)*

- *The benefits of low/intermediate Btu gas are based on projections, and the benefits of the fluidized bed are also based on projections; i.e., the R&D is not yet complete. (IP)*

- *The fluidized bed process can be used to make process steam at 600 F. It can be used to produce electricity, but it cannot be used to make synthetic chemicals. (IP)*

- *In the low/intermediate Btu gas system, there is a need to operate the gas producer at a constant rate.*

- *The largest users of low Btu gas will be power plants and these gas plants will be on-site. The gasification plant will be run at a constant rate and the clean gas could be run through a liquid synthesizer with sufficient conversion, once through. This would then be used to supply intermediate and peak load facilities. The cleaned liquids could be fired in combined-cycle systems. (IP)*

7. Pipeline-Quality Gas

Ranking

- The Gas Industry Group top ranked pipeline-quality gas or SNG (ranking first in terms of weighted scores). The Composite Group ranked this second. The ranking by all other groups was low (ranking 5 to 8). Table 8

Evaluation Ratings

- Wide differences were recorded in the views of the different groups as to the contribution of SNG to energy self-sufficiency, the highest being the Gas Industry Group and the lowest being the Electric Power Industry Group and the Coal Industry Group. Table 6-a

- The Groups perceived many unsolved technical problems associated with SNG, the Gas Industry Group being the most pessimistic. The Composite Group was the most optimistic. Table 6-b

- The view of economics associated with SNG yielded the widest variation among the groups of any of the fuel categories. The most favorable cost picture was expected by the Gas Industry Group and the least favorable by the Electric Power Industry and Coal Industry. Table 6-c

- Concerns over environmental impacts associated with SNG production were reflected in the evaluation by six of the groups. The most favorable evaluations were by the Gas Industry Group, the Composite Group, and the Electric Power Industry Group. The Gas Industry view was the most favorable environmental impact rating recorded for any of the fuel categories. Table 6-d

- Human impacts of SNG were judged moderate to favorable. The Gas Industry Group evaluation yielded the most favorable human impact rating of any of the fuel categories. Tables 6-d,e

Significant Comments in Workshops on Pipeline-Quality Gas

- *The Electric Power Industry Group and the Gas Industry Group took the position that it is desirable to discourage the use of SNG or natural gas as a boiler fuel to preserve for applications that are difficult to convert.*

- *A representative from the Electric Power Industry Group commented that pipeline quality gas is so expensive that it will not be viable for a long time. (IP)*

- *The Oil and Chemical Industry Group stated that the problem with synthetic fuels is the difficulty in obtaining financing.*

- *The Gas Industry Group stated that the country cannot afford to give up a highly efficient distribution system; i.e., the gas distribution system.*

8. Mixed Fuels

The Coal Industry was the only group that added this fuel category, combining solid coal and a liquid--but fired as a liquid. Firing of coal/oil slurries would fall into this category.

Ranking

- This fuel concept was ranked third by the Coal Industry in terms of final weighted scores. Table 8

Evaluation Ratings

- The contribution of this fuel category to energy self-sufficiency was considered moderate. Table 6-a

- Technical problems associated with mixed fuel were judged not extensive compared to other fuel categories. (Problems include preparation, transportation, and firing.) Table 6-b

- Costs associated with this fuel use category were rated moderate. Table 6-c

- The mixed fuel concept was judged favorably as to environmental impact, comparable to chemically cleaned coal. Table 6-d

- Human impacts were regarded as moderate. Table 6-e

Significant Comments in Workshop Regarding Mixed Fuels

- *Many R&D opportunities with the blending technologies are being missed. This is not esoteric; it is close at hand. A demonstration project was mentioned.*

- *The costs associated with mixed fuels will depend on several factors: whether the liquid is natural or synthetic, whether the coal is pulverized to a size for transporting as a slurry or collodial suspension. These possibilities suggest that this is a fruitful area of research.*

- *There may be more problems with mixed fuels than first realized; e.g., materials handling. A new technology may be required to make possible delivery as a liquid; e.g., a stabilized liquid.*

SUPPLEMENTARY INFORMATION FROM WORKSHOPS ACTIVITIES

The following section presents the results of the two supplemental activities requested by groups as a result of discussion in early workshops. These related to (1) a forecast of the relative mix of fuels by categories expected in future years, and (2) a suggested allocation of relative emphasis for R&D effort.

Forecast of Relative Mix of Fuels

This supplementary activity was added near the end of the workshop session to take advantage of the tendency of participants to predict what will occur — as opposed to the intended thrust in the preceding ratings of what should be encouraged to occur to meet national needs.

Participants were asked to complete a rating sheet calling for their best estimate as to the relative utilization of coal in the various fuel categories in the years 1980, 1990, and 2000. (The rating sheet used to collect this information is included in Appendix A.) This also allowed participants to focus on different time scales to accommodate differences in time required for development and commercialization.

Figure 4-A presents a summary by combining this fuel mix forecast for all participants. Note that the information is expressed in terms of relative or percentage mix rather than absolute energy units, so it is possible for a declining percentage mix to be an actual increase in absolute utilization of coal energy.

A substantial increase in relative utilization mix of derived or synthetic fuels was forecast (Fuel Categories 5, 6, and 7). In percentage of energy originating from coal, the participants forecast that utilization of these synthetic fuel categories would grow from 13 percent in 1980 to 44 percent by the year 2000. Over half of the coal energy was expected still to be utilized in solid or pulverized forms by the year 2000.

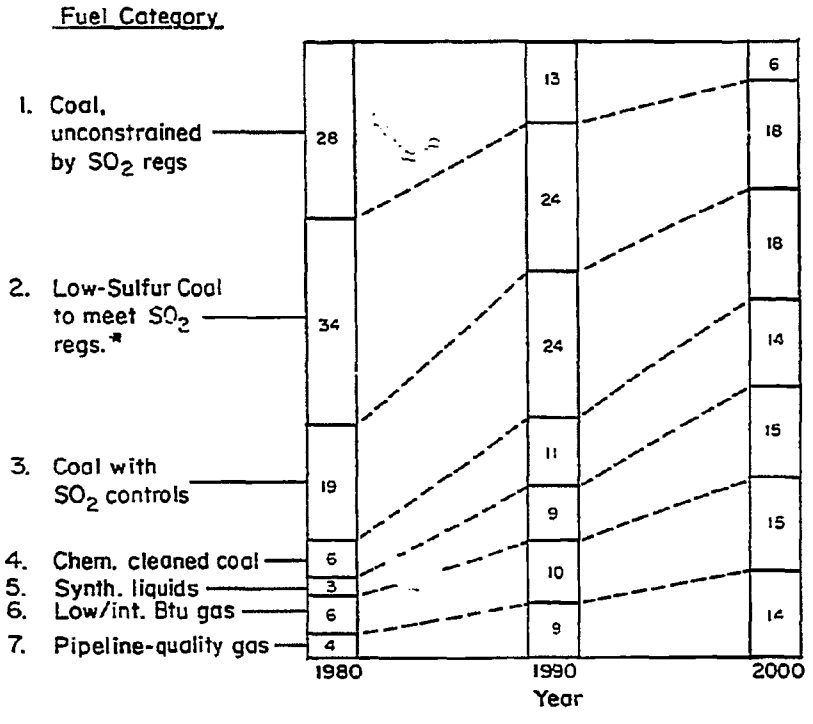

FIGURE A-4. FORECAST OF RELATIVE MIX OF FUELS AS A PERCENTAGE OF TOTAL COAL ENERGY UTILIZATION — All Groups Combined

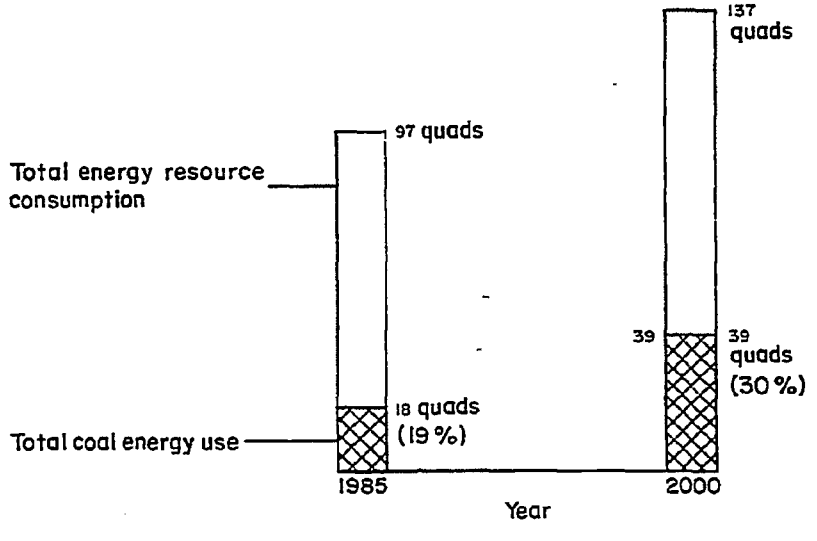

FIGURE 4-B. ERDA FORECAST OF TOTAL COAL ENERGY UTILIZATION AND TOTAL ENERGY RESOURCE CONSUMPTION
From ERDA 48, Scenario V, Combination of all Technologies

Figure 4-B provides a perspective of the expected growth of all coal energy utilization. This shows the forecasts of coal energy and total resource consumption that were made for two scenarios in ERDA-48* for the years 1985 and 2000.

Figure 5 shows the fuel mix as forecast by each of the groups. Some significant aspects of the group viewpoints were observed.

- Several groups were optimistic with respect to the near-term growth of SO_2 control technology in Fuel Category 3. Five groups forecast a percentage growth in this category from 1980 to 1990, but none forecast that there would be continued growth to 2000. The highest utilization of this fuel category in 2000 was forecast by the State Governments Group, Federal Agency Group, and the Composite Group (at 24 and 25 percent). In contrast, the Electric Power Industry Group were more pessimistic about SO_2 control technology and forecast that 13 percent utilization in 2000; this group also forecast that 13 percent of coal energy still would be fired without regard to SO_2 controls by the year 2000.

- The Industrial Fuel Users Group and the Public Interest Groups expected chemically-refined coal to have a substantial future, growing to approximately 20 percent of the coal energy by 2000.

- The Oil and Chemical Industry Group and the Gas Industry Group were the most optimistic about the growth of

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* "A National Plan for Energy Research, Development, and Demonstration: Creating Energy Choices for the Future", ERDA-48, Volume 1. The Energy Research and Development Administration (June, 1975).

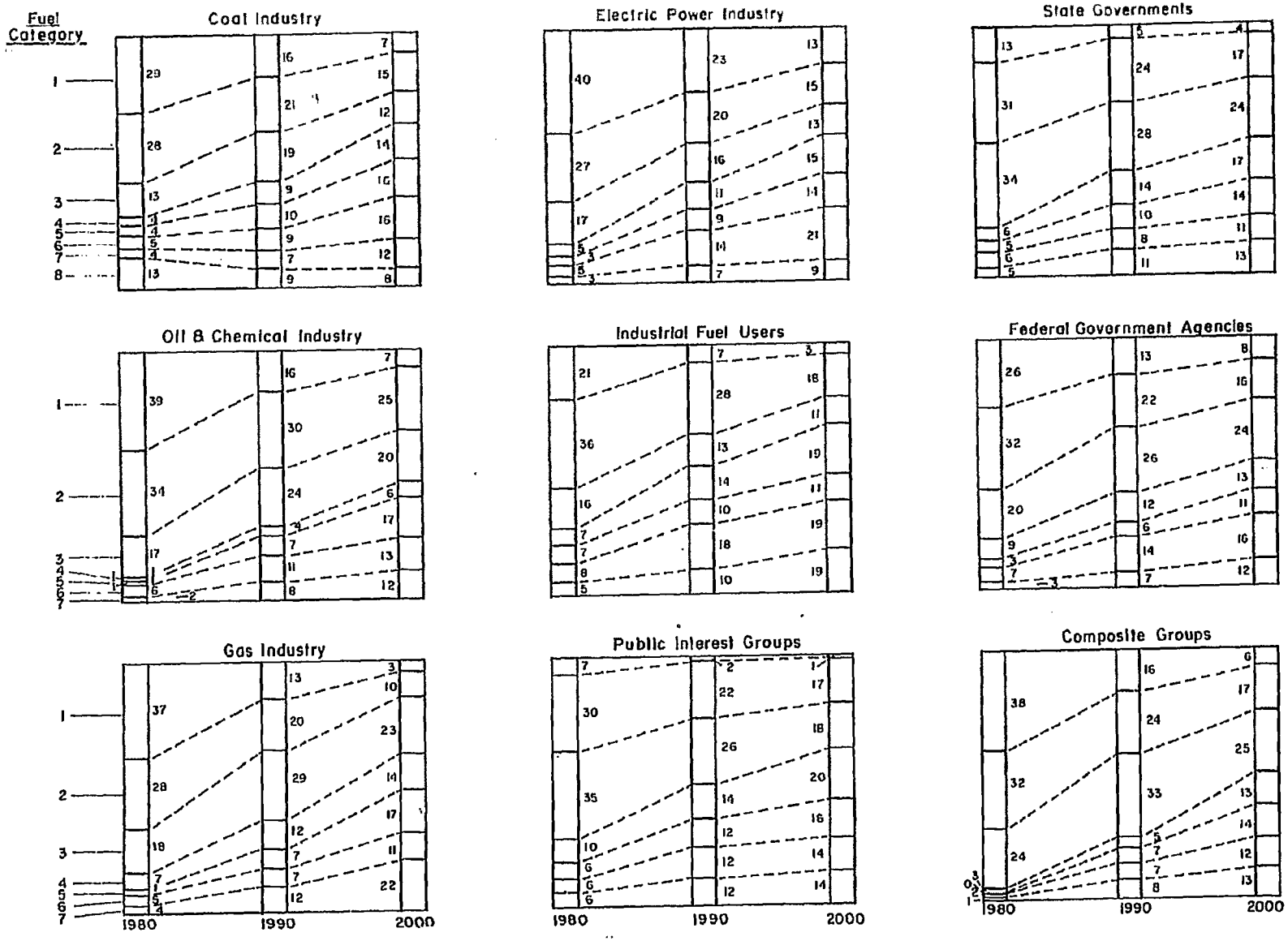

FIGURE 5. FORECAST OF RELATING MIX OF FUELS BY EACH GROUP AS A PERCENTAGE OF TOTAL COAL ENERGY

Bars Show Predicted Usage for Fuels in Order of Numbered Categories, Top to Bottom (See Figure 4)

synthetic liquids, forecasting 17 percent of coal energy by 2000.

- The Electric Power Industry Group and Industrial Fuel Users Group were the most optimistic group concerning low and intermediate Btu gas, forecasting respectively 21 and 19 percent by 2000.

Although there were these differences in views among groups, it was clear that each of the seven fuel categories were recognized as having a substantial role in meeting future energy needs.

Suggested Relative Emphasis for R&D

Several of the industry groups suggested that a direct rating be conducted on the relative emphasis for R&D directed to each of the fuel categories. A point recognized and discussed by most of the groups was that the fuel category ratings (of what should be encouraged on a priority basis) do not necessarily relate directly to the allocation of R&D needed to bring about commercialization, as this depends on the state of the technology, the extent of technical problems, and relative R&D costs.

In response to this request, a recording form was developed (included in Appendix A). This called for participants to indicate the relative R&D effort that they believe appropriate to allocate to each fuel category, considering the evaluation criteria from his or her own viewpoint and the relative costs of R&D in the various areas.* A percentage scale was used, so the allocations added to 100 percent.

Figure 6 shows graphically the combined result of this allocation by all participants. This summary indicates that the participants generally

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* In the later workshops, this rating was conducted at the very end of the session. For the earlier groups, a letter ballot was used following the workshops. Thus, the participants did not have the benefit of detailed discussion and subsequent revision of responses as in the previous evaluation of fuel categories.

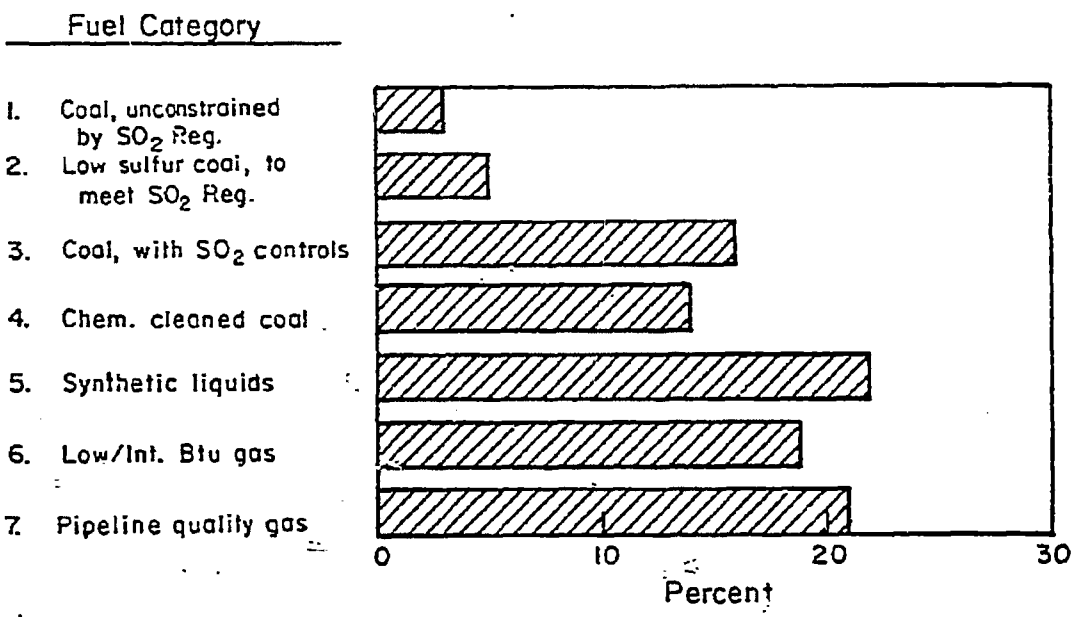

FIGURE 6. RECOMMENDED RELATIVE R&D EMPHASIS IN PERCENT ALLOCATION OF R&D EFFORT -- All Groups Combined

viewed that the greatest R&D efforts should be directed to synthetic liquids and to gasification. Substantial allocations were suggested for SO_2 control and for chemically refined coal.

Figure 7 presents the result of the R&D emphasis suggested by separate groups. Significant observations are as follows, presented in order of highest allocation suggested by a single group.

- The Gas Industry Group and the Industrial Fuel Users Group showed strong emphasis for R&D directed to pipeline-quality gas (44 and 27 percent, respectively).

- Both the Oil and Chemical Industry Group and the Coal Industry Group placed strong emphasis on R&D for synthetic liquids (39 and 24 percent, respectively). In addition to Federal R&D and demonstration in synthetic liquids processing, comments by participants suggested that R&D is needed in the production and utilization of synthetic liquid fuels with minimum environmental impacts.

- The Electric Power Industry Group revealed a preference for low and intermediate-Btu gas (27 percent). R&D needs in both gasification and utilization were mentioned in group discussions.

- The State Governments Group showed a preference for R&D allocated to SO_2 control (25 percent). The groups representing public interest and government suggested greater allocations for this category than did the industrial groups. Participants commented that advancements are needed both in stack-gas treatment and in fluidized-bed combustion.

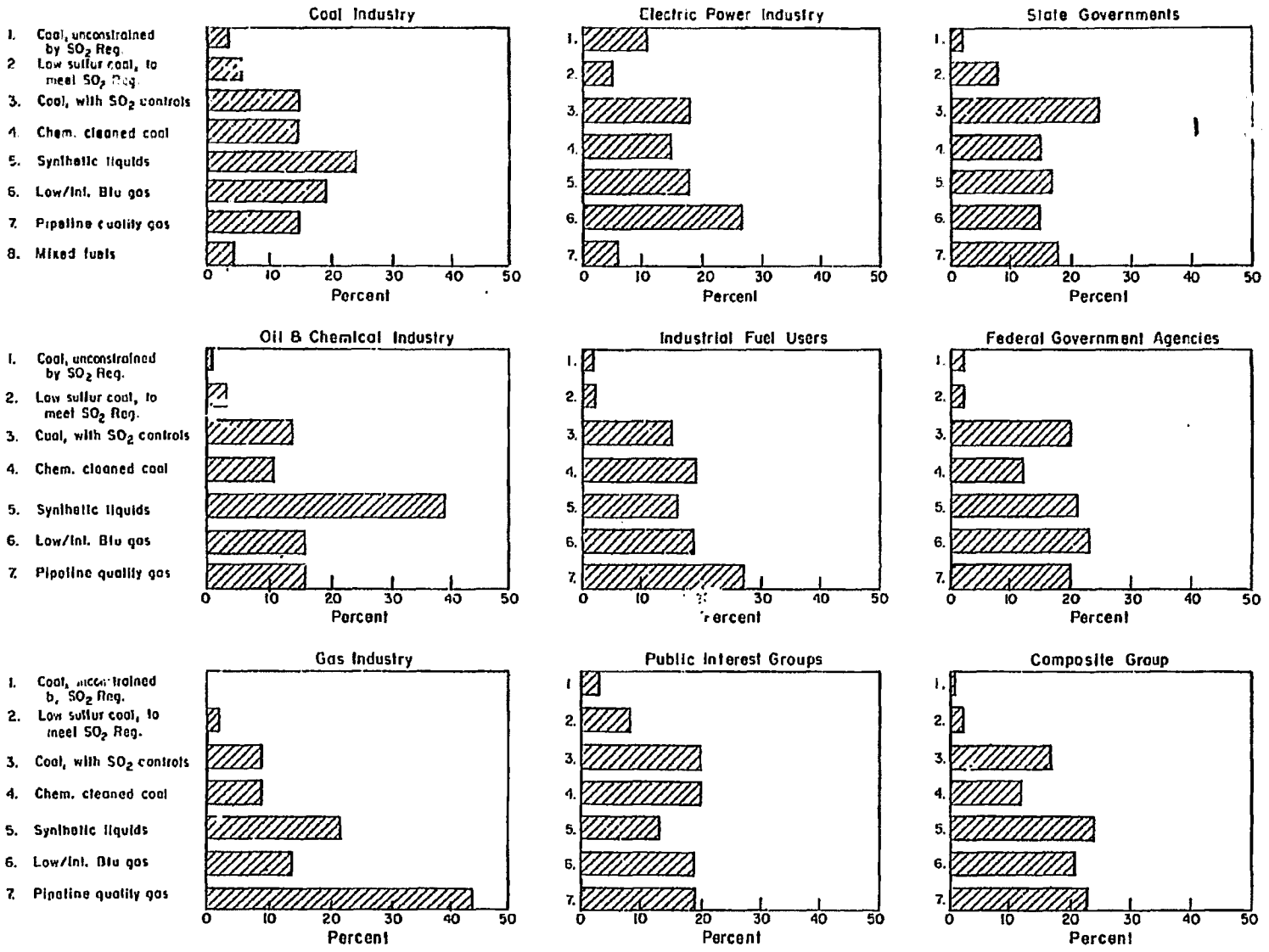

FIGURE 7. RECOMMENDED RELATIVE R&D EMPHASIS IN PERCENT -- EACH WORKSHOP GROUP

- The Public Interest Group placed its highest allocation on chemically-cleaned coal (20 percent). Participants commented on the need for improvements both in chemical cleaning processes and in techniques of firing the finished fuels.

- Relatively little emphasis was placed on Fuel Categories 1 and 2, coal fired unconstrained by SO_2 regulation and low sulfur coal. The Electric Power Industry Group suggested the highest allocation of any group for Category 1 allocation (11 percent); their comments indicated this allocation was based on R&D to be directed mainly to health effects and other research to establish cost-benefits aspects of ambient air standards. Comments of the Industrial Fuel Users Group showed broad interest in R&D on aspects of air-pollution control in addition to SO_2 (e.g., particulates and NO_x).

- The Coal Industry Group suggested a modest allocation for the mixed fuel category. While the concept is based on firing the fuel generally as a liquid, needed R&D was cited to solve problems in preparation, transportation, and firing of mixed fuels.

FIGURE 8. OVERVIEW OF WORKSHOP GROUP VIEWPOINTS ON FUEL CATEGORIES

Group	Top Ranked	Largest Use Forecast For 1980	Largest Use Forecast For 2000	Major R&D Emphasis
Coal Industry	Coal, no controls →	Coal, no controls	·	·
	LS coal →	LS coal	·	·
	·	·	Synth liquids →	Synth liquids
	·	·	Low-Btu gas	·
Oil & Chemical	LS coal →		LS coal	·
	Coal, no controls →	Coal, no controls	·	·
	·	·	·	Snyth liquids
Gas Industry	SNG →		SNG →	SNG
	·	Coal, no controls	·	·
	·	·	Coal, with controls	·
Electric Power	Coal, no controls →	Coal, no controls	·	·
	·	·	Low-Btu gas →	Low-Btu gas
Industrial Fuel Users	Coal, no controls →	Coal, no controls	·	·
	LS coal →	LS coal	·	·
	·	·	Chem Cl Coal	·
	·	·	Low-Btu gas	·
	·	·	SNG →	SNG
Public Interest	LS coal →	LS coal	·	· *
	·	Coal, with controls	Coal, with controls	·
	·	·	·	·
State Governments	LS coal →	LS coal	·	·
	Coal, no control	·	·	·
	·	Coal, with controls →	Coal, with controls →	Coal, with controls
Federal Agencies	LS coal →	LS coal	·	· *
	Coal, no controls →	Coal, no controls	·	·
	·	·	Coal, with controls	·
Composite Group	Low-Btu gas	·	·	· *
	SNG	·	·	·
	·	Coal, no controls	·	·
	·	LS coal	·	·
	·	·	Coal, with controls	·

* Note: Little difference among responses by these groups on R&D emphasis for the highest 3 or 4 fuel categories.

SUMMARY PROFILES OF GROUPS

Figure 8 provides an overview of responses of all groups on the fuel categories -- covering top rankings by weighted scores, largest uses forecast for 1980 and for 2000, and the R&D emphasis. In the first listed fuel category, the ranking column is the top ranking; a second category having high scores is noted in some cases. The 1980 and 2000 columns denote, respectively, the largest utilization forecast for the near-term and longer-term; note that many groups' viewpoints were different for the near-term and long-term forecasts. Fuel categories receiving highest R&D emphasis are listed in the last column

The arrows in Figure 8 connect fuel categories in successive columns where a category is carried over to another column. For example, the Oil and Chemical Industry Group carried over their high rankings of coal fired without SO_2 control to the near-term forecast and then carried the high ranking of low-sulfur coal to the longer-term forecast. Only the Gas Industry Group carried over their highest ranked category, pipeline quality gas (SNG), as far as the long-term forecast or the R&D emphasis column.

Further insight into the viewpoints of each of the groups can be gained from examining the principal results by the various groups. A summary by groups follows.

Coal Industry Group

The Coal Industry Group placed most importance on energy self-sufficiency as a criterion, least on environmental impacts.

- This group ranked coal fired unconstrained by SO_2 regulation and low-sulfur coal as the fuel categories best meeting the evaluation criteria (ranking by

weighted scores)* The Coal Industry Group introduced the mixed fuel category which they ranked third.

- The largest category of utilization for near term was forecast by this group as coal fired unconstrained by SO_2 regulations and low-sulfur coal. For the longer term, synthetic liquids and low/intermediate Btu gas were forecast as largest uses.

- This group suggested greatest R&D emphasis on synthetic liquids.

Oil and Chemical Industry Croup

Among the criteria, this group placed most importance on energy self-sufficiency and economics, least on the environmental and human impacts.

- This group ranked low-sulfur coal and coal fired unconstrained by SO_2 regulations as the highest fuel categories in meeting the criteria (based on ranking by weighted scores). While they placed synthetic liquids in sixth position as meeting the evaluation criteria, the group noted that this low ranking did not reflect the group's position as to the long-range importance of this category.

- The largest category of utilization in the near term was forecast as coal fired unconstrained by SO_2 regulations. For the longer term, low-sulfur coal was forecast as the largest use.

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* One member of the Coal Industry Group submitted a "dissenting view" that emphasized the need to meet fuel requirements for industrial users as well as the electric utility industry. This line of reasoning for ratings, together with criteria weighted heavily toward energy self-sufficiency, resulted in his top ranking of low-sulfur coal -- with a tie for second by coal fired unconstrained by SO_2 regulations, synthetic liquids, and low/intermediate Btu gas. This report is included in Appendix C.

- This group recommended greatest R&D emphasis on synthetic liquids.

Gas Industry Group

Among the criteria, the Gas Industry Group placed most importance on economics, least on environmental impacts.

- Not surprisingly, the Gas Industry Group ranked pipeline-quality gas or SNG as the highest against the evaluation criteria. They placed low/intermediate-Btu gas and synthetic liquids as a tie for second ranking.

- On Figure 3, the graphical profile of fuel ratings for the Gas Industry Group is in marked contrast (nearly a mirror image) to that for the other industry groups for energy self-sufficiency and for economics.

- The largest category of utilization in the near term was forecast by this group as coal fired unconstrained by SO_2 regulations. For the longer term, coal fired with SO_2 controls and pipeline-quality gas (SNG) were forecast as the largest uses.

- This group suggested greatest R&D emphasis on pipeline-quality gas.

Electric Power Industry Group

This group placed greatest importance nearly equally on three criteria: energy self-sufficiency, extent of technical problems, and economics.

- The Electric Power Industry ranked coal fired unconstrained by SO_2 regulation highest in meeting the evaluation criteria (ranking by weighted scores). Low-sulfur coal was second ranked by this group.

- The largest category of utilization in the near term was forecast by this group as coal fired unconstrained by SO_2 controls. For the longer term, low/intermediate-Btu gas was forecast as the largest use.

- This group suggested greatest R&D emphasis on low/intermediate-Btu gas.

Industrial Fuel Users Group

Among the criteria, this group placed greatest importance on economics and self-sufficiency, least on extent of technical problems.

- The Industrial Fuel Users Group ranked coal fired unconstrained by SO_2 regulation and low-sulfur coal as the fuel categories best meeting the criteria (ranking by weighted scores).

- The largest categories of utilization in the near term were forecast by this group as coal fired unconstrained by SO_2 regulations and low-sulfur coal. For the longer term, chemically-cleaned coal, low/intermediate-Btu gas, and pipeline-quality gas were forecast as largest uses.

- This group suggested greatest R&D emphasis on pipeline-quality gas to substitute for natural gas that is presently preferred for most industrial processing applications.

Public Interest Group

In contrast to the industrial groups, the Public Interest Group placed greatest importance on human and environmental impacts, least on extent of technical problems. A special point was made by this group that the most valuable contribution they could make in the study was in the weighting of criteria, rather than judging specific areas of fuels technology.

- The Public Interest Group ranked low-sulfur coal as the fuel category best meeting the evaluation criteria (ranking by weighted scores). Coal fired with SO_2 control equipment was second ranked.

- The largest category of utilization in the near term was forecast by the group as low-sulfur coal and coal fired with SO_2 controls. For the longer term, this latter category and chemically cleaned coal were forecast as the largest uses.

- This group suggested nearly identical R&D emphasis for four fuel categories: coal fired with SO_2 controls, chemically cleaned coal, low/intermediate-Btu gas, and pipeline-quality gas.

This group suggested the separation between R&D and regulatory agencies of fuels or energy-systems development from final judgments as to resulting human and environmental impacts. A further suggestion was that "internalization of costs" associated with human and environmental impacts should be an integral part of the evaluation of energy options.

State Governments Group

This group made little distinction as to the importance of the separate evaluation criteria.

- The State Governments Group ranked low-sulfur coal and coal fired unconstrained by SO_2 regulations as the fuel categories best meeting the criteria (ranking by weighted scores).*

- The largest categories of utilization in the near term were forecast by this group as low-sulfur coal and coal fired with SO_2 controls. For the longer term, this latter category was forecast as the largest use.

- This group suggested greatest R&D emphasis on coal fired with SO_2 controls..

Federal Government Agencies Group

This group made little distinction as to the importance of the separate criteria.

- The Federal Government Agencies Group ranked low-sulfur coal and coal fired unconstrained by SO_2 regulations as the fuel categories best meeting the criteria (ranking by weighted scores).

- The largest categories of utilization in the near term were forecast by this group as low-sulfur coal and coal fired unconstrained by SO_2 regulations. For the longer term, coal fired with SO_2 controls was forecast as the largest use.

* See comments on scoring and ranking pertaining to this group on page 75.

- This group suggested greatest R&D emphasis on low/intermediate-Btu gas.

Composite Group

This group was selected to provide a single representative of each of the preceding interest groups. The Composite Group made little distinction between the importance of the evaluation criteria. (In workshop discussions, there were suggestions that energy self-sufficiency and environmental impacts should be viewed as the main criteria or "goals", with the other criteria as background factors; extent of technical problems or economics were cited as relevant constraints.) Other observations are:

- The Composite Group ranked low-Btu gas first and pipeline-quality gas second as best meeting the criteria (ranking by weighted scores).

- The largest categories of utilization in the near term were forecast by this group as coal fired unconstrained by SO_2 regulations and low-sulfur coal. For the longer term, coal fired with SO_2 controls was forecast as the largest use.

- This group suggested main R&D emphasis on synthetic liquids, pipeline-quality gas, and low/intermediate-Btu gas.

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Additional insight on the profiles of groups can be gained from the comments which supplement the above. Significant comments from each of the groups are contained in Appendix B.

ASSESSMENT OF THE WORKSHOP METHODOLOGY

This section is intended as background and clarification for those who are interested in the methodology used in the workshop and the analysis of the rating data. Discussion and evaluation of the various activities conducted during a single workshop are presented below. Except for minor variations, as noted where relevant in this report, all workshops were procedurally identical. Assessment of the methodology through participant feedback is also discussed below.

WORKSHOP PROCEDURES

Members of the Battelle study team served as facilitator and observers for the workshops. The role of the facilitator was in "chairing" the meeting to keep the discussion and activities on schedule, without entering into or influencing the substantive discussion. Two or more observers took notes, tape-recorded statements (when requested), and generally assisted the facilitator with scoring and arrangements. One team member served as facilitator for an entire workshop session; however, two persons rotated as facilitator for different workshops.

Workshop Agenda

The first activity of the meeting was for each of the participants to complete a set of rating sheets, evaluating the seven fuel categories independently for each criterion. A copy of the complete kit of materials provided to the participants before the workshop is included with this report as Appendix A, including the actual rating sheets used.

Following the initial completion of the rating sheets, there was open discussion within the group to clarify and define appropriate concepts and to adjust definitions as required to remove any ambiguities in the broadly labeled categories and criteria. After the discussions,

the rating sheets were completed again to provide an opportunity for participants to adjust positions on the basis of new or clarified information.

The results from the first two ratings were presented to the group for review and discussion. Opportunity was provided for advocates of particular positions to make arguments or adjustments in the group position. Following these discussions the rating sheets were completed for a third, and final time. The results were again presented to the group, and time was provided for recording of dissenting views.

An electronic voting aid was used to speed up the process of recording the ratings of all participants simultaneously and tabulating results. Anonymity of the individual participants' votes was assured, while information related to averages and spreads in votes was made available to the group as a whole.

As a result of concerns expressed by participants during the first two meetings, two additional activities were added to the process. After the third evaluation rating, each participant was asked to forecast the relative mix of fuels at three future years, and to recommend relative emphasis for R&D effort for the various fuel categories.

Finally, the participants were asked to complete an assessment of the workshop activities and results. At the end of the day, each participant was provided with a copy of the group's final position.

Processing and Display of Results

In the meeting plan there were two group discussion periods separating the three formal evaluation activities. The initial discussion period was intended to focus on interpretation and clarification of the definitions. The results of the first and second ratings were presented

to each group to provide a basis for the afternoon discussion period. These results were presented graphically on charts taped to the wall of the meeting room--showing the average, the high, and the low ratings for each fuel category and for each criterion. These results were also presented in numerical form as an "evaluation matrix", an example of which is shown in Figure 9.

There are three types of information summarized and displayed on the evaluation matrix:

1. The entries to the body of the matrix are the averages, the high, and the low votes for group ratings of the extent to which the various fuel categories satisfy the criteria, based on a scale from 0 to 9. (In all scale definitions, low ratings are "unfavorable" and high ratings are "favorable", i.e., a high rating on Energy Self-Sufficiency means high contribution; a high rating on Economics means low cost; a high rating on Extent of Technical Problems means few problems; for Environmental and Human Impacts a high rating refers to few adverse impacts.

2. The row of numbers below the column headings for the criteria indicate the average, high, and low ratings of the relative importance of these criteria.

3. The column of numbers labelled "score", indicates the results of a mathematical aggregation of the fuel ratings and the criteria ratings. The criteria ratings were converted to relative weights, and these were multiplied by normalized fuel ratings and summed for each fuel category. The scores produced by this operation for each fuel were also normalized so that the maximum score was ten, in order to provide a simpler basis for comparison across fuels. This is referred to in the presentation of results in this report as the weighted score.

	A) Energy Self-Sufficiency	B) Extent of Technical Problems	C) Economics	D) Environmental Impacts	E) Human Impacts	Score
Weights	7.4 (5–9)	6.2 (4–9)	7.4 (4–9)	6.8 (6–9)	4.8 (0–7)	
1. Coal, fired unconstrained by SO_2 regulations	1.2 (0–2)	8.6 (8–9)	7.0 (5–9)	0.2 (0–1)	1.8 (0–4)	6.1
2. Low sulfur coal, fired to meet SO_2 regulations	4.6 (2–7)	8.0 (7–9)	5.4 (1–8)	5.2 (2–9)	4.8 (3–6)	8.8
3. Coal, fired with SO_2 control equipment	5.4 (3–8)	2.8 (1–4)	3.4 (1–7)	5.2 (4–7)	5.2 (4–7)	7.0
4. Chemically cleaned coal	4.0 (1–9)	3.0 (2–4)	4.0 (1–7)	6.0 (3–8)	6.0 (4–9)	7.1
5. Synthetic liquids	5.8 (3–9)	3.4 (2–6)	3.0 (1–5)	7.6 (7–9)	6.2 (4–7)	8.1
6. Low/intermediate Btu gas	5.6 (3–9)	7.0 (6–8)	5.4 (3–7)	7.8 (7–9)	6.2 (4–9)	10.0
7. Pipeline-quality gas	5.6 (3–9)	6.0 (3–8)	4.0 (2–6)	7.8 (7–9)	6.6 (5–9)	9.3

FIGURE 9. SAMPLE EVALUATION MATRIX

Average ratings are shown; small numbers indicate ranges in individual votes.

The scoring operation is one that is commonly used by analysts to rank order alternative choices. However, it was the subject of some confusion and controversy during some of the workshops. The State Governments group formally rejected the scoring operation, and members of several other groups questioned its validity in the context of this particular exercise.

ASSESSMENT OF THE METHODOLOGY

This subsection presents assessment information based on participant feedback, reviews the basic concepts of the methodology with reference to events during the workshops, and presents a summary of the observations and conclusions of the research team with regard to the methodology.

Participant Feedback

The final questionnaire completed by the participants at the end of the workshop was an evaluation and feedback form (included in Appendix A). This collected the participant's views as to the degree to which the final results were representative of: (1) the viewpoints of the group, and (2) the viewpoints of the larger interest sector which the group participants were selected to represent. This assessment was requested for both the results of the evaluation activity and the forecast of fuel mixes. A rating scale from 0 to 9 was used, as for previous activities, and the averages of each group's responses are presented in Table 9.

The participants' assessments of the extent to which the evaluation ratings were representative of the assembled group (Column 1a of Table 9) is, in effect, their assessment of how well the workshop design succeeded in capturing the views of the group in an objective and communicable format. The assessment in Column 1b provides an indirect

TABLE 9. ASSESSMENTS OF THE PRINCIPAL RESULTS BY PARTICIPANTS

Average group assessments on a scale 0 to 9.

	Group Assessments of the extent to which the:			
	1) Evaluation Ratings were representative of:		2) Fuel Mix Forecast was representative of:	
	a) The Assembled Group	b) Their Industry or Public	a) The Assembled Group	b) Their Industry or Public
Coal Industry	7.8	6.8	6.6	6.0
Oil and Chemical Industry	6.9	5.9	5.8	4.1
Gas Industry	6.4	(a)	6.4	(a)
Electric Power Industry	7.6	(a)	7.6	(a)
Industrial Fuel Users	6.7	4.5	5.7	4.8
Public Interest Groups	6.7	6.8	6.9	6.5
State Governments	2.6(b)	2.4(b)	6.5	6.3
Federal Government Agencies	7.4	5.3	6.1	4.6
Composite Group	7.5	5.7	5.2	4.5

(a) The Gas Industry Group and Electric Power Industry Group were the first two workshops; the assessment of broad representation was begun with the third workshop.

(b) The low rating here was aimed at the aggregated scores for fuel categories; see text for further elaboration.

measure of the adequacy of the participant selection process. Recall that the fuel mix forecast was a single-pass survey conducted at the end of the workshop session. The ratings in Columns 2a and 2b are useful in assessing the results, but are less useful in assessing the methodology.

In general, the groups felt that the results were fairly representative of the participants' views. Most of the groups considered the results to be more representative for the evaluation ratings than for the fuel mix forecasts in Figures 4 and 5. This observation holds both for the groups themselves as well as for the broader groups they represented. Note that for the Public Interest Groups and the State Governments Groups, there was little difference between the "group" and "industry or public" assessments for both categories of results, indicating that these representatives thought that their personal views were an adequate representation of their larger constituencies.

The strikingly low assessment of the evaluation ratings by the State Governments group was really addressed to the aggregated scores for the fuel categories (see Figure 8), rather than to the evaluation ratings themselves. This group was particularly critical of the scoring operation, having made a formal statement for the record that they did not consider the scores as being a representation of their positions. This discussion had been particularly sharp just before filling in the feedback questionnaire. On hearing the low average of the assessment, the members of this group confirmed verbally that they had indeed been evaluating the scores, and that they felt that the ratings themselves were actually representative, and what they wished to have considered. In later workshops it was made clear verbally by the facilitator that it was the ratings rather than the scores that were being evaluated by this questionnaire.

Concepts and Hypotheses

The central concept of the methodology upon which this series of workshops was based is that of the "Evaluation Matrix", illustrated previously in Figures 1 and 8. Examples of completed evaluation matrices are contained in Appendix C. The basic idea is that a set of "alternatives", in this case categories of coal and coal-derived fuels, are systematically evaluated against a set of "criteria", and this information is assembled in a compact form (e.g., a matrix or a bar chart). This information is submitted for consideration by the decision makers who must ultimately choose among the alternatives, or, as in this case, allocate resources to the alternatives according to some formula. It was a root hypothesis to the development of the original methodology that the "scoring" operation, which is commonly used to generate a rank ordering of alternatives, had serious deficiencies when applied in complex decision-making contexts. As noted in the final report* of the previous study:

- It is difficult to ensure completeness of the list of alternatives.
- It is practically impossible to define a complete, valid, and independent set of criteria for evaluating the alternatives.
- It is difficult to develop an adequate characterization of the alternatives and the potential impacts.
- There are theoretical and practical limitations to available techniques for aggregating an evaluation by individual criterion into an overall evaluation.

These difficulties are particularly aggravated when there is a large heterogeneous body of people with differing stakes in the consequences of the decision.

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* "Development of Alternative Paths for Clean Utilization of Coal as an Energy Source and Development of a Methodology for Decision Making", by D. W. Malone, E. H. Hall, K. Kawamura, and D. L. Morrison, Battelle-Columbus report to U.S. Department of the Interior, Contract No. 14-0001-1936 (December 20, 1974).

The allocation of funds for R&D in coal and coal-derived fuels is such a "complex decision-making context", and all of the difficulties identified above were observed in the workshops, as noted below:

- Completeness of alternatives
  - Several participants noted absence of consideration for oil shale and in-situ gasification.
  - Many participants found it difficult to evaluate coal and coal-derived fuels without giving consideration to alternative energy sources such as nuclear and solar power.
- Validity and independence of criteria
  - Many groups insisted on emphasising inter-dependence of criteria, despite initial staff efforts to define them in such a way that they would be reasonably independent initially; apparently the semantic implications of the words used to label the criteria dominated the specific interpretations provided by the extended definitions.
  - Several of the groups proposed using only one or two of the criteria as "goal" or decision-oriented criteria, with the others acting as "constraints".
- Characterization of the alternatives and their impacts
  - Many participants had trouble evaluating the fuel categories without making reference to specific technologies; where more than one technology was available, and the characteristics were very different, (as, e.g., for liquefaction) evaluation was difficult. The spread between high and low individual ratings tended to be high in such cases.
  - The different technologies within some of the fuel categories also made it difficult to assess the impact of a general fuel category on a particular criterion.

- Theoretical and practical limitations of scoring techniques

  - When the criteria are interdependent, the scoring operation is theoretically questionable; as noted above, many groups insisted that the criteria were inseparable.

  - From the evaluation of the criteria (Figure 2 or Table 5), it was seen that different groups had different ideas about which criteria were most important; aggregating assessments broadly over such diverse, yet coherent, positions to get a single assessment seems questionable in a situation such as this.

  - Further, some of the participants and one whole group insisted that the results of the scoring operation not be considered as a basis for decision-making.

Conclusions and Recommendations Relating to the Methodology

Recall that the work plan for the workshops involved three repetitions of the rating operation. The initial rating was performed first thing in the morning, and was based solely on the information and definitions contained in the kit included as Appendix A. A statistical analysis of the results of these ratings indicated that all of the groups voted similarly on the first rating; that is, the results are what one might expect from a broad survey or mailed questionnaire. For the second and third evaluations (performed after considerable discussion, interpretation, and sharing of information among the group members) the groups developed unique response patterns. This result suggests that the workshop design was effective in capturing views which are characteristics of the assembled interest groups. However, complete confirmation of this conclusion would require demonstration of repeatability of the results, which was beyond the scope of the present work.

Following are the procedural conclusions reached by the research team involved in the design and execution of this series of workshops:

- The three-pass rating strategy, with interspersed discussion, was effective and should be retained in future activities of a similar nature. The use of an electronic voting aid was invaluable in making it possible to feed back voting results almost instantaneously.

- There should be some end-of-day activity to provide closure and a feeling of accomplishment by the participants; this was provided here by the expression of preferences for allocation of R&D effort, an activity which was added after the first two workshops.

- The size of evaluation matrix used here, seven alternatives and five criteria, is about right for a 1-day workshop format.

- To more effectively capture individual and group subjective comments, some formal group-writing* exercise should be performed within the context of workshop activities, rather than relying on tape-recorded comments or notes taken by facilitators and observers. This would greatly facilitate the evaluation and report preparation activity and would probably more accurately capture group opinion.

* For example: Geschka, et al, "Modern Techniques for Solving Problems", Chemical Engineering, August 6, 1973; and Delbecq, A. L., A. H. Van de Ven, and D. H. Gustafson, Group Techniques for Program Planning, A Guide to Nominal Group and Delphi Processes, Scott, Foresman, and Company, 1975.

OVERALL OBSERVATIONS

The approach used in this study was successful in capturing, in a consistent way, views of the various interest groups selected for participation in the workshops. There was sufficient interest in the approach that high-level people were willing to participate in the workshops.

Evaluation of the results, through specific feedback from the participants themselves, indicates that they regarded the ratings to be fairly representative of their interest group. The only exception was the State Governments Group. (These evaluations are outlined in this report in the section on assessment of methodology.) While the precision of the final ratings and other recorded viewpoints have recognized limitations (regarding sample size, subjectivity, and overlap of criteria definitions, etc.), the results can provide useful inputs to ERDA in terms of general viewpoints that should be considered in the planning process for R&D on coal and coal-derived fuels.

An overall observation regarding group viewpoints, that were reflected in the forecast of fuel categories, is the continued significance of direct firing of solid coal (fuel categories 1 through 4) as perceived by the most interest groups. Even with the expected development and utilization of synthetic fuels, the total utilization of solid coal categories was forecast to exceed the total utilization of synthetic fuels from coal (fuel categories 5 through 7) in the year 2000.

Additional observations follow, based on discussion in the workshops.

- Regarding the extent of unsolved technical problems associated with the fuel categories, the point was emphasized by several groups that the technical feasibility of producing fuels for each of the categories has been demonstrated on some scale. However, the last five categories have not been demonstrated in a commercial way as fully meeting modern technological and economic needs.

- Philosophical questions related to short-term or long-term R&D were discussed by several groups. It was agreed that high-risk programs, in areas with many technical problems, could be justified where potential benefits are high and might never be developed without a continuing national program. At the same time, there were strong suggestions, in the light of urgent needs, to emphasize those developments "right on the threshold" in order to commercialize developments more quickly.

- The groups emphasized that ratings or scores in the evaluation did not necessarily imply a recommendation for R&D emphasis, due to differences in the extent of technical problems and the costs of needed R&D in the different areas. Also a distinction was recognized between action plans and R&D needs.

- In suggestions of R&D emphasis and in comments on R&D needs, the groups generally agreed to refer to the broad view of the federal role, rather than attempting to delineate the respective roles of ERDA and other agencies.

- Strong views were expressed by the industrial groups that uncertainties of government regulation and policy both at federal and local levels, has the effect of discouraging investment decisions by the private sector to undertake needed development on its own. Consistency of policy and regulations, and possibly federal incentives, were suggested.

- The Oil and Chemical Industry viewed synthetic liquids as having significant importance in the future (for transportation fuels, for home heating, and for use as feedstock). They urged major emphasis on federal R&D and demonstration to advance this technology.

- The Gas Industry Group expressed concern that federal policy or R&D decisions may tend to encourage electrification of the U.S. They cited that the nation cannot afford to underutilize or give up the efficient energy distribution system already in existence in the gas industry.

- The Electric Power Industry Group suggested that greater flexibility in utilization of the different fuel categories could be achieved if environmental protection regulations were based on controlling to ambient air-quality standards rather than on constant emission standards applying to point sources. This would allow for the use of higher sulfur fuels except during periods of adverse meteorological conditions. To aid in setting ambient air-quality standards on a cost-benefit basis the group recommended additional research related to health effects of SO_2 and other pollutants.

- In considering aspects of environmental and human impacts in decisions related to fuels options, the Public Interest Group recommended that an attempt be made to internalize all social and environmental costs in considering fuel options.

- Several groups called attention to the fact that environmental issues, traditionally, had concentrated on SO_2, but other pollutants like sulfates and fine particulates are of concern.

- It was clear that the groups perceive that fuels in the various categories are capable of serving a variety of uses, and each form of fuel has applications that it will serve most effectively and/or competitively. This multiplicity of needs, both short-term and long-term, underscores the desirability of a balanced R&D program.

- Most groups expressed the philosophy that essentially all of the categories of coal and coal-derived fuels are expected to be important to the nation for some uses and should be encouraged as options within the framework of the criteria.*

In short, the various findings as presented in this report contribute useful background to the formulation of national energy policies and plans.

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* This is consistent with the ERDA Plan: "A National Plan for Energy Research, Development and Demonstration" (ERDA 48, Volume 1. June, 1975).

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