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FEDERAL ENERGY R&D PRIORITIES

REPORT OF THE

RESEARCH AND DEVELOPMENT PANEL

ENERGY RESEARCH ADVISORY BOARD

November 1981

Department of Energy
Washington, D.C. 20585

December 4, 1981

Honorable W. Kenneth Davis
Deputy Secretary of Energy
1000 Independence Avenue, SW
Washington, DC 20585

Dear Ken:

I am pleased to forward the Report of the Energy Research Advisory Board on Federal Energy RD&D Priorities. This report was prepared in response to your request on August 13, 1981, to review the relative merits of each major R&D program.

The Board is in full agreement that the Federal Government must continue to support research and development for the technologies upon which the nation's energy future depends. Although all the members (except for Philip Handler) participated in the development of this report and reached a consensus on most recommendations, there are a few statements that represent majority opinions where every member did not agree to every statement. Dissenting views on those recommendations for which overall agreement was not possible are included in the Appendices.

Sincerely,

Louis H. Roddis, Jr.
Chairman
Energy Research Advisory Board

Enclosure

cc:
Thomas J. Kuehn, ERAB
Joel Snow, ER-4

Department of Energy
Washington, D.C. 20585

December 4, 1981

Louis H. Roddis, Chairman
Energy Research Advisory Board
110 Broad Street
Charleston, SC 29401

SUBJECT: Letter of Transmittal of the R&D Panel RD&D Priorities Report

Dear Lou:

This letter transmits to you the RD&D Priorities Report. The report contains inputs from all members of the Board, and except where minority views are presented, there is general agreement with its contents.

As you know, the methodology required members of the Panel to evaluate each R&D program in terms of a specific set of criteria. The evaluations were combined to arrive at composite figures of merit which were then reviewed and discussed by the R&D Panel. At the outset of this project, there was some uneasiness about the validity of the evaluation methodology. To guard against possible difficulties, each section of the report, after drafting by two members of the Panel, was reviewed and discussed thoroughly by the full Panel before final judgments were made.

I believe that the evaluation methodology worked quite well. It provided assurance that the key criteria were explicitly considered, and this helped us identify quickly the sources of agreement and disagreement. The second stage of the process provided for resolution of the areas of disagreement. Where necessary, members of the Board voted to arrive at final recommendations. You offered the opportunity to members to advance minority views, and such views are included in the final report.

The preparation of this report in such a short time was a formidable task. In my view, the Board did remarkably well to complete this study on time.

Sincerely,

John S. Foster, Jr.
R&D Panel Chairman

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FEDERAL ENERGY R&D PRIORITIES

APPENDICES

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FEDERAL ENERGY RD&D PRIORITIES

I. EXECUTIVE SUMMARY

Background

In a letter dated August 13, 1981, the Deputy Secretary of Energy asked for the advice of the Energy Research Advisory Board (ERAB) on DOE's R&D priorities and on "hard choices" the Department must soon make as to "which programs to pursue vigorously and which to de-emphasize based on a realistic appraisal of both our energy options and energy needs for the foreseeable future." This report of ERAB responds to that request in the context of continuing pressure for further reductions in DOE's budget. This report presents recommendations on priorities within DOE's non-defense R&D program and suggests where funding should be changed, either increased or decreased relative to the President's FY 82 budget request.

During the last year, major changes in policy have been made; these have already led to changes in DOE's objectives, strategies, R&D funding and internal allocations of R&D funds. In carrying out its study of DOE's R&D priorities, the ERAB has generally accepted these new policies and has confined its recommendations to matters of science, technology and engineering. In some areas, however, particularly in electric supply and conservation, the ERAB's application of these policies has resulted in somewhat different conclusions than those reflected in the President's FY82 budget. Moreover, the application of these policies has led to recommendations by the ERAB that differ significantly from those it made to the Secretary of Energy on September 5, 1980 in the interim report on research and development needs in which the Board applied funding policies of the previous administration.

Recommendations of this study resulted from application of both a new assessment methodology developed by the R&D Panel of ERAB and more conventional and traditional evaluation techniques. The new methodology required Board members to evaluate each R&D program in terms of a specific set of well defined criteria. This insured that each program was evaluated comprehensively by each member. The evaluations of all R&D Panel members were then combined numerically. These composite evaluations were then used as the basis for more traditional judgments, discussions and consensus building, leading to conclusions and recommendations by the Board. The salient findings of the Board are:

- Funding relative to the President's FY82 budget request for the science and technology base programs should be increased in some programs and remain the same in others. Within these programs high priority should be given to:

- research on the phenomena governing accumulation of CO_2 in the atmosphere from combustion of fossil fuels, climatic effects of this accumulation, tolerable levels of CO_2 and ways to control CO_2 accumulations

- research into acid rain, its causes, effects and control technologies

• In the electric supply sector, priority should be given to supporting:

  - nuclear waste isolation research and demonstration
  - conventional reactor systems and safety
  - the LMFBR base program
  - uranium enrichment R&D

• Programs in which reductions can be made include:

  - small reductions in magnetic fusion

  - significant reductions in the Clinch River breeder,* the light water breeder, electricity transmission, and high temperature geothermal

  - phase-out of funding for hydropower and magnetohydrodynamics

• The Board noted that the electric supply technology is receiving a fraction of DOE's funding that is substantially in excess of its contribution to present and future energy supplies.

• In fuels supply technologies, the Board believes that technologies such as enhanced oil and gas recovery, while urgent because of near term benefits, will be adequately supported by the private sector. DOE's support of these programs can thus be reduced. The Board also recommends that:

  - the major Federal effort in synthetic fuels research and development be directed at innovative concepts at the laboratory and small pilot-plant scale. In view of the financial guarantees available from DOE and the Synfuels Corporation, DOE's budget for cost-shared projects at the large pilot plant and demonstration-plant scale and for in situ shale recovery should be reduced.

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*See dissenting opinion and additional remarks in Appendix D.

- the funding level for R&D directed at producing liquids and gases from biomass and the production of alcohol is at an appropriate level.

- ERAB urges that the parts of Advanced Research and Environmental Control Technology R&D (FE) concerned with technologies to control SO_x, NO_x and particulates emissions be increased and strengthened at the expense of other activities in this program.

- On an overall basis within the Department of Energy, R&D funding for energy conservation and end-use technology is underfunded, particularly when compared with funding levels for supply technologies. A balance that better reflects the opportunities, importance, and nature of the Federal role in supporting private sector response needs to be achieved. This should be achieved by increases in funds allocated to buildings and community systems and industrial conservation.

- The Board believes that if its recommendations are implemented, a net reduction in DOE's budget will result.

II. INTRODUCTION

A. Background and Purpose

On April 30, 1980, the Deputy Secretary of Energy* requested that the Energy Research Advisory Board (ERAB) participate in the Department's review of the technology base component of its R&D programs by addressing the following concerns:

- The adequacy of the research underpinning for technology development programs
- Possible gaps or duplications of effort
- The balance among research performers in the universities, laboratories, and industry
- Significant R&D opportunities that our programs may be missing.

As a result of more than 16 public meetings during July and August 1980, a report was prepared by an R&D Panel and seven subpanels covering each of the major DOE program areas. This report titled, R&D Needs in the Department of Energy, was submitted to the Secretary of Energy on September 5, 1980, and recommended enhanced funding for a number of DOE program areas.

In the original request for an R&D study by ERAB, the Deputy Secretary expressed the view that this project should be a continuing effort through which ERAB would assist the Department in its R&D program evaluations. After the publication of the interim report, several members of the original panel continued to review various methodologies for evaluating R&D programs. On August 13, 1981, the Deputy Secretary* requested ERAB's recommendations on overall Federal energy R&D priorities specifically including the following concerns:

- The relative merits of each major R&D program with respect to such criteria as the technical and economic potential, urgency and lead time required, benefits and costs of Federal funding, contribution to energy security, health and environmental risks, and the appropriate Federal role;
- The appropriate R&D funding balance between electric power supply, fuels supply conservation, and technology base program areas;

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*See Appendix A.

- The appropriate program orientation and balance between research, development, and demonstration activities;

- The strategic R&D objectives for the near, mid, and long term.

In September 1981, the R&D Panel was restructured to include all members of ERAB who contributed individually to the evaluation of 49 program areas covering all energy R&D programs. The Panel met on September 24, 1981, to discuss the results of their evaluations (see Appendix B for details on methods and criteria) and to reach a consensus on its recommendations for R&D priorities. The R&D Executive Committee met on October 30, 1981, to revise the draft report before it was discussed and the body of the report approved by ERAB at its November 4-5, 1981 meeting.

In these times of budgetary restraints, it is imperative that maximum effectiveness be attained in the use of Federal R&D funds. It is essential that a rational basis for evaluating priorities and the proper balance of funding be used to allocate increasingly scarce fiscal resources. The purpose of this assessment is to provide the Secretary of Energy with ERAB's best advice toward the accomplishment of that goal. The ERAB devised a methodology for structuring the discussion of RD&D priorities and relative funding levels for energy RD&D. A brief description appears in section II.C.

B. Energy Policy Context of R&D: "The Federal Role".

Between our 1980 study and the present one a new Administration has re-defined the appropriate role of Federally-sponsored energy R&D. Differences in our conclusions and recommendations from the earlier study result to a considerable extent from this redefinition and our adherence to it -- with certain exceptions noted below.

The previous Administration defined an expansive role for Federally-sponsored R&D, including demonstration and commercialization. The new Administration, by contrast, proposes to:

- Drastically shift the emphasis from Federal sponsorship to reliance on the private sector. With few exceptions this includes total reliance on the private sector for demonstration and commercialization.

- Limit appropriate Federally-sponsored R&D to: 1) Basic energy science and technology base; 2) Energy R&D of a long-term high-risk character; and 3) Research on the health, safety, and environmental aspects of energy supply and use.

- Strive to reduce Federal expenditure and the Federal deficit.

ERAB's deliberations have reflected an expectation that Federal funds for R&D will be stringently limited for the foreseeable future. In evaluating R&D programs ERAB has conformed generally but not slavishly to this policy. We applaud greater reliance on the private sector whenever possible. We applaud the restoration of a free market in petroleum. ERAB believes that much, perhaps most, of new energy supplies and greater efficiency in energy use will in fact be achieved by higher energy prices. But ERAB is concerned that some energy R&D of great potential significance for the achievement of the Nation's energy goals will fall between Federal and industry responsibilities.

The new policy recognizes that private industry cannot be expected to do basic energy research or projects of a long term, higher risk character. But there are other circumstances in which it would be unrealistic to expect timely and effective assumption by industry of R&D responsibilities abdicated by the Government, however worthy the projects involved, and despite the provision of new generous tax incentives. Some of these circumstances are discussed below.

Some of the markets on which energy is sold are not "free." Oil and coal are the exceptions. A little over half our primary energy finds its way to consumers through the electric and gas utilities, and the utilities are regulated, price-controlled industries, selling their products not at free market prices, but at controlled prices well below replacement cost. The consequences are that consumers of gas and electricity have less of an incentive to conserve (and therefore to undertake research on conservation) and that producers of electricity are so strapped financially that they cannot afford conventional additions to capacity, let alone demonstration projects or any expensive R&D. Gas producers are faring somewhat better and can look forward to eventual decontrol at the well head, but gas transmission and distribution will remain under control indefinitely and so presumably will the investor-owned electric utilities.

Both these regulated industries have weak incentives to spend on R&D. If successful, the benefits go to rate payers; if unsuccessful, the expenditure may be disallowed as "imprudent." In the case of electricity (but not gas) a substantial amount of R&D has been undertaken by large research-oriented equipment suppliers. And during the past decade the "invention" of a device for financing industry-wide R&D by rate payer levies through EPRI and GRI has enhanced the ability of both industries to respond to R&D needs and provided an alternative to some government-sponsored R&D, but the total annual budgets of the two institutions (less than $300M and $100M respectively) are far too small to permit them even to contemplate financing demonstration or first-of-a-kind commercial plants at a billion or more each.

Some energy related industries are too fragmented to organize and finance a strong R&D response to market signals. Individual units lack the financial strength, and realize too well that the benefits would accrue mainly to other units. Before the advent of agribusiness, the tremendous gains in agricultural productivity resulted from government and government-supported university research and an extension network to convey the results of the research to individual farmers. The building industry, to take an important example, is now similarly fragmented and similarly incapable of organizing and funding its own research.

Even where some larger units exist, industries with a strong R&D orientation and capability are the exception in America. Most of our industry-sponsored R&D is now highly concentrated in a few industries. The reasons may be historical, institutional, or adventitious. A strong R&D response to price signals requires both motivation and capability. In many cases the capability is simply lacking, and while it can be developed given time, the time required to build a strong research organization is measured in years.

A common reason for no response or inappropriate response by consumers to market signals is ignorance. EPA ratings of the fuel efficiency of automobiles, however faulty, focused attention on the potential savings and gave buyers useful guidance. The effect on the average fuel economy of new cars has been dramatic. In the case of buildings, particularly their heating and cooling, ignorance still reigns supreme. Almost no one knows what is cost effective at different prices, or where to go to get reliable, objective information. Almost no one knows how much reduced ventilation in super insulated buildings is safe or how to reconcile tightness and safety. The retrofit problems are extremely complex, and even the best "house doctors" are only beginning to learn their job. In the meantime we are consuming more energy in heating and cooling residential and commercial buildings than in running our automobiles, and the potential savings are also greater. The government can provide some of the research needed to achieve them.

To conclude: ERAB in its evaluations of programs has taken the new policies and guidelines relative to the Federal role very seriously, but ERAB has made exceptions where there is reasonable certainty that timely and adequate response by industry and commerce is an unrealistic assumption, and that continued Federal research support is therefore still required, at least for a time.*

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*We have not, in this report, responded to the Deputy Secretary's request for advice on the respective roles of industry, university, and national laboratory R&D efforts. This will be a major focus of our new study on DOE laboratories, initiated on November 3, 1981.

C. Methods and Criteria

This assessment features an evaluation technique in which each member of ERAB evaluated 49 program areas covering all DOE energy R&D programs in terms of seven criteria for energy supply and conservation programs and five criteria for science and technology base programs. Each member evaluated the relative importance of these criteria and judged whether more, less, or the same amounts of money relative to the President's request for FY 1982 should be allocated to the various programs. The judgments of the Panel members were combined numerically to arrive at figures of merit for each program on the relative priorities of energy technologies and whether financial allocations to each program should be increased, held the same, or decreased relative to the President's request for FY 1982. The resulting figure of merit was used to rank the programs in order of importance.

Criteria used in evaluating the priority of each technology were selected and the definitions for each criterion agreed upon. The criteria for the R&D programs were technology potential, urgency, economic potential, benefit/cost, energy/national security, health/safety/environment, and federal RD&D role. The criteria for the Science and Technology Base programs were scientific potential, risk/benefit, mission impact, urgency and federal role. A more detailed definition of these criteria is given in Appendix C.

Each member of ERAB determined the relative importance of each criterion and then judged its importance for each technology. From this information normalized weighting factors for the criteria were determined. Using these factors and the criteria/technology judgement information, figures of merit were calculated for each technology. Recommended funding levels for each technology were also provided by ERAB members. This information was used as the basis for discussing recommendations of future funding -- namely, whether the funding for each program should be decreased, remain the same or be increased relative to the President's FY82 budget request.

The results of this method allowed for a systematic, well structured debate on issues where the level of agreement was not clear or where clear disagreement was obvious. It was also quite effective in identifying areas of strong agreement by ERAB on a particular value judgment. It is important to note that the assessment or evaluation methodology which used decision questionnaires from each member was not intended to and did not "fix" the results of the final priority ratings. Rather the methodology was designed as an initial point of departure for discussion from which final conclusions would ultimately evolve -- conclusions that were not necessarily consistent with the initial ratings. Where reasonable consensus could not be reached, the expression of minority views is included.

III. ENERGY PROSPECTS

A. Supply and Demand Projections

Table III-A shows the latest DOE projections* of U.S. energy consumption for 1990 and 2000 compared with actual consumption for 1980. Table III-B shows similar projections for U.S. energy production and net imports.

The most striking aspect of recent supply/demand projections has been the sharp drop, especially over the last two years, in the projections for total consumption of energy in the years 1990 and 2000. Figure III-1 illustrates the point. What lies behind this development are (1) a much stronger user response to rising energy prices than had been expected; i.e., greatly and steadily increasing efficiency in the use of energy, which has been expressed as a less than proportionate increase in energy consumption associated with a given increase in GDP, gross domestic product, (see Figure III-2), and (2) a substantial reduction in the expected rate of economic growth. This double-barreled assault on earlier projections has now reduced them to the equivalent of an annual growth between now and the year 2000 of about 1 Q/yr (equal to 0.5 MBD of oil, or 40-50 million tons of coal per year, or a trillion cubic feet of natural gas per year).

A second characteristic of energy consumption and production projections is that there remains a sizeable band of uncertainty. This is especially disconcerting where imported oil -- the country's Achilles heel -- is concerned. Imported oil is the principal balancing factor, and thus carries the combined impact of uncertainties in all other source projections. For this reason there is wide divergence in estimates of U.S. oil imports ten or twenty years from now. Table III-B shows a range from 4 to 15 Q/yr (2 to 7.5 MBD) in 1990 and from zero to 11 Q/yr (5.5 MBD) in 2000. There are estimates outside this range.

With few exceptions, current projections expect the completion of most nuclear plants now on the books, though opinions differ as to time of completion during the next two decades. Even if new orders are placed, this will barely, if at all, affect the number on stream for the balance of the century.

Expectations for coal- or shale-based gases and liquids are modest, with many observers judging the projection of the Synfuels Act of 4.2 Q/yr (2 MBD) in 1992 to be substantially unrealistic. Projections of solar energy (narrowly defined to exclude hydropower, biomass, etc.) are

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*National Energy Policy Plan, USDOE, July 1981, DOE/PE-0029.

TABLE III-A

U.S. ENERGY CONSUMPTION
(Quadrillion Btu Per Year)

	ACTUAL	PROJECTED				% CHANGE
	1980	1990		2000		1980-2000
		MIDRANGE	RANGE	MIDRANGE	RANGE	
Direct Oil 1/	31.2	27	26-29	24	23-25	-23.0
Direct Gas 2/	16.7	18	17.5-18.5	20	18-22	19.8
Direct Coal	3.5	5.5	5.0-6.4	7.5	6.6-8.2	114
Direct Renewable 3/	1.8	2.7	2.6-2.8	4.2	3.9-4.5	133
Electricity	7.1	9.6	8.5-11	12	10-14	69
End-Use Consumption	60.3	63	59-67	68	62-74	
Conversion Losses*	17.7	24	21-27	32	28-36	
Total Consumption 4/	78.0	87	80-94	100	90-110	

1/ Includes coal liquids.

2/ Includes synthetic gas from naptha and coal.

3/ Not included in conventional accounting.

4/ Range results from varying GNP assumptions.

*Includes conversion losses in generation and distribution of electricity and in production of synthetic fuels from coal and oil shale, but not similar conversion losses associated with other forms of energy, e.g. losses in petroleum refining and gas transmission.

Source: National Energy Policy Plan, USDOE, July 1981.

TABLE III-B

U.S. ENERGY PRODUCTION AND IMPORTS[1/]
(Quadrillion Btu Per Year)

	ACTUAL	PROJECTED			
	1980	1990		2000	
		MIDRANGE	RANGE	MIDRANGE	RANGE
DOMESTIC PRODUCTION					
Oil and NGL	20.5	18	16-21	20.0	17-24
Conventional	20.5	16.4	14.7-19.1	13.7	11.1-18.1
Unconventional[2/]	--	1.7	1.0-3.0	6.1	4.2-8.5
Natural Gas	19.8	18.5	16-21	18.0	14-21
Conventional	19.8	17.4	14.6-19.7	14.7	11.4-18.2
Unconventional[3/]	--	1.3	1.0-1.6	3.3	2.0-5.1
Coal[4/]	18.9	27	24-30	42	37-45
Nuclear	2.7	7.6	6.7-8.7	10.6	7.4-14.0
Hydro/Geothermal	3.2	3.6	3.3-3.9	4.3	3.7-4.9
Renewables[5/]	1.8	2.8	2.4-3.3	5.4	3.9-7.0
Total Production[6/]	66.9	78	68-88	100	83-116
NET IMPORTS					
Oil	13.3	10	4-15	3	0-11
Gas	1.0	2	1-3	2	1-3
Coal	(2.4)	(3.5)	(2.3-4.3)	(5.9)	(3.4-8.4)
Total Consumption[7/]	78	87	80-94	100	90-110

1/ Ranges in production reflect uncertainties about US energy supply.

2/ Includes shale oil and incremental enhanced oil recovery, but excludes coal liquids.

3/ Includes unconventional gas production from tight sands, Devonian shale and geopressurized methane. Does not include synthetic gas.

4/ Includes coal production for synthetics and coal exports.

5/ Includes about 1.8 quads of biomass not currently included in EIA/DOE statistics.

6/ Totals may not add due to rounding.

7/ Includes 0.8 quads of net stock increases in 1980. Range in total energy consumption results from varying GNP assumptions.

Source: National Energy Policy Plan, USDOE, July 1981.

FIGURE III-1

TRENDS IN U.S. ENERGY DEMAND PROJECTIONS FOR THE YEAR 2000

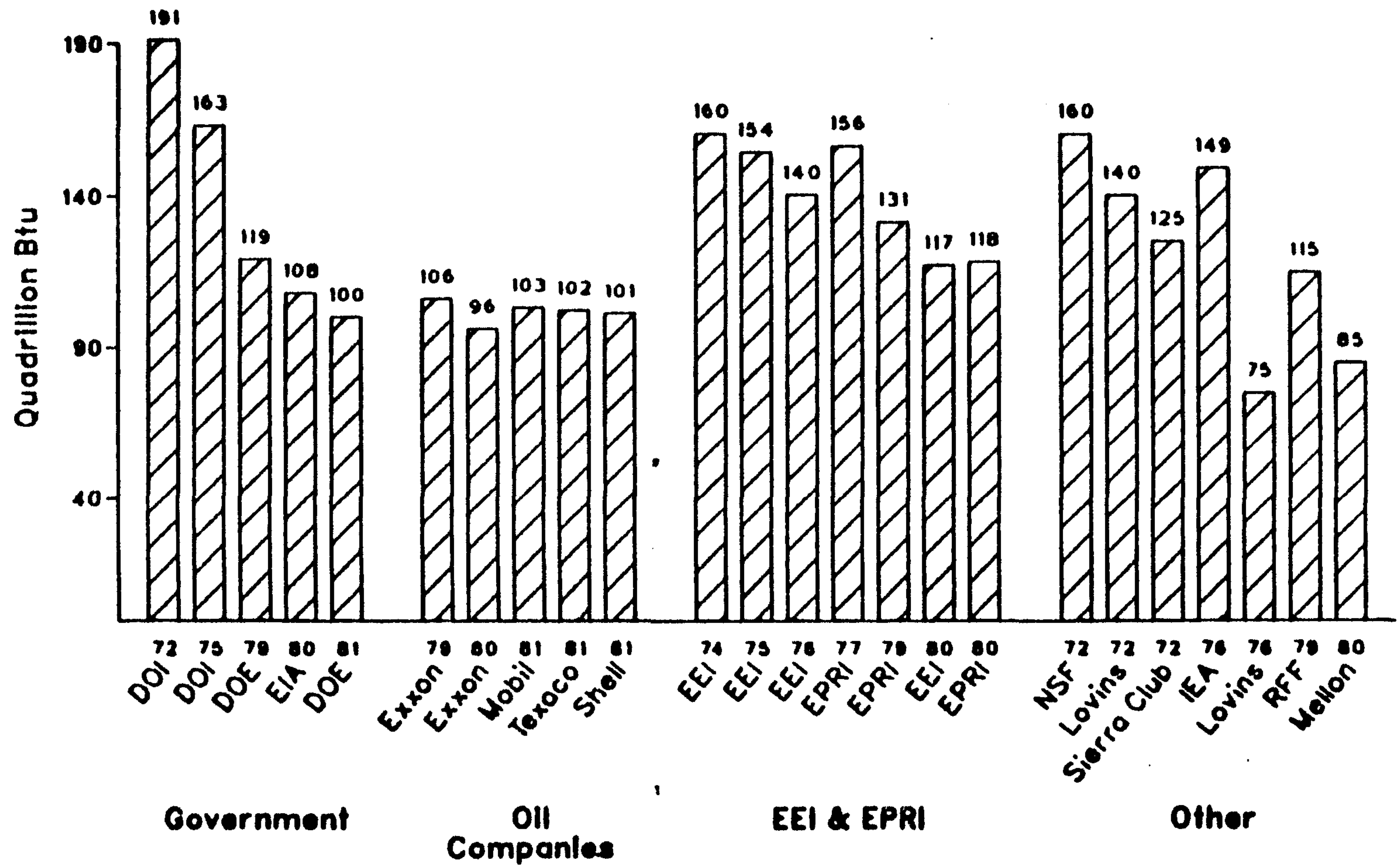
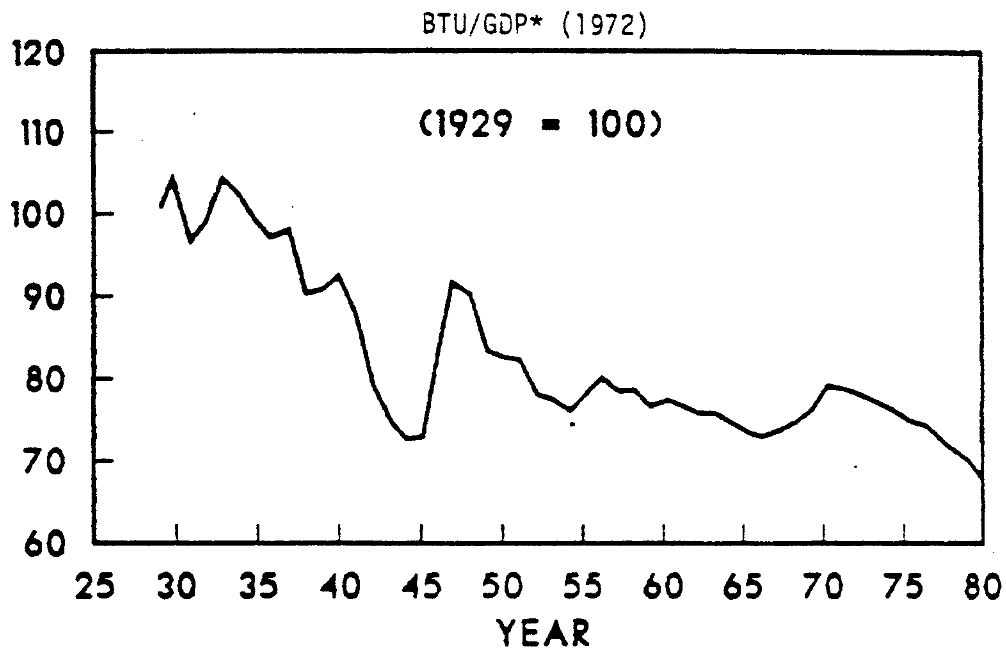


Figure III-2



*GDP represents gross domestic product

Source: Work in Process. Resources for the Future. Washington, DC: July 1981.

modest, largely connected with the continued depression in the consumer market, the cost of retrofitting and little progress in alleviation of institutional obstacles. Thus, for the next two decades oil, natural gas, and coal with a modest contribution of nuclear and an even more modest one of hydropower will remain the basic components of the U.S. energy supply.

Lest this quick sketch be interpreted as reflecting a mind-set of complacency, we should stress that a large number of assumptions may prove mistaken. These range all the way from the expected continuation of increased efficiency in use (i.e., how soon will that downward slope in the Btu/GNP ratio flatten out?) to the completion, more or less on schedule, of all nuclear plants now being constructed or having construction permits. Finally, a major perturbation in the oil import segment would play havoc with all projections.

B. Energy R&D Budget Analysis

Table III-C (FY1981) and III-D (President's proposals FY 1982) analyze the DOE budget by output energy form (electricity, fuels, and conservation) related to the resource base. Tables III-E and III-F analyze the budget by the same output energy forms related to the timing of impact: near term (next 10 years), mid term (1990-2010) and long term (beyond 2010). These tables are based on a categorization of programs selected by ERAB (see Appendix B-3).

C. Energy R & D Balance and Timing

Initial inspection of the FY 81 and FY 82 Federal energy R&D budgets (Tables III-C and III-D) reveals what appear to be imbalances in the program.

- There is very heavy stress on electrical technology in FY 81, further accented in FY 82, although it is noted that fluid fuels constitute our principal vulnerability.

- Similarly, within electricity, federally-sponsored nuclear programs are receiving a larger proportion of funding than the expected nuclear share of the U.S. energy mix during the next few decades.

- Finally, conservation, a very small fraction of the energy R&D budget in FY 81, is further and drastically reduced in FY 82, although it has so far contributed much more than supply augmentations in reducing our dependence on insecure oil imports.

TABLE III-C

FY 81 Budget as a Function of Technology Area and Energy Form, Millions of $

Output Energy Form / Resource Base	Electricity	Fuels	Utilization and Conservation	Science and Technology Base	TOTALS
Conservation	-	-	311.5	-	311.5 (7%)[9%]
Nuclear & Fusion	1793.1 *	-	-	-	1793.1 (39%)[50%]
Coal	66.6	492.4	37.4	-	596.5 (13%)[16%]
Solar	224.3	49.6	363.1	-	637.0 (14%)[18%]
Geothermal	153.6	-	-	-	153.6 (3%)[4%]
Oil/Gas/Shale	-	78.9	-	-	78.9 (2%)[3%]
Science and Technology Base	-	-	-	979.3	979.3 (22%)
TOTALS (% of Total) [% less science and tech base]	2237.6 (49%) [63%]	621.0 (14%) [17%]	712.0 (16%) [20%]	979.3 (21%)	4549.9 [3570.6]

*Centrifuge R&D costs included, construction costs excluded.

[] signify Science & Technology Base funding excluded.

TABLE III-D

President's FY 82 Budget as a Function of Technology Area and Energy Form, Millions of $

Output Energy Form / Resource Base	Electricity	Fuels	Utilization and Conservation	Science and Technology Base	TOTALS
Conservation	-	-	126.7	-	126.7 (3%)[5%]
Nuclear & Fusion	2022.2 *	-	-	-	2022.2 (53%)[72%]
Coal	-	282.4	38.8	-	321.2 (8%)[11%]
Solar	66.9	30.5	128.7	-	226.1 (6%)[8%]
Geothermal	46.8	-	-	-	46.8 (1%)[2%]
Oil/Gas/Shale	-	46.5	-	-	46.5 (1%)[2%]
Science and Technology Base	-	-	-	1073.4	1073.4 (28%)
TOTALS (% of Total) [% less science & tech base]	2135.9 (55%) [76%]	359.4 (9%) [13%]	294.2 (8%) [11%]	1073.4 (28%)	3862.9 [2789.5]

*Centrifuge R&D costs included, construction costs excluded.

[] signify Science & Technology Base funding excluded.

The questions whether these apparent imbalances are truly misallocations, or are justified, are addressed in detail in later sections of the report, and ERAB's recommendations for specific allocations within the overall budget are summarized in the conclusions at the end of the report.

No "correct" balance among energy forms and resources can be defined a priori: it would be absurd, for example, to assign coal or natural gas a "fair" share of Federal research dollars if there are no promising research projects in those areas which industry cannot be expected to undertake.

Tables III-E and III-F illustrate the Reagan administration shift toward research with longer range impacts. ERAB does not question this shift as a general proposition as long as it recognizes valid exceptions. Indeed, private industry is not likely to undertake long-range high risk R&D. It is also the area in which energy R&D can expect the highest payoffs and addresses the great national energy objectives -- affordable and environmentally benign sources of electricity and fluid fuels, used efficiently, for the indefinite future.

A summary of the timing impact of the various supply technologies used in preparing Tables III-E and III-F appears in Appendix B.

TABLE III-E*

FY81 Budget as a Function of Energy Form and Timing of Impact, Millions of $

	Near	Mid	Long	TOTALS
Electricity	827.2 **	539.6	870.8	2237.6 (49%)[63%]
Fuels	96.3	482.5	42.0	620.8 (14%) [17%]
Utilization and Conservation	509.2	203.0	-	712.2 (16%)[20%]
Science and Technology Base	-	-	979.3	979.3 (21%)
TOTALS (% of Total) [% less science & tech base]	1432.7 (31%) [40%]	1225.1 (27%) [34%]	[912.8][26%] 1892.1 (42%)	4549.9 [3570.6]

*The timeframe for impact of the various technologies used in making the above table is given in Appendix B.

**Centrifuge R&D costs included, construction costs excluded.

[] signify Science & Technology Base funding excluded.

TABLE III-F*

President's FY82 Budget as a Function of Energy Form and Timing of Impact, Millions of $

	Near	Mid	Long	TOTALS
Electricity	802.1 **	406.1	928.0	2136.2 (55%)[77%]
Fuels	60.7	274.0	24.4	359.1 (9%)[13%]
Utilization and Conservation	174.2	120.0	-	294.2 (8%)[10%]
Science and Technology Base	-	-	1073.4	1073.4 (28%)
TOTALS (% of Total) [% less science & tech base]	1037.0 (27%) [37%]	800.1 (21%) [29%]	[952.4][34%] 2025.8 (52%)	3862.9 [2789.5]

*The timeframe for impact of the various technologies used in making the above table is given in Appendix B.

**Centrifuge R&D costs included, construction costs excluded.

[] signify Science & Technology Base funding excluded.

IV. ELECTRIC-RELATED SUPPLY PROGRAMS

A. Introduction

Electric-related supply programs constitute $2.1B of the FY 82 President's budget in energy supply R&D. Of this, $2.0B is devoted to nuclear fission and fusion R&D. The programs classified under this heading are on average larger in size than those in other R&D categories. This is because programs involving nuclear fission and nuclear fusion necessarily involve large research teams and also frequently involve expensive equipment and facilities for demonstration projects. This applies whether the impact of the program is near term as in research on conventional reactor systems, or long term as in fusion research.

The extent to which these programs should be financed by the Federal Government rather than by private industry is regarded by ERAB members as a key criterion. In many programs the Federal Government has assumed responsibilities (uranium enrichment, nuclear waste disposal and nuclear safety) that are not now assumed by private industry. In other programs (e.g., magnetohydrodynamics, breeder reactors, magnetic fusion) the risk is presently too great and the time scale too long for substantial private industry funding. For such programs the key criteria for continued government funding are the chance of technical success and the ultimate potential for providing a secure energy supply.

A major shift in the Administration's Energy Policy has been to give increased support to assuring the viability of the light water reactor (LWR) electric power industry. In order to carry out this new policy, ERAB recommends that the Administration give high priority to:

- R&D in nuclear waste disposal, particularly in accelerating early demonstration of specific, most promising waste disposal methods

- R&D on current generation LWR's

The summary of ERAB conclusions on priorities and funding for electric related supply is given in Table IV-A.

B. Near Term Nuclear Programs

Conventional reactor systems ($81.5/$68.0)* Increased funding for R&D on conventional reactor systems is recommended. Increased funding

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*FY81 funding/FY82 President's Request in million $ are shown in parenthesis.

should be concentrated in high pay-off areas -- Three-Mile Island analysis, high burn-up fuel, safety related research and lower enriched fuel for research reactors while high temperature gas reactor funding has a lower priority.

Nuclear waste programs ($499.8/$617.6) ERAB thinks that the proposed funding for these programs is satisfactory, even though they have the highest priority. Funding increases are not considered necessary because technology is regarded as available; the main obstacles are political. It is recommended that demonstration and site work should be accelerated. Safe waste disposal is critical for assuring the viability of the light water reactor cycle.

Uranium enrichment programs ($142.3/$149.7) There is strong agreement that funding for advanced isotope separation and advanced centrifuge R&D should be continued. It should be noted that $293.3M in FY81 funds and $695.8M in FY82 funds for construction of the near term gas centifuge capacity were excluded from consideration of R&D expenditures as the decision on this project should be based on normal payback criteria. In this regard, the ERAB recommends that consideration be given to formation of a quasi-government or private corporation to handle enrichment on a commercial basis.

Uranium resources assessment ($25.9/$5.8) The President's 1982 Budget for this program represents a substantial reduction from past plans. ERAB recommends that funding be continued at approximately the 1982 budget level so that gathering of readily accessible data and periodic publication of reports can be continued.

C. Long Term Nuclear Programs

Liquid metal fast breeder reactor (base program) and fuel cycle R&D ($419.4/413.9) It is considered desirable to maintain present levels of effort in the LMFBR base program and fuel cycle R&D, except those aspects that are closely tied to near term demonstration should be reviewed for appropriate changes. Breeders with attendant reprocessing could have a high ultimate impact on energy supply security. Although the ultimate impact is post-2000, ERAB recommends that this base technology program must be maintained.

Clinch River Breeder Reactor ($172.0/$254.0) The ERAB believes that the construction of a breeder reactor demonstration at this time is not an urgent priority and thus, under current budget constraints, recommends that such a demonstration be delayed until a future time.*

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*See dissenting opinion and additional remarks in Appendix D.

TABLE IV-A

SUMMARY
R&D PRIORITIES
ELECTRIC SUPPLY PROGRAMS

RANK[1]	PROGRAM	PRIORITY[2]	President's FY82 Budget	ERAB Funding[2] Recommendations
1	Nuclear Waste Commercial (NE)	HIGHER	227.6	Same
2	Nuclear Waste Defense (DP)		390.0	Same
3	Conventional Reactor System (NE)	MEDIUM	68.0	More
4	Breeder Reactor Fuel Cycle R&D (NE)		26.1	Little Less
5	U E - Centrifuge (NE)[3]		64.5	Same
6	Liquid Metal Fast Breeder (NE) (Base Program)		387.8	Same
7	Solar Power Technology (CE)		19.4	Less
8	U E - Advanced Isotope Separation (NE)		85.2	Same
9	Magnetic Fusion (ER)	LOWER	456.1	Little Less
10	Light Water Breeder Reactor (NE)		58.0	Less
11	Uranium Resources Assessment (NE)		5.8	Same
12	Electric Energy & Storage Systems (CE)		47.5	Less
13	Hydropower (CE)		0.0	Zero
14	Clinch River Breeder Reactor (NE)		254.0	Less
15	Geothermal (CE)		46.8	Less
16	Magnetohydrodynamics (FE)		0.0	Zero

[1]Rankings represent consensus view of ERAB and should be interpreted with caution; the differentiation between any two consecutive programs is not necessarily significant.

[2]Priority reflects ERAB view of overall merit of program; funding recommendations relative to the President's budget request for FY82 reflect on Federal role.

[3]Excludes $695.8 million for centrifuge plant construction.

Light water breeder reactor ($60.2/$58.0) This program has the potential of extending the long-term supply of nuclear fuels. The ERAB agrees however that decreased funding for the LWBR may be warranted. The unattractive economics and the lack of industry interest are cited as reasons. Further reductions in funding are recommended.

Magnetic fusion ($391.0/$456.1) ERAB members agree on the long-term importance of this program and that the primary Federal role should be to continue to sponsor a joint program of the federal laboratories, industry and university scientific communities to determine if fusion can be practical.* The potential payoff is very large, but is much too far in the future for significant private sector support. There was agreement that a stretch-out of the program is possible if budgetary pressures demanded it, but maintenance of a substantial level of Federal R&D funding is judged to be essential. It is also recommended that an enhanced effort to examine the use of fusion for the breeding of nuclear fuels deserves consideration.

D. Non-nuclear Electric Programs**

Solar power technology ($112.1/$19.4) This technology area includes wind energy and Ocean Thermal Energy Conversion. (Photovoltaics is included under Solar Applications for Building in the conservation section.) Wind energy is regarded as the most technologically advanced and as having achieved commercial potential. Since there are no critical technical R&D problems preventing commercialization by industry, and since there is limited potential to be realized, the Board recommends less funding for this technology. In the case of OTEC, technical feasibility has been shown on a small scale, thus fulfilling the primary Federal role. The Board recommends that remaining funding should be used to facilitate the transition to industrial commercialization.

Hydropower ($2.4/$0.0) Technical success for small scale hydropower has been proved, and private industry is active (although it is noted that U.S. manufacturers of low-head hydro equipment are absent). Little, if any, R&D is needed; therefore, the Board recommends phase-out of funding. Investment tax and other credits are sufficient to commercialize this technology.

Magnetohydrodynamics ($66.5/$0.0) There are other technologies (such as combined cycle gas turbines) available for increasing the

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*See Report on the DOE Magnetic Fusion Program, prepared by the Fusion Review Panel of ERAB, August 1980.

**Dispersed electric and co-generation technology, direct coal combustion, and fuel cell programs included in Section VI.

efficiency of large, central power generation stations that do not have the extreme temperature/erosion problems associated with the use of coal in MHD. For this reason the Board foresees little commercial demand for this technology and therefore concurs with the planned phase-out of this program. The Board recommends that existing government facilities be utilized by industry if they wish to pursue research in this area.

Geothermal ($153.6/$46.8) Strong agreement that funding should be decreased is predicated upon the fact that private industry should be undertaking the development of the part of the resource that appears economic, and is in fact doing so. The program is also seen as having low impact on national energy supply. If a Federal geothermal program is continued, emphasis should be on low temperature process heat and completing the ongoing hot dry rock program, not on geopressured energy resources, where the technical risk appears high or geothermal electric where industry is capable of solving the remaining problems.

Electric Energy and Storage ($109.8/$47.5) This program consists of two parts, R&D on electricity transmission and distribution and R&D on energy storage. R&D on electricity transmission and distribution is regarded as essentially the responsibility of private industry. As a result, there is agreement that the overall program should decrease in such a way that at least some results can be obtained from programs now at the point of yielding valuable data. R&D on energy storage, however, is regarded as important; this part of the program should be strengthened. The Board supports direct participation of Federal electricity producing and marketing agencies in the Electric Power Research Institute as a mechanism for supporting R&D on utility-related needs.

V. FUELS SUPPLY TECHNOLOGY

A. Introduction

Fuel supply technologies represent approximately 9% of the President's total FY 82 budget for energy supply. This sector of energy supply is not as highly regulated as the electric energy industry and has historically developed these supplies with private resources. In general, ERAB concludes that the more urgent technologies, such as enhanced gas and oil recovery, can have an early impact in the market but that the Federal role is significantly less since private industry will develop these sources. Conversely, as discussed in Chapter VII, on the Science and Technology Base, the Federal Government has important roles to play in environmental research on accumulation of CO_2 in the atmosphere and on acid rain. Either of these problems has the potential for substantially limiting expanded use of fossil fuels.

Table V-A provides a summary of the relative priorities and recommended funding levels discussed is this section.

B. Synthetic and Natural Gas

Enhanced Gas Recovery ($30.6/$10.2)* Enhanced gas recovery is given a medium priority with respect to urgency, benefit/cost ratio, supply security and a high priority with respect to technical and economic potential and health and environment. Government funding of the program should be decreased because the private sector is conducting adequate research and development in these areas. Only low level government funding is needed to assist in the funding of some private sector experiments by small companies and to maintain government awareness of what is being accomplished.

Surface Coal Gasification ($69.6/$53.4) Gasification is the most important step in the conversion of coals to synthetic gases and liquids by almost every process and possibly even in the conversion to electricity. While private sector efforts here and abroad are very extensive a continued DOE effort is well justified. Specifically, DOE gasification R&D should concentrate on (a) exploration of new process concepts; (b) R&D on the various auxiliary steps such as evaluation and preparation of gasifier feeds from U.S. coals and raw gas clean-up systems.

Most importantly R&D towards closing the gaps in the knowledge of environmental issues related to gasification is not only important but a most appropriate area for government research.

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*FY81 funding/FY82 President's request in million $ are shown in parenthesis.

TABLE V-A

SUMMARY
R&D PRIORITIES
LIQUIDS AND GAS SUPPLY PROGRAMS

RANK[1]	PROGRAM	PRIORITY[2]	President's FY82 Budget	ERAB Funding[2] Recommendations
1	Enhanced Oil Recovery (FE)	HIGHER	20.1	Less
2	Advanced Research and Environmental Control Technology (FE)	MEDIUM	94.5	Same
3	Enhanced Gas Recovery (FE)		10.2	Less
4	Coal Liquefaction (FE)		105.2	Less
5	Biomass Energy (CE)		20.5	Same
6	Surface Coal Gasification (FE)		53.4	Less
7	Mining R&D (FE)	LOWER	21.0	Less
8	In Situ Oil Shale (FE)		16.3	Less
9	Alcohol Fuels (CE)		10.0	Same
10	In Situ Coal Gasification (FE)		8.3	Less

[1]Rankings represent consensus view of ERAB and should be interpreted with caution; the differentiation between any two consecutive programs is not necessarily significant.

[2]Priority reflects ERAB view of overall merit of program; funding recommendations relative to the President's budget request for FY82 reflect on Federal role.

Since a very broad pilot and demonstration program is under way outside DOE (much of it abroad) the need for continued pilot plant operation is eliminated (example Bi-gas project). R&D elsewhere involves efforts on both air- and oxygen-blown gasifiers, thus a separate DOE program on air-blown (low-BTU) gasifiers appears redundant.

In view of the above, the Board concludes that a funding level somewhat below that proposed in the President's budget would be adequate.

In-Situ Coal Gasification ($10.0/$8.3) In-situ gasification has been attempted here and abroad for many decades but with limited success. One of the more interesting parts of this DOE program aims at gasification of coal in steeply dipping beds. Tests now underway should be completed during the next year. This is a unique application which can be evaluated at the end of the present program; if successful, further development can then be carried on by private sector sponsors with an interest in this type of coal deposit. With this exception, the in-situ coal gasification program has a low probability of a commercially viable success and can be phased out.

C. Petroleum and Synthetic Liquids

Enhanced Oil Recovery ($16.2/$20.1) ERAB gives enhanced oil recovery a very high priority with respect to technological and economic potential, benefit/cost ratio, urgency, supply security and health/environmental problems. However, the Board recommends that Federal funding, even though relatively small, be decreased. A small Federal expenditure can be justified only for some of the environmental research and to keep current with technical developments in the private sector. This recommendation stems from the considerable evidence that the larger energy companies have the ability, the know-how and the willingness to engage in sustained long-term R&D. Also, the oil companies have the financial strength to commercialize enhanced oil recovery processes without government financed demonstrations.

Coal Liquefaction ($277.0/$105.2) Commercially demonstrated coal liquefaction technology is currently available. This is based on the so-called "indirect" route. Large plants are now in operation abroad; a full size plant is under construction in the U.S. that will demonstrate the critical components. Although this plant is designed to produce synthetic natural gas, not liquids, some 4/5 of the total process sequence is identical with that required for liquids, specifically the gasification and gas purification. Improved processes for conversion of the resulting CO/H_2 mixtures to liquids are in the process of commercialization. Although the competitive route to coal based liquids, namely direct hydrogenation, was once considered superior, it has not been practiced for 35 years and now requires an extensive R&D and demonstration program if it is to become competitive. This is desirable to avoid reliance on a single technology. DOE has been engaged in coal hydrogenation for over ten years and has advanced the art to the point where the private sector can evaluate the merit of direct hydrogenation. At the present time, there is no unanimity on any inherent advantage of direct hydrogenation over indirect liquefaction although it should be more thermally efficient in principle.

Outside of DOE activities, the Synthetic Fuels Corporation is even now considering support of several commercial scale liquefaction projects. All of the foregoing has made it possible for DOE to begin phasing out the large scale pilot and demonstration hydrogenation projects that were intended to close the gap between indirect and direct liquefaction of coal. This should be done in a manner protecting the major investments in these projects which include the 200 ton/Day Exxon Donor Solvent Unit, the 250 ton/Day H-Coal Catalytic hydro unit and the 6000 ton/Day Solvent Refined Coal-I (SRC-I) demonstration project; in context with the latter it should be noted that real progress in coal hydrogenation (by any one of its many variants) will ultimately require a large commercial scale demonstration facility to resolve the difficult engineering problems. As a result, completion of the present design phase of SRC-I will serve to highlight the key difficulties on which future R&D should concentrate. It now appears that DOE will remain the key source of future R&D in direct liquefaction (hydrogenation). ERAB supports the continued effort in this area by DOE at the laboratory and small pilot plant scale with particular emphasis toward a broadening of the program to explore a wider range of technologies including 2-stage conversion based on carbonization or extraction with catalytic hydrocracking, new catalyst development, new solid/liquid separation.

DOE's intention to pursue development of improved indirect-liquefaction processes is not considered appropriate by ERAB, given the very extensive effort in the private sector; therefore, ERAB recommends elimination of this part of the liquefaction program.

In summary, ERAB recommends a reduced budget for coal liquefaction focusing on R&D in direct liquefaction area and particularly on R&D to resolve the environmental problems associated with this technology.

<u>In-Situ Oil Shale</u> ($32.2/$16.3) In-Situ Oil Shale is given a medium priority with respect to urgency, technical and economic potential, and benefit/cost ratio. Oil shale is given a high priority with respect to supply security. Since the rich shales will be used first and are concentrated in about a 600 square mile area in Colorado, special attention should be given to the environmental problems that will arise if commercial production rises to the level of one or two million barrels per

day. Likewise, the infrastructure needed to support this level of production in such a small area needs study. The government has an important role to play with respect to both the environment and the infrastructure problems; the present funding should be focused on these problems.

The in-situ oil shale program is really only a minor variation of the process for exploiting the oil shale resource. Both subsurface retorting and surface retorting of shale is under active investigation by the private sector. Several companies are designing commercial facilities with the intention of producing oil from shale in the late 80's. There is no need for a government role in the development of the technology of recovery of oil from oil shale; Federal expenditures in this area should be eliminated.

D. Biomass and Solid Fuels

Biomass Energy* ($31.7/$20.5) and Alcohol Fuels ($18.0/$10.0) Both programs are given a high priority with respect to technical potential. Biomass is given a medium priority with respect to all other criteria. Alcohol fuels differ from biomass in that they have a lower priority with respect to economic potential, benefit cost/ratio, supply security and urgency. The Board recommends that these funding levels not be changed. Particular attention should be given to the conversion of lignocellulose to fuels.

Mining R&D ($40.2/$21.0) Coal mining is an area deserving of substantial attention and support of R&D by the Federal Government. Much of this work is conducted by agencies other than DOE.

The Board recommends that coal mining R&D be concentrated in one agency and that DOE/FE instead concentrate its efforts on innovative concepts, particularly for preparation of fine sized coal.

E. Advanced Fossil Energy Research

Advanced Research and Environmental Control Research ($95.8/$94.5)** The Board believes this program should be funded at its present level but with some redirection.

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*Report of the Biomass Panel of the Energy Research Advisory Board, November 1981.

**For FY82 budget request $67.1 for advanced fossil R&D and $27.4 for environmental control technology development.

Advanced Research and Environmental Control Technology R&D (FE) includes, in addition to all exploratory R&D on coal conversion, research towards substitution of coal for oil and gas in direct combustion; this is an extremely important program since the vast majority of coal must be used as boiler fuel over the next several decades, both in existing and new units. Equally important is the development of improved emission control technology to reduce SO_x, NO_x and particulates in fluegas. The Board therefore urges that these parts of the Advanced Research and Environmental Control Programs be increased and given higher priority at the expense of other activities in this program. The remainder of the program is designed to provide technology base support to other fossil energy programs in such areas as materials, diagnostics, instrumentation, and applied research on new concepts and processes. This work is also important, but is longer range and should be closely coordinated with other technology base efforts.

VI. UTILIZATION AND CONSERVATION TECHNOLOGY

A. Introduction

Utilization and conservation technologies represent approximately 8% of the total FY 82 budget for energy research and development (see Tables III-C) divided 4% for utilization and 4% for conservation. The President's budget itself reflects severe budget cuts for these areas, up to 80% reductions over FY 81 in some cases.

Relative to their potential contributions to the solution of the near- and medium-term energy problems, there is an imbalance in the allocation of R&D funds between the conservation programs and those directed at supply. The budget needs a reordering of priorities to reflect better the opportunities that exist for efficiency improvements and the unique Federal role in conservation R&D.

ERAB's views on this point are reflected in the high priorities that members gave to conservation R&D: in the Board's ranking, three of the top five programs (and five of the top ten programs) of the entire Department's R&D projects were drawn from conservation/end-use R&D.

The priorities assigned to conservation and end use programs are summarized in Table VI-A.

B. Conservation Programs

Buildings and Community Systems ($53.0/$28.0)* ERAB ranked research on Buildings and Community Systems in the high priority range. Recognizing its importance to the energy problem as a whole and to the oil import problem particularly, the Board noted that private sector R&D in this area is rare because of the fragmented and undercapitalized nature of the industries involved. The efficiency improvements that can be made in existing structures are large, and no R&D capability exists within the remodeling or retrofit private sector. A Federal role is highly appropriate in this field; indeed, Federally-supported work at several of the National Laboratories, university centers, and elsewhere has been productive in product and design innovation and in transferring research results into the field quickly. The same is true of the consumer products work undertaken by these groups.

ERAB recommends that funding levels in this area be increased, emphasizing R&D that the private sector is not funding, while maintaining active R&D and technology transfer programs involving industry.

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*FY81 funding/FY82 President's request in million $ in parenthesis.

TABLE VI-A

SUMMARY
R&D PRIORITIES
CONSERVATION AND UTILIZATION

RANK[1]	PROGRAM	PRIORITY[2]	President's FY82 Budget	ERAB Funding[2] Recommendations
1	Coal Combustion Systems	HIGHER	38.8	Same
2	Buildings and Community Systems		28.0	More
3	Industrial Conservation		0.0	More
4	Transportation Conservation	MEDIUM	37.0	Same
5	Solar Applications for Buildings		84.7	Same
6	Heat Engines and Heat Recovery		15.6	Same
7	Multi-Sectors Conservation		17.5	Same
8	Fuel Cells		28.6	Same
9	Solar Applications for Industry	LOWER	44.0	Less

[1]Rankings represent consensus view of ERAB and should be interpreted with caution; the differentiation between any two consecutive programs is not necessarily significant.

[2]Priority reflects ERAB view of overall merit of program; funding recommendations relative to the President's budget request for FY82 reflect on Federal role.

The Federal Energy Management Program will be one of the subjects of discussion by the Board's Conservation Panel. It is not an R&D program; its shortcomings appear to have little to do with budget levels.

Transportation Conservation ($102.1/$37.0) Transportation Conservation R&D ranks at the top of the medium priority group of R&D programs. ERAB recommends that the funding level remain the same.

R&D emphasis should shift from the automobile to the heavy freight truck sector. The vehicle propulsion technology development program should be transferred to industry in an orderly way; the market, driven by consumer preference and foreign competition, should determine the necessity for and the direction of this R&D, not the Federal government. Likewise, electric and hybrid vehicle R&D should be sharply reduced.* Alternative fuels utilization R&D should continue but with closer cooperation with potential ultimate users. The transportation systems utilization activities deserve firm support. This program includes work that the private sector either will not do on systems improvements or cannot provide candidly.

Multi-Sector Conservation ($25.8/$17.5) The Multi-Sector Conservation program historically has been made up of three elements: the small inventions program, the appropriate technology program, and the Energy Conversion and Utilization Technology (ECUT) program. The President's budget has eliminated the appropriate technology program, but kept portions of the other two activities..

Even though it is required by legislation, the inventions program deserves relatively less emphasis within the Department; money devoted to it could be more productively used in the ECUT program, particularly if that program is restructured along the lines the Board recommends.

ECUT now devotes a major share of its budget to research on understanding combustion phenomenon, heat exchanger technology, chemical processes, and materials. Much of this work has been cooperative with the using industries and appears to be bearing fruit.

ECUT management itself, working with a group of outside reviewers drawn from industry and elsewhere, has recommended that its research be principally directed toward work on chemical and physical processes that have generic applications in improving efficiency. ERAB concurs with augmenting ECUT's activities along these lines, using funds drawn from savings realized from the phasing out of the inventions and the appropriate technology program.

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*See dissenting opinion in Appendix D.

Overall, ERAB recommends that the funding level remain the same, but that virtually all the R&D money be used in a redirected ECUT program.

Industrial Conservation ($67.3/$0.0) Industrial Conservation ranked in the high category when compared with all other DOE R&D programs. ERAB recommends that this program be restored close to FY81 funding levels. Thus, ERAB recommends an increase in the proposed budget.

ERAB expressed concern that, although all industries have incentives to conserve energy, many of them lack the ability to conduct R&D either because of their fragmented industrial structure or because of historic failure to support research. This appears to be true of many small and medium sized businesses that, in the aggregate, consume large amounts of energy. Short-term, high-payoff R&D will not be conducted unless Federal leadership is given.

ERAB noted that many of the industrial conservation projects previously undertaken by DOE have been highly effective and have included cost recovery features for the Government. Continuity and continued skilled management are important features in the prior (and future) success of this R&D component.

C. Solar Programs

Solar Applications for Buildings ($224.9/$84.7) The Solar Applications for Buildings program was given a high priority within the medium range. ERAB believes the funding should remain the same, recognizing that the lower funding levels will stretch out the time frame for achieving lower cost photovoltaic electricity.

Photovoltaic (PV) R&D has approximately 75% of the budget in this program. PV and fusion are the major renewable options available for electricity generation if the CO_2 problem is found to be significant. Major cost reductions in PV have been achieved, and further reductions leading to an attractive economic potential appear highly likely if Federal funding is maintained. A separate report recently submitted to ERAB by the Solar Photovoltaic Advisory Committee of the Board provides detailed recommendations in this area. A halving of the budget for PV (as the President has recommended) will mean that development of low-cost PV will slow down, increasing the opportunities for foreign manufacturers to dominate the technology. Therefore, continued support of PV is important to maintain the momentum developed by this program. Emphasis should be placed on advancing those photovoltaic technologies required to achieve cost reductions in both module and cell areas as well as balance of system areas. Premature demonstration activities should be curtailed.

Continued Federal support for basic and applied research in passive solar technology will pay high dividends. The building industry is fragmented and has no institutions capable of supporting this R&D activity. R&D activity on active, building-by-building solar heating should be relinquished to private industry. Research on passive solar cooling deserves support, particularly cooling systems that are effective in humid sections of the country. Similarly, solar pond technology should be continued since it is highly promising.

Solar Thermal Applications for Industry ($138.3/$44.0) ERAB recommends reduced overall funding with increased emphasis on selected elements within this medium priority program. High temperature collectors (concentrators and receivers) deserve increased support because of their great versatility in application and the lack of industrial R&D. Dish technology development should remain at the module level until technical and economic feasibility has been attained with several different modules.

Areas to be considered for reduced Federal support include those technologies where significant industrial interest is expressed already, specifically development in heliostat and external steam receivers, operation of Solar One and Shenandoah, and technology for process heat applications.

D. Other End-Use Technologies

Direct Coal Combustion Systems ($37.4/$38.8) No other direct combustion alternative exists that eliminates the need for scrubbers and is close to commercialization. Hence, ERAB recommends that the direct coal combustion systems program be continued with the same level of funding, although some redirection of emphasis is appropriate.

Atmospheric fluidized bed combusters for industrial applications are ready to move into the commercial market in configurations supported by the Federal Government in the past; further funding is no longer needed and should support instead advanced combustors that appear capable of burning with lower SO_X and NO_X emissions.

Research on pressurized fluidized bed combustors for utility and industrial applications is longer term with a promise of providing multifuel capabilities in, for example, cogeneration applications. In addition, advanced combustion concepts and alternative fuel utilization research may provide environmental or fuel substitution advantages.

Fuel Cells ($32.0/$28.6) Fuel cells represent an undeveloped technology with important environmental advantages. Although both the electric and gas industries are supporting research, some Federal support is essential for its continuation. ERAB recommends no change in the level of funding.

During FY 82, the phosphoric acid fuel cell technology will be tested in a 4.8 MW plant under construction in New York City; extension of the program should be assured to include testing of coal-derived fuel (methanol) and possibly shale liquids. The solid oxide fuel cell, while beyond the proof-of-principle stage, still requires subsystem development. In addition, the molten carbonate fuel cell with its high susceptibility to sulphur catalyst contamination and other high risk advanced technologies deserve continued support.

Heat Engines and Heat Recovery ($31.5/$15.6) ERAB recommends no change in funding for the heat engine program, but some redirection of effort is needed. The coal fueled diesel engine has little chance of economic success; its funding should be shifted to development of high temperature gas turbines. Since high risk technology for high efficiency central and dispersed power systems is the goal of this program, a major effort directed at higher efficiency/higher temperature gas turbines, the sine qua non for an efficient combined cycle, coal-fired power system, is more appropriate.

The heat recovery program supported with carry-over funds from FY 81 should be continued with additional funding requested for continuation of uranium enrichment plant heat recovery projects in FY 83.

VII. SCIENCE AND TECHNOLOGY BASE

A. Introduction

It has long been agreed that the Federal Government must play a primary role in the maintenance of research programs that contribute to new understanding and to expansion of the U.S. technology base. Generally, the activities sponsored by the DOE for this purpose represent an appropriate set of programs for maintaining and expanding the energy technology base, the body of knowledge and know-how upon which the nation must rely for implementation of our overall objectives in the energy field.

The program elements in DOE that constitute the science and technology base fall largely into two categories: general science and energy supporting research. It is the assessment of the Energy Research Advisory Board that both components are appropriate, represent research of high quality and scientific potential and, with minor exceptions, especially in basic and biological energy sciences, that the President's proposed budget for FY 82 calls for an adequate allocation of funds for these programs or allows for adjustments and reallocations that can assure continued progress towards the Nation's goals under the overall constrained budgetary circumstances.

Table VII-A summarizes the relative priorities and funding recommendations. It should again be noted that a separate set of criteria were used to evaluate these programs; thus, the rankings are not directly comparable with the R&D programs discussed in prior sections of this report.

B. General Science

These programs in General Science support the Nation's effort in high energy physics, nuclear physics, general life sciences, nuclear medicine, and the preparation of certain radioactive and heavy isotopes for scientific and commercial uses in a myriad of endeavors. Historically and by interagency agreement, DOE is the lead agency for these national programs that are of long-range importance in the energy effort but, in addition, have broader significance for continued progress in many commercial developments, in space, in defense, and in health-related fields. These basic research programs are sometimes characterized as a "national trust." ERAB proposes no change in these missions and no modification in present budgetary projections for them.

TABLE VII-A

SUMMARY
R&D PRIORITIES
SCIENCE AND TECHNOLOGY BASE

RANK[1]	PROGRAM	PRIORITY[2]	President's FY82 Budget	ERAB Funding[2] Recommendations
1	Materials Sciences	HIGHER	112.1	More
2	Climate and CO_2 Research		16.7[3]	More
3	Chemical Sciences		73.9	More
4	Biological & Environmental Research		153.8[3]	More
5	Biological Energy Sciences		9.4	More
6	Nuclear Medicine		50.5	Same
7	High Energy Physics		392.7	Same
8	University Research		10.6	More
9	Environment and Safety		49.6	Same
10	Engineering, Math & Geosciences		32.3	Same
11	Nuclear Physics		122.9	Same
12	Nuclear Sciences	MEDIUM	37.7	Same
13	Advanced Energy Projects		8.2	Same
14	Technology Assessments	LOWER	3.0	Same

[1]Rankings represent consensus view of ERAB and should be interpreted with caution; the differentiation between any two consecutive programs is not necessarily significant.

[2]Priority reflects ERAB view of overall merit of program; funding recommendations relative to the President's budget request for FY82 reflect on Federal role.

[3]The Biological and Environmental Research Program includes Climate and CO_2 Research with a total budget of $170.5 M.

High Energy Physics ($348.2/$392.7)* This program is the Nation's principal effort to explore the fundamental components and interactions of matter. It depends upon unique, large scale, high cost experimental facilities that are used by laboratory and university scientists to probe ever deeper into the structure of matter and the universe. Support of such research is a Federal responsibility since it is not expected to have commercial significance, although many commercial applications have arisen from technology developed through this program. Some university scientists who work at DOE facilities are supported by NSF; a joint planning process is used to ensure coordination. Support at about the present level will continue a longstanding U.S. commitment toward excellence in this field of science.

Nuclear Physics ($109.2/$122.9) The Nuclear Physics Program addresses the fundamental interactions and structure of the atomic nucleus. It develops and uses unique large-scale facilities at national laboratories and universities with a particular emphasis on heavy ion research and meson interactions with matter. Such research is long-range and would not be carried out without Federal support. Joint planning with NSF, the only other sponsor in this field, is intended to provide a balanced national effort. Support should be continued at about the same level-of-effort.

General Life Sciences and Nuclear Medicine ($45.9/$50.5) This combination of long-term biological research and unique medical application of nuclear techniques is clearly of value to the public and is unlikely to be undertaken by private industry. The genetic and cellular research provides a fundamental scientific underpinning for the more applied Biological and Environmental Research program while the nuclear medicine component exploits unique DOE facilities for the production, testing and application of radioisotopes. The current level-of-effort seems appropriate.

C. Energy Supporting Research

The Energy Supporting Research Programs of DOE are intended to expand the nation's technological alternatives by explorations in chemistry, materials science, biology, engineering and mathematics, geosciences and environmentally-related fields of health. Particularly important is the Climate and CO_2 research program since CO_2 accumulation may prove to be a "show-stopper" in terms of expanded fossil (but not biomass) energy alternatives. Additionally, the problem of acid rain is suggested as an important new area for emphasis by DOE.

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*FY81 funding/FY82 President's request in million $ are shown in parenthesis.

Materials Sciences ($95.2/$112.1) This program includes long-range research in solid state physics, materials chemistry, metallurgy and ceramics that is intended to provide a knowledge base that will lead to improved economics and performance of energy systems. Materials problems plague many energy production and conversion systems; a strengthening of this program would be a sound long-term investment since it addresses such important generic areas as high temperature alloys, corrosion, radiation damage and the physics and chemistry of surfaces. Increased operating costs of major facilities (such as neutron sources) has squeezed this program in recent years. Increased funding is recommended.

Climate and CO_2 Research ($12.9/$16.7*) ERAB members are in strong agreement on the importance of this program due to its long-term significance for public policy toward the use of fossil fuels. Although the predicted effects of increased CO_2 in the atmosphere occur well in the future, an intensified research effort is needed now in order to ensure that better information will be available for future decision making. The Federal Government clearly has the principal responsibility for research in this area; an increased effort is recommended.

Chemical Sciences ($69.0/$73.9) ERAB members are in general agreement that this program should be increased. The research supported is long-range and fundamental and addresses processes, interactions, and chemical transformations in liquids, gases and plasmas. Potential applications include developments ranging from new chemical catalysts for coal liquefaction to improved knowledge of combustion in automotive engines. Increased support in this area has recently been recommended by a detailed study of the Committee on Chemical Sciences of the National Research Council; ERAB concurs with that view.

Biological Energy Research ($7.7/$9.4) This program is designed to investigate the fundamental processes underlying plant biomass productivity and conversion of biomass to other materials for use as fuels or chemicals. ERAB members were generally in agreement that this program should be increased due to the long-term potential contribution from biomass and the small size of the present effort.

University Research ($11.8/$10.6) This program is primarily oriented toward improving the quality and quantity of scientific personnel in energy-related areas. This is clearly an area appropriate for Federal concern; an expanded program is recommended due to the modest level of the present effort.

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*Funded under Biological and Environmental Research. Excluded from Basic Energy Sciences budget.

Engineering, Math and Geosciences ($25.9/$32.3) Each of these areas of science, engineering, and mathematics is pertinent to energy and should be addressed by DOE programs. For example, the programs of the Atomic Energy Commission (AEC) were the first of the high technologies to rely effectively on computer modeling. For this reason, the AEC and its successor agencies, including DOE, have been the leading government agencies in supporting R&D in these areas. The DOE support should be targeted carefully toward those topics that are most obviously relevant to energy and correspond to scientific information needed by other DOE programs. In view of the importance of this effort, the present overall program is minimal.

Nuclear Sciences ($33.7/$37.9) This program includes research in low energy nuclear physics, actinide element chemistry and compilation of nuclear data relevant to the needs of the fission and fusion programs. It also supports the production, using unique federally funded facilities, and distribution of isotopes for medical and industrial use. The present funding level should suffice.

Advanced Energy Projects ($6.7/$8.2) This program identifies and tests the scientific feasibility of novel energy concepts. Particular attention is paid to proposed approaches that do not fit neatly in the scope of other DOE programs with the expectation that concepts that prove scientifically feasible and appear economically promising will be subsequently developed by other DOE programs or by private industry. In the view of ERAB, this program provides a worthwhile safety valve to ensure that promising ideas will not be ignored. The program should not be allowed to grow unduly at the expense of the higher priorities that have been identified, but should remain at about present funding levels.

Technical Assessment Projects ($9.5/$3.0) This program provides support for independent, objective analyses of R&D programs and needs and contributes to the overall planning effort of the Department. Present funding levels seem sufficient; expansion in this area is not needed.

D. Environmental Research

Biological and Environmental Research ($168.4/$170.5) This program investigates the potential human health and environmental impacts of new energy technology. It involves identifying the substances produced by energy systems, including such phenomena as acid rain; tracing their movement through air, water and land; and assessing their effects on humans and other living systems. Such research is clearly a Federal responsibility. It could not and should not be entrusted to private industry due not only to the long-term generic character of the work but also to the need for credibility and comprehensiveness. Certain unique long-baseline programs in ecology and radiation effects can only be carried out under Federal auspicies. This program has been about level or reduced in recent years; an increase in funding is warranted.

ERAB recommends a change in program emphasis with a major, urgent concentration of effort to resolve the acid rain problem. The ability to increase the use of coal, particularly the high sulfur coals in the Eastern U.S., depends on a far better understanding of the causes as well as the impacts of acid rain. The information currently available raises as many questions as it seems to answer regarding the relation of coal-based emissions to the occurrence of acid rain. Thus, a major effort by DOE is in order to assure that future increased use of coal remains an acceptable option.

Environment and Safety ($48.5/$49.6) This program is designed to assess information concerning the environmental impacts of energy development, the safety impacts of various technologies, and the health and safety aspects of DOE and contractor facilities. Clearly, DOE must be concerned with the safety both of energy systems and of the facilities for which it is responsible.

E. Federal Role and the Energy Technology Base

The distribution of performer efforts for the DOE technology base program (government laboratories, universities, or industry) deserves reexamination and both ERAB and DOE have embarked upon studies that will culminate in recommendations on this score within a few months.

The high Federal role in these efforts is worthy of emphasis if the Nation's long-run energy needs are to be met. Industry conducts and will continue to conduct basic and applied research to serve its short-term economic needs, but interim economic incentives will always result in disjointed efforts from the national perspective. Only the Federal Government can assure a balanced approach for the longer run. The DOE research program also contributes to the technology base relevant to other national missions since advances in underlying knowledge can be widely applicable.

Finally, the reluctance of Congress, until now, to appropriate funds for the support of economic and social science studies relevant to energy demand usage and conservation has resulted in an incomplete DOE program for its technology base. ERAB again endorses the authorization and implementation of such programs in DOE.

VIII. CONCLUSIONS AND RECOMMENDATIONS CONCERNING ENERGY R & D PRIORITIES

A. Overall R & D Program Priorities

Table VIII-A summarizes the results of the Board's evaluations of the four major energy R&D sectors: Electric supply, liquid and gas supply, conservation and utilization, and technology base. There are a number of electric-supply-related R&D programs that, for a variety of reasons, are of low priority and whose funding should either be substantially reduced or terminated. This reflects, in part, the Board's view that although no "correct balance among energy forms and resources can be defined *a priori*," R&D for electric supply technology is receiving a larger proportion of funding than the present and projected share of electricity in our national energy supplies.

The Board concluded that the overall Federal funding level in the liquid and gas R&D supply was higher than needed. This view results from the belief that the oil and gas industries are in a good position to take advantage of energy R&D opportunities and that the Federal Government role should be primarily focused on longer-term, higher-risk, applied research and development. It should not directly support costly demonstrations or large pilot plant projects (except as funded by loan or price guarantees through DOE and later under the Synthetic Fuels Corporation). However, great care should be taken in phasing out existing Federal R&D programs to insure technology transfer to the private sector.

In the conservation and end-use utilization area, the Board concluded that funding should be increased. The Board recognizes that higher energy prices have resulted in substantial reductions in energy demand and that this process is likely to continue. However, private enterprise in the buildings sector and, to a large degree, in the industrial sector is unlikely to do all the R&D needed. The Board believes that funds allocated to R&D in these two sectors should be increased. Such increases, combined with other ERAB recommendations, would increase the total allocation to the utilization and conservation technologies.

With regard to technology base programs, it was the Board's view that the funding for such programs should not be decreased and in certain areas should be increased. This stems from the Board's belief that, of all the sectors for energy R&D funding, the technology base programs are less likely to attract industry support; therefore, the Federal Government's role is greatest. Continued and increased support in the technology base programs offers the best chance for substantial technological break-throughs and improvements.

TABLE VIII-A

RELATIVE PROGRAM RANKING

Priority	Electric Supply Program	Funding	Fuel Supply Program	Funding	Conservation & Utilization Programs	Funding	Science and Technology Base[1] Programs	Funding
HIGHER							Materials Sciences	More
							Climate & CO_2 Research	More
							Chemical Sciences	More
	Commercial Nuclear Waste	Same					Biol/Environmental Research	More
							Biological Energy Sciences	More
					Coal Combustion	Same	Nuclear Medicine	Same
	Defense Nuclear Waste	Same			Buildings/Community Systems	More	High Energy Physics	Same
					Industrial Conservation	More	University Research	More
			Enhanced Oil Recovery	Less				
							Environment & Safety	Same
							Engineering/Math/Geosciences	Same
							Nuclear Physics	Same
MEDIUM	Conventional Reactors	More	Advanced Technology	Same	Transportation Conservation	Same		
			Enhanced Gas Recovery	Less	Solar Applications/Bldgs	Same		
	Breeder Fuel Cycle R&D	Little Less					Nuclear Sciences	Same
	Centrifuge	Same						
	LMFBR	Same			Heat Engines/Heat Recovery	Same		
			Coal Liquefaction	Less			Advanced Energy Projects	Same
	Solar Power Technology	Less			Multi-Sectors Conservation	Same		
	Advanced Isotope Separation	Same			Fuel Cells	Same		
			Biomass Energy	Same				
			Surface Coal Gasification	Less				
LOWER			Mining R&D	Less	Solar Applications/Industry	Less		
	Magnetic Fusion	Little Less	In-Situ Oil Shale	Less			Technology Assessments	Same
	Light Water Breeder	Less						
	Uranium Resource	Same						
	Electric Energy/Storage	Less						
	Hydropower	Zero						
	Clinch River Breeder	Less						
	Geothermal	Less						
			Alcohol Fuels	Same				
			In-Situ Coal Gasification	Less				
	Magnetohydrodynamics	Zero						

[1]Science and technology base programs were evaluated by a different set of criteria from the RD&D programs and are not directly comparable to th[illegible].

The remainder of this Chapter summarizes the conclusions and recommendations* of the Board in each of the Energy R&D program areas.

B. Electric Supply R&D Programs

With regard to Electric Supply R&D Programs, the major conclusions of the Board are as follows:

1. Continued emphasis is needed to complete the development and commercialization of light water nuclear power reactors in the U.S. A commitment has been made by this Administration to nuclear power. It has a significant role in the nation's energy mix; continued Federal support at this time is necessary. Hence, the Board recommends that continued funding be given to conventional reactor systems and safety, waste disposal programs (particularly accelerated demonstration), and uranium enrichment.

2. With respect to the liquid metal breeder reactor, research and development should be continued in order to maintain the capability for demonstrating breeder technology in the future. However, construction of a demonstration plant in the early 1980s is not an urgent national priority. Sufficient coal and uranium supplies exist to satisfy projected levels of electrical demand for at least 40 years and possibly well beyond. For these reasons, the panel recommends continued research and development on the liquid metal breeder reactor, as well as other breeder concepts, but that demonstration of breeder technology be delayed until a future time.**

3. With respect to fusion, ERAB members agree on the long-term importance of this program and that the primary Federal role should be to continue to sponsor a joint program of the federal laboratories, industry and university scientific communities to determine if fusion can be practical. The potential payoff is very large, but is much too far in the future for significant private sector support. There was agreement that a stretch-out of the program is possible if budgetary pressures demanded it, but maintenance of a substantial level of Federal R&D funding is judged to be essential. It is also recommended that an enhanced effort to examine the use of fusion for the breeding of nuclear fuels deserves consideration.

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*All funding recommendations are relative to the President's FY82 budget request.

**See dissenting opinion and additional remarks in Appendix D.

4. Finally, there are several electric programs for which funding should be reduced or eliminated (such as solar power technology, light water breeder reactors, electric transmission systems, geothermal, magnetohydrodynamics, and hydropower) due to their relatively small contribution to electric supplies in comparison with other programs.

C. Liquid and Gas Supply R&D Programs

With regard to Liquid and Gas Supply R&D Programs, the major conclusions of the Board are as follows:

1. With respect to enhanced oil and gas R&D recovery programs, the ERAB concluded that the U.S. oil and gas industry has sufficient resources and financial incentives to develop these technologies without substantial government assistance. The Board concluded that, even though these programs are important from the standpoint of urgency and energy security, the Federal R&D role should be minimal with less Federal funding needed.

2. With regard to coal liquefaction and coal gasification, it was concluded that large-scale demonstration projects involving substantial cost-shared Federal outlays are not necessary or appropriate considering the financial guarantees (e.g., loan guarantees, price guarantees) that are available from DOE and the Synthetic Fuels Corporation. The major Federal effort in synthetic fuels research and development should be directed at innovative concepts at the laboratory and small pilot-plant scale with particular emphasis toward exploring a wider range of technological options with potential for significant efficiency and cost improvements. The Board recommends a reduced budget for DOE's cost-shared projects at the large pilot plant and demonstration-plant scale.

3. With respect to in-situ oil shale recovery, the Board recommends a decrease in funding based on the fact that several major oil companies have in-situ shale projects that do not involve Federal assistance.

4. The funding level for R&D directed at producing liquids and gases from biomass and the production of alcohol is at an appropriate level.*

5. Continuing increases in the price of conventional oil and gas suggest that the time when coal and oil shale will be economic sources of oil may be near at hand. This situation is stimulating the private sector to consider some commercial operations by 1990. ERAB concludes that

*See ERAB reports on Biomass and Alcohol Fuels.

the private sector can be expected to carry out important actions that justify a lessening of DOE research in these technologies. However, it is recommended that DOE accelerate its research in environmental problems and infrastructure problems associated with the commercialization of these technologies.

6. The bulk of the coal produced for the next several decades will be used directly as boiler fuel, both in existing and new units, reducing dependence on oil and gas for this purpose. But improved emission control technologies to reduce SO_x, NO_x and particulate emission in flue gases will be essential to the success of this effort. ERAB therefore urges that this part of the Advanced Research and Environmental Control Technology (FE) programs be increased and given higher priority at the expense of the other activities in this program.

D. Conservation and Utilization R&D Programs

With regard to Conservation and Utilization R&D Programs, the major conclusions of the Board are as follows:

1. The overall level of Federal R&D funding for conservation and improved utilization programs is too low in view of their potential for energy improvements and the inability of many important energy-consuming sectors to conduct R&D. Moreover, Department-wide, the balance between supply oriented R&D and conservation R&D is too heavily weighted toward the supply side.

2. The Board concluded that R&D in Buildings and Community Systems needs increased funding in view of the large amount of energy consumed in this sector and the lack of private sector institutions able to undertake building systems R&D. This is particularly true in the case of the important retrofit technologies.

3. R&D in the transportation sector should be redirected away from its present heavy emphasis on automobile engines and toward the heavy freight truck sector. The phase out should include a sharp reduction in work on the electric and hybrid vehicle.* Transportation systems utilization activities deserve support. Overall, funding levels in this area should remain the same.

4. Funding for the Multi-Sector Conservation program should remain the same and should be concentrated on work in the Energy Conversion and Utilization Technology program (ECUT).

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*See dissenting opinion in Appendix D.

5. Funding for the Industrial Conservation programs should be restored to approximately the level in FY81. Many industries have no capacity for private sector R&D and that the close cooperation with users that characterized this program deserves continuation.

6. Solar Applications for Buildings should be redirected slightly to emphasize passive heating and cooling. Solar pond and ice cooling technology should be continued since it is highly promising.

7. Funding for Solar Thermal Applications for Industry deserves slightly lower levels of support with redirection toward high temperature collector and dish technology development.

8. Funding for direct coal combustion systems (a high priority program), fuel cells, and heat engines and heat recovery should remain at the same levels.

E. Science and Technology Base Programs

The Board recommends increased Federal funding in a number of program areas. The Board would give particular emphasis to environmental and health-related research, clearly important from the standpoint of understanding and evaluating the long-term impact of the introduction of new energy technologies. Of particular importance are the CO_2 and acid rain issues. As previously indicated, the panel believes that the science and technology base programs should have a relatively higher Federal priority because of the lower likelihood that industry would provide adequate funds for such basic and applied research.

F. General Conclusions and Recommendations

1. Serious attention must be paid to several related environmental issues. First, development of nuclear waste disposal technologies and control technologies in the Advanced Research and Environmental Control Technology Program are necessary for environmentally sound implementation of present and future technologies. Second, several of the programs in the science and technology base are essential if a proper energy mix is to be employed. These include the acid rain program, the climate CO_2 program, and Health and Environmental Research.

2. Our energy system is a web of machines and people; the current budget is focused on machines. Consideration should be given to research in social areas, to prepare for rapid energy development in certain portions of the country and to help transfer conservation technologies for the industrial and residential sectors.

APPENDIX A

Department of Energy
Washington, D.C. 20585

AUG 13 1981

Mr. Louis H. Roddis, Chairman
Energy Research Advisory Board
110 Broad Street
Charleston, S. C. 29401

Dear Lou:

The Department of Energy has invested heavily over the past several years in research and development on a wide range of energy alternatives. DOE now plans to increase emphasis on long-term, high-risk, and potentially high-payoff R&D programs. As such, it is timely to review our R&D priorities and to make some hard choices on which programs to pursue vigorously and which to deemphasize based on a realistic appraisal of both our energy options and energy needs for the foreseeable future. I would appreciate the advice of the Energy Research Advisory Board on these matters and particularly the Board's recommendations on overall Federal energy R&D priorities.

This effort can be based on the Board's broad knowledge of DOE programs and especially on the recent R&D panel activities to review the energy technology base and to develop criteria and methods for assessing priorities. Your terms-of-reference should include review and recommendations on the following concerns:

- o The relative merits of each major R&D program with respect to such criteria as the technical and economic potential, urgency and lead time required, benefits and costs of Federal funding, contribution to energy security, health and environmental risks, and the appropriate Federal role;
- o The appropriate R&D funding balance between electric power supply, fuels supply, conservation, and technology base program areas;
- o The appropriate program orientation and balance between research, development, and demonstration activities;
- o The strategic R&D objectives for the near-, mid-, and long-term.

Your thoughts on these matters would be particularly useful by November 16, 1981, to assist the Secretary and myself with our reviews of the DOE Sunset Report and the FY83 budget. However, I regard this as a continuing and important assignment for the Board and would also appreciate your recommendation on the next steps. Specifically, you should consider what efforts both ERAB and the Department should undertake toward improving our overall R&D planning, management, and evaluation processes and decisions. I will personally look forward to your report and hope to meet frequently with you and the Board as the study progresses.

Sincerely,

W. Kenneth Davis
Deputy Secretary

THE SECRETARY OF ENERGY
WASHINGTON, D.C. 20585

April 30, 1980

Dr. Solomon J. Buchsbaum
Executive Vice President
Customer Systems
Bell Laboratories
Crawford Corner Road
Holmdel, New Jersey 07733

Dear Dr. Buchsbaum:

Research and development to increase the supply, conversion efficiency and conservation of energy is vital to our national interest. I am particularly concerned about the adequacy of the Department's efforts in this area. The Department is presently undertaking a review of the technology base component of our R&D programs under the leadership of the Director of Energy Research with a view toward improving their effectiveness. I would appreciate the participation of ERAB in this process in order to give us the benefit of external views on the adequacy of these programs.

There are some broad concerns that need to be addressed:

- o The adequacy of the research underpinning for technology development programs.
- o Possible gaps or duplications of effort.
- o The balance among research performers (universities, laboratories, industry).
- o Significant R&D opportunities that our programs may be missing.

Obviously, a complete review of this whole area would be a lengthy and complex task and I view this as a continuing effort through which ERAB might help the Department. In the shorter term, an initial review of the technology base in conjunction with the work Ed Frieman already has underway could be helpful in contributing to our final decisions on the FY 1982 budget if it could be completed by the end of the summer. I hope that ERAB can devote a portion of its summer study to this task.

Sincerely,

John C. Sawhill
Deputy Secretary

APPENDIX B: BACKGROUND INFORMATION

CHRONOLOGY OF R&D PANEL MEETINGS[1/] APRIL 30, 1980 TO NOVEMBER 5, 1981

1. Planning and Implementation

On April 30, 1980, Deputy Secretary John C. Sawhill requested ERAB to review the R&D programs in the Department. An initial review of the technology base in conjunction with the work the ER Director had underway would be helpful in contributing to the final decision on the FY 82 budget. ERAB approved the terms of reference and established a panel.

On June 7, 1980, the R&D Panel met to formulate questions and issues for Panel consideration, to develop outlines for Panel and Subpanel reports, and to discuss organizational matters. The Panel also approved an agenda for the first full-scale Panel and Subpanel organizational meetings to be held.

2. Technology Base Assessment and Detailed Program Reviews

On July 10, 1980, the Fossil R&D Subpanel met in Washington to receive briefings on fossil energy technology and R&D programs, review DOE's documents on technology base assessment, and discuss preparation of the initial draft input to final R&D Panel report.

On July 10th and 11th, 1980, the Conservation R&D Subpanel met in Washington, was briefed on conservation technology and R&D programs, and held initial discussions on Conservation Subpanel input into ERAB Technology Base Report.

On July 22, 1980, the Nuclear R&D Subpanel met in Washington for a summary of fact-finding briefings on nuclear technology and R&D programs. They discussed eight items pertaining to the technology base assessment of DOE's Nuclear R&D programs.

- Converter Reactor Systems
- Commercial Nuclear Systems
- Advanced Nuclear Systems
- Spent Nuclear Fuel
- Breeder Reactor Systems
- Advanced Isotope Separation Systems
- Nuclear Uranium Assessment
- Gas Centrifuge

1/ All meetings were open to the public with notice in Federal Register.

On July 23, 1980, the Solar R&D Subpanel met in Washington for briefings on solar technology and R&D programs to review DOE documents on the technology base component of DOE's Solar Energy R&D program and to hold initial discussions on Solar Energy R&D Subpanel input into the ERAB Report.

On July 23, 1980, the Energy Research R&D Subpanel met in Washington for briefings on Basic Energy Sciences and other energy research programs and to review the technology base research support by the Office of Energy Research.

On July 29, 1980, the Environment R&D Subpanel met in Washington for discussions on the status of technology base assessment. Representatives from the research offices within DOE Office of Environment discussed highlights of their programs. Office of Technology Impacts discussed the complexity of doing good assessments stressing the problems of the data collection and management.

On July 29, 1980, the Resource Applications R&D Subpanel met in Washington for briefings on resource application programs to review DOE documents on the technology base component of DOE's Resource Applications R&D Program, and to hold initial discussions on Resource Applications R&D Subpanel's input into ERAB Technology Base Report.

On July 30th and 31st, 1980, the R&D Panel met in Washington for discussions on crosscutting issues and integration problems. Subpanel members discussed status of membership, information needs, plans to complete reports and planned for activities at La Jolla.

3. Interim Report on DOE Technology Base "R&D Needs in DOE"

On August 18th, 1980, the Board met as a whole, then divided into their individual subpanels to complete the initial phase of the study and report to the full ERAB during the course of the meeting.

On August 18th - August 22nd, 1980, the ERAB Summer Study meetings were held to develop an interim report, findings, conclusions and recommendations on the technology base assessment (TBA) study. The following seven (7) subpanels were involved

8/19/80 - R&D Integration Panel - La Jolla
8/19-21/80 - Energy Research R&D Subpanel - La Jolla
8/21/80 - Resource Applications R&D Subpanel - La Jolla
8/19/80 - Solar R&D Subpanel - La Jolla
8/18-20/80 - Environment R&D Subpanel - La Jolla
8/18-20/80 - Nuclear R&D Subpanel - La Jolla
8/19-21/80 - Fossil R&D Subpanel - La Jolla

In addition, ERAB conducted several in-depth technical reviews which were also used as a basis for the R&D priorities study. Specifically, ERAB conducted studies on: (1) Efficient Use of Energy (Conservation); (2) Fossil Energy; (3) Nuclear Energy; (4) Solar Energy; (5) Resource Applications; (6) Environment; and (7) Energy Research.

On August 22, 1980, the ERAB Board in La Jolla received the draft TBA report and approved it subject to incorporation of the members' revisions. The report was subsequently transmitted to the Secretary of Energy as an interim report on 9/5/80 (Research and Development Needs in the Department of Energy).

4. Methodology for Setting R&D Priorities

On December 19, 1980, the R&D Panel met in Washington to discuss a methodology for evaluating energy R&D priorities. Discussions were held on alternative approaches to implementing R&D Priorities Study proposed in Bill McCormick's "White Paper," suggesting the R&D needs exercise should be expanded to set overall priorities and trade-offs between R&D program areas based on consistent criteria.

On January 26, 1981, the R&D Panel met in Cleveland to dicuss the methodology for evaluating energy R&D priorities. Discussions were held to reveiw methodology for ranking priorities and structure of Panel/Subpanels. Other topics discussed were:

Membership, Technical Support Group
Definition of Criteria
Weight/Value Functions
Input, Value Judgments, and Outputs (by Subpanel)
Technology Lists
Schedule
Report Outlines

5. R&D Priorities and Study Report

At the February 5-6, 1981 ERAB meeting, discussions were held on the recent activities of the R&D Panel and alternate approaches. It was proposed that a number of subpanels could be formed to provide input on energy technologies and one which is to cover technology base and environmental considerations. Several energy product subpanels would then utilize input from the foregoing subpanels. The plan also included possible utilization of the MARKAL computer model developed by BNL.

At the July 9-10, 1981 ERAB meeting, John Foster, Chairman of the Panel, reviewed their past efforts beginning with the Interim Report transmitted to the Department last September, following an extensive effort culminating in the Summer Study meeting in August 1980.

On August 13, 1981, Deputy Secretary Kenneth Davis requested advice of the Energy Research Advisory Board on the R&D priorities and the Board's recommendations on the overall Federal energy R&D priorities.

The Panel was in the process of developing a methodology which would assist in assigning priorities to the nation's energy R&D programs, and would also help to illuminate the appropriate role of the Federal Government in these programs. For the purposes of the R&D priorities study, the R&D Panel would consist of all the members of ERAB with an Executive Committee appointed by the Chairman to include John Foster (Chairman, R&D Panel), William McCormick (Vice Chairman, R&D Panel), Lou Roddis (Chairman of ERAB), and Ivan Bennett (Vice Chairman of ERAB). Whether additional Panel members would be appointed would be decided at a later date; previous subpanels to the R&D Panel were dissolved.

At the September 2-3, 1981 ERAB meeting, the Chairman reported on the progress and current status of the R&D study and noted the August 13 letter request from the Deputy Secretary which sets the framework for it. The Deputy had asked that the report be completed by mid-November. John Foster, R&D Panel Chairman, described in detail the activities of the Panel, the methodology they were applying, and the evaluation forms each member will be asked to complete and return for collation. He urged each member to include any narrative comments along with their program evaluations which would serve to explain any particular rating made by a member and serve as a basis for drafting the report.

A detailed discussion then followed among all ERAB members in an attempt to establish a uniform basis among them all for their responses. These responses were discussed at a special meeting of the Panel on September 24. Preliminary results were sent to members on October 1. ERAB members submitted respective subsection drafts October 15, and a draft of the report was sent to ERAB members by October 30. The final review took place at the ERAB meeting on November 4-5.

On September 24, 1981, the R&D Panel met in Washington to discuss a number of cases in which overall programs were not highly rated, but individual aspects of subprograms of the major program were essential. The Panel concluded that considerations for subprograms of the major programs, particularly those involving subprogram funding recommendations, should be highlighted by discussion in the narrative portion of its report.

The initial results of the prioritization study were discussed at the Energy R&D Panel Meeting held September 24, 1981, in Washington, DC. At that meeting consensus recommendations were reached concerning funding where no consensus had resulted from the raw data evaluation. It was recognized that the final priority ratings would be the result of an evaluating process.

TABLE B-1

ENERGY R,D&D PROGRAM BUDGET SUMMARY

	Congress. Budget Authority FY1981	Pres. Request FY1982	Congress. Budget Authority FY1982
	(in $thousands)*		
A. Electric-Related Supply			
1. Magnetohydrodynamics (FE)	66,533	0	29,000
2. Geothermal (CE)	153,645	46,775	57,775
3. Hydropower (CE)	2,409	0	2,750
4. Electrical Energy Systems and Energy Storage Systems	109,800	47,525	65,625
5. Solar Power Technology (CE)	112,100	19,400	73,800
6. Magnetic Fusion (ER)	391,000	456,100	484,600
7. Uranium Resource Assessment (NE)	25,925	5,800	5,800
8. Uranium Enrichment (NE)			
a-Centrifuges (NE)**	356,315	760,300	691,800
b-Advanced Isotope Separation (NE)	79,300	85,237	85,237
9. Conventional Reactor Systems (NE)	81,500	68,000	101,750
10. Breeder Reactors (NE)			
a-Liquid Metal Fast Breeder Reactor	371,919	387,842	405,628
b-Clinch River Breeder Reactor	172,000	254,000	228,000
c-Light Water Breeder	60,200	58,000	45,000
d-Fuel Cycle R&D	47,500	26,100	48,100
11. Nuclear Waste			
a-Commercial (BE)	201,415	227,551	208,701
b-Defense (DP)	298,445	390,000	384,800
12. Mining R&D (FE)	40,169	21,000	17,000
Subtotal	2,570,175	2,853,630	2,935,366
B. Liquids and Gas-Related Supply			
13. Advanced Technology (FE)	95,761	94,500	84,500
14. Coal Liquefaction (FE)	276,997	105,200	248,200
15. Surface Coal Gasification (FE)	69,618	53,440	56,300
16. In Situ Coal Gasification (FE)	9,960	8,300	8,300
17. Enhanced Oil Recovery (FE)	16,158	20,100	20,100
18. Enhanced Gas Recovery (FE)	30,598	10,200	14,200
19. In Situ Oil Shale (FE)	32,151	16,250	22,350
20. Biomass Energy (CE)	31,650	20,500	20,500
21. Alcohol Fuels (CE)	18,000	10,000	10,000
Subtotal	580,893	338,490	484,450

* Includes deferrals and rescissions, but excludes program direction.

** Includes $293.3M in FY 81 and $695.8M in FY 82 for construction of gas centrifuge plant.

TABLE B-1 (continued)

	Congress. Budget Authority FY1981	Pres. Request FY1982	Congress. Budget Authority FY1982
	(in $thousands)*		
C. Conservation & Improved End-Use Utilization			
22. Coal Combustion Systems (FE)	37,368	38,800	42,800
23. Heat Engines & Heat Recovery (FE)	31,468	15,600	15,600
24. Fuels Cells (FE)	32,012	28,600	35,900
25. Buildings & Community Systems (CE)	52,990	28,000	47,400
26. Industrial Conservation (CE)	67,300	0	29,600
27. Transportation Conservation (CE)	102,120	37,000	59,550
28. Multi-Sector Conservation (CE)	25,800	17,500	19,600
29. Solar Applications for Buildings (CE)	224,900	84,700	118,050
30. Solar Applications for Industry (CE)	138,270	44,000	66,050
Subtotal	712,228	294,200	434,550
D. Technology Base			
31. Energy Supporting Research (ER)			
a-Basic Energy Sciences			
aa-Nuclear Sciences	33,700	37,670	37,670
ab-Materials Sciences	95,150	112,060	112,060
ac-Chemical Sciences	69,040	73,940	73,940
ad-Engineering, Math & Geosciences	25,860	32,300	32,300
ae-Advanced Energy Projects	6,650	8,220	8,220
af-Biological Energy Sciences	7,650	9,410	9,410
ag-CO_2 and Climate Research**	12,900	16,700	0
b-Technology Assessments	9,500	3,000	3,000
c-University Research	11,800	10,600	10,600
32. General Science (ER)			
a-High Energy Physics	348,180	392,700	392,700
b-Nuclear Physics	109,200	122,900	122,900
c-Nuclear Medicine	45,900	50,500	50,500
33. Environment & Safety (EP)	48,510	49,600	43,600
34. Biological & Environment Research (ER)**	155,272	153,800	176,500
Subtotal	979,312	1,073,400	1,073,400
TOTAL	4,842,600	4,559,220	4,927,766

*Includes deferrals and rescissions, but excludes program direction.

**The biological and environmental research program includes climate and CO_2 research with a total budget of $168,172 in FY1981 and $170,500 in FY1982.

TABLE B-2

TIME OF EXPECTED IMPACT

PROGRAMS	TIMEFRAME OF IMPACT* Near	Mid	Long
A. Electric-Related Supply			
1. Magnetohydrodynamics (FE)		X	
2. Geothermal (CE)	X		
3. Hydropower (CE)	X		
4. Electrical Energy and Storage Systems (CE)		X	
5. Solar Power Technology (CE)		X	
6. Magnetic Fusion (ER)			X
7. Uranium Resource Assessment (NE)	X		
8. Uranium Enrichment (NE)			
a- Centrifuge (NE)	X		
b- Advanced Isotope Separation (NE)		X	
9. Conventional Reactor Systems (NE)	X		
10. Breeder Reactors (NE)			
a- Liquid Metal Fast Breeder Reactor			X
b- Clinch River Breeder Reactor		X	
c- Light Water Breeder Reactor			X
d- Fuel Cycle (R&D)			X
11. Nuclear Waste			
a- Commercial (NE)	X		
b- Defense (DP)	X		
B. Liquids and Gas-Related Supply			
12. Mining R&D (FE)		X	
13. Advanced Research Tech. Development (FE)		X	
14. Coal Liquefaction (FE)		X	
15. Surface Coal Gasification (FE)		X	
16. In Situ Coal Gasification (FE)			X
17. Enhanced Oil Recovery (FE)	X		
18. Enhanced Gas Recovery (FE)	X		
19. In Situ Oil Shale (FE)			X
20. Biomass Energy (CE)	X		
21. Alcohol Fuels (CE)	X		
C. Conservation & Improved End-Use Utilization			
22. Coal Combustion Systems (FE)		X	
23. Heat Engines & Heat Recovery (FE)		X	
24. Fuels Cells (FE)		X	
25. Buildings & Community Systems (CE)	X		
26. Industrial Conservation (CE)	X		
27. Transportation Conservation (CE)		X	
28. Multi-Sector Conservation (CE)	X		
29. Solar Applications for Buildings (CE)	X		
30. Solar Applications for Industry (CE)	X		
D. Science and Technology Base			X

APPENDIX C: DESCRIPTION OF METHODOLOGY

1. Overview Description of Methodology

The methodology used in this study can be summarized as follows. The list of RD&D programs to be prioritized was agreed upon and then each program was placed into one of four end-use areas: electric-related supply, liquids- and gas-related supply, conservation and utilization, and science and technology base programs (see Table C-1). Criteria to be used in assessing the technology priorities were selected and the definitions for each criterion agreed upon. Two sets of criteria were developed--one set of seven for the R&D programs and one set of five for the Science and Technology Base programs (see Tables C-2 and C-3).

It is important to note that the assessment or evaluation process involving the decision questionnaires which each member was asked to complete were not intended to and would not "fix" the results of the final priority ratings but were designed as an initial point of departure from which final conclusions would ultimately evolve--conclusions which may or may not be consistent with the initial ratings.

Each member of the R&D Panel was asked to make two assessments. The first was used to determine each individual's view concerning the relative importance of criteria for R&D programs and for Science and Technology Base programs. Each criterion was judged "very important" (value of 3), "reasonably important" (value of 2), or "slightly important" (value of 1) relative to Federal energy R&D priorities. A consensus weighting for reach criterion based on the average of all responses was calculated and then normalized to a value of one. The second form was the program evaluation form. For each criterion for each technology the members judged whether that criterion had a high (value of 3), medium (value of 2) or low (value of 1) importance. In addition each member was asked to state a recommended program funding level for each technology, his or her perceived level of knowledge concerning each technology, and any comments he or she wished to make concerning each technology.

The above information was then used to calculate figures of merit (FOM) for each technology. On the basis of the FOM the technologies were then ranked. The funding information was used as the basis for recommendations of future funding--namely, whether the funding for each program should be decreased, remain the same or be increased relative to the President's FY82 budget.

TABLE C-1

R,D&D PROGRAMS

Energy Related Supply Programs

- Magnetohydrodynamics (FE)
- Geothermal
- Hydropower
- Electric Energy & Storage Systems
- Solar Power Technology (CE)
- Magnetic Fusion (ER)
- Uranium Resources Assessment (NE)
- Uranium Enrichment - Centrifuge (NE)
- Uranium Enrichment - Advanced Isotope Separation (NE)
- Conventional Reactor Systems (NE)
- Liquid Metal Fast Breeder Reactor
- Clinch River Breeder Reactor
- Light Water Breeder Reactor
- Fuel Cycle R&D
- Nuclear Waste - Commercial (NE)
- Nuclear Waste - Defense (DP)

Liquids and Gas Related Supply Programs

- Mining R&D (FE)
- Advanced Technology (FE)
- Coal Liquefaction (FE)
- Surface Coal Gasification (FE)
- In Situ Coal Gasification (FE)
- Enhanced Oil Recovery (FE)
- Enhanced Gas Recovery (FE)
- In Situ Oil Shale (FE)
- Biomass Energy (CE)
- Alcohol Fuels (CE)

TABLE C-1 (continued)

Conservation and Improved End-Use Utilization Programs

- Coal Combustion Systems
- Heat Engines and Heat Recovery
- Fuel Cells (FE)
- Buildings & Community Systems
- Industrial Conservation
- Transportation Conservation
- Multi-Sectors Conservation (CE)
- Solar Applications for Buildings
- Solar Applications for Industry (CE)

Science and Technology Programs

- Energy Supporting Research (Overall)
- Basic Energy Sciences (Overall)
- Nuclear Sciences
- Materials Sciences
- Chemical Sciences
- Engineering, Math & Geosciences
- Advanced Energy Projects
- Biological Energy Sciences
- Climate and CO_2 Research
- Technology /Assessments
- University Research
- General Science (Overall)
- High Energy Physics
- Nuclear Physics
- Nuclear Medicine
- Environment and Safety
- Health & Environmental Research

TABLE C-2

EVALUATION CRITERIA FOR ENERGY R,D&D PROGRAMS

1. Technological Potential/Risk

Definition: Likelihood that the R,D&D Program will, within a reasonable period of time, result in technical success.

High (3) - Very good likelihood of technical success. (in other words, low technical risk)

Med. (2) - Reasonable chance of technical success. (in other words, moderate technical risk)

Low (1) - Only a slim chance of technical success. (in other words, high technical risk)

2. Urgency

Definition: Considering both the time period before which the technology is needed and the lead time for development, how urgent is the R,D&D program.

High (3) - Program must be started now (or continued) at a high level of effort.

Med. (2) - Program could be carried on at a moderate level now or, alternatively, delayed for 5 years or possibly 10 years.

Low (1) - There is no urgency in the program and it could be delayed for 10 years or more.

3. Economic Potential

Definition: Likelihood that the technology, when it is developed, will be economically competitive with then existing technologies providing energy in the same form or available alternative substitutable sources (note: assume development is completed no later than the year 2000).

High (3) - Economics are likely to be very competitive.

Med. (2) - Economics are uncertain or are likely to be marginally competitive.

Low (1) - Economics are likely to be non-competitive.

4. Benefit/Cost

Definition: Considering the size of the R,D&D investment needed to develop the technology, how substantial is the impact of the development of the technology in terms of end-use energy produced or saved.

High (3) - Less than $1 billion of total R,D&D investment required for each 1 Quad of energy produced or saved annually (in the year 2000).

Med. (2) - Between $1 billion and $10 billion of total R,D&D investment for each 1 Quad of energy produced or saved annually (in the year 2000).

Low (1) - More than $10 billion of total R,D&D investment for each 1 Quad of energy produced or saved annually (in the year 2000).

5. Energy/National Security

Definition: How significant is the energy technology from the standpoint of displacing or substituting for insecure foreign energy sources (primarily oil).

High (3) - Will displace or substitute for 2.0 million barrels/day or more (about 4 quads/yr) or oil equivalent by the year 2000.

Med. (2) - Will displace or substitute for 0.5 to 1.99 million barrels/days of oil equivalent by 2000.

Low (1) - Will displace or substitute for less than 0.5 million barrels/day of oil equivalent by 2000.

6. Safety, Security, Health and Environmental Impact

Definition: Both from the standpoint of the general public and the worker, the degree to which the technology is safe, secure, healthy and has minimal (or even positive) environmental impacts.

High (3) technology results in improved safety, health and environmental impact.

Med. (2) technology would have some adverse safety, health or environmental consequences, but not serious ones considering potential control measures.

Low (1) technology has serious safety, security, health or environmental problems.

7. <u>Federal RD&D Role</u>

<u>Definition</u>: considering the RD&D support for the technology that is likely to come from industry, how important to timely commercialization is Federal RD&D support.

High (3) - heavy Federal support is essential since because of the risk or long development period, industry support will be small.

Med. (2) - some Federal support is needed to complement industry efforts or to ensure timely development.

Low (1) - little or no Federal support is needed since industry efforts are likely to be adequate.

ADDITIONAL EVALUATION CRITERIA FOR SCIENCE AND TECHNOLOGY BASE PROGRAMS

Most of the above criteria are not directly applicable to evaluating DOE Technology Base programs. The benefits of these basic and applied research and engineering development activities must be measured against different criteria for obvious reasons. The following criteria are to be used for evaluation of the science and technology programs listed in Attachment 4D:

8. Scientific Potential

   Definition: degree to which the research program will aovance scientific knowledge or contribute toward maintenance of American scientific leadership and achievements in a respective field and, therefore, represents an important national trust.

   High (3) - Very likely to produce significant advances in scientific knowledge on important new frontiers of science.

   Med. (2) - likely to add substantially to fundamental knowledge in relatively developed and mature fields.

   Low (1) - not likely to add substantially to new knowledge.

9. Inventive Potential (Risk/Benefit)

   Definition: likelihood that the R&D program will over the long term directly produce breakthroughs, discoveries, or inventions in energy production, usage, or conservation which have significant economic, social or environmental benefits and, thereby, justify the risks/costs of the applied science and engineering research efforts.

   High (3) - very likely that the R&D program will directly result in energy developments with significant economic, social, or environmental benefits over the long-run.

   Med. (2) - likely that the program will at least break even in producing energy developments with economic, social, and environmental benefits over the long-run.

Low (1) - not likely to produce energy developments with direct economic, social, or environmental benefits.

10. Mission Impact

Definition: degree to which the R&D program supports or underwrites the success of DOE technology development programs by providing the technology base for understanding fundamental working properties of the technology, solving known and unanticipated engineering development problems, and transferring new engineering knowledge to other energy applications and missions.

High (3) - program provides essential research and engineering support for critical energy technology development missions and goals.

Med. (2) - program provides general support with widespread applications to technology development missions or areas with less critical problems or secondary missions.

Low (1) - program does not directly support technology development programs, but may have general applications.

The following two RD&D program criteria are applicable to the science and technology base programs and are to also be used in evaluating the science and technology base programs.

2. Urgency

Definition: same as RD&D criterion Number 2 above

7. Federal Role

Definition: same as RD&D criterion Number 7 above

APPENDIX D

ENERGY RESEARCH ADVISORY BOARD
DISSENT TO RECOMMENDATIONS WITH RESPECT TO CLINCH RIVER BREEDER REACTOR

EXECUTIVE SUMMARY

Cancellation of the Clinch River Breeder Reactor Project at this time would not only result in time loss of investment of over $1 billion already incurred to date, but would also dissipate the hard-won technology capability already developed in the U.S., probably for the remainder of the century. Even if one accepts the argument that the breeder reactor program would only provide a useful option for energy generation sometime in the future, it is still necessary to complete the Clinch River Project in order to actually demonstrate this technology in the U.S. licensing and safety environment. Proven technology does not exist without an actual demonstration of acceptable safety, reliability, and operability. Although it is obvious from the achievements of the French, Japanese, British and Russian programs that sodium-cooled fast breeder reactors are practical, it has not been demonstrated that such plants can be designed, built and operated by U.S. technology and industry within the constraints imposed by domestic safety and licensing standards. The consideration of technology demonstration and preservation of U.S. presence in the world-wide breeder development program requires that the CRBR project be rapidly completed.

BASIS OF DISSENT

The energy future of the U.S. is subject to so many variables that no one can adequately predict what course the future will take with respect to energy. We do not know with any certainty how much energy will be used in 2000, for example, or what effect this will have on the growth of our economy.

It is also far from clear what quantities of the various fuels will be available. The U.S. must be prepared to cope with such undesirable events as partial or total cut-off of imported oil.

Electricity is a uniquely flexible form of energy. The transmission and distribution systems can be used to accommodate any source of generation, thus utilizing the energy source available at the time. The electricity can be transmitted to almost any desired point of use. This would be particularly useful in the event of disruption of energy sources due to any cause including enemy action.

The most available sources of energy, coal and uranium, can be best used to produce electricity. A larger part of U.S. energy needs could be supplied by electricity. It could be used for almost all space heating and provide much of the process energy required. This could be done in a more energy efficient and environmentally satisfactory way by the use of heat pumps.

It is predicted by the DOE that from 36 to 50 percent of the primary energy in 2000 will be used for the generation of electricity. It is probably possible to accomplish this, almost entirely by burning coal, but it almost certainly would not be the optimum choice on either economic or environmental grounds. There are clearly some undesirable health effects from burning coal and these should be minimized.

If one assumes that the upper end of the DOE 2000 LWR capacity projection of 200 GW occurs, this would require committing about 50 GW between now and 1990. Most, if not all of these reactors would be committed between 1985 and 1990. If there is about 900 GW of generating capacity in 2000 and the growth rate is 3.5 percent per year, then 31.5 GW plus replacements will be committed per year by 1990. It would seem reasonable for the nation to be in a position to have as much as 20 GW per year by nuclear plants. While it is possible that many of these plants could be coal burning, there are enough potential problems with coal plus the possible economic advantages of nuclear, that we should be able to take advantage of that option. This might amount to 243 GW of nuclear plants being committed between 1990 and 2000.

A 3.5 percent growth rate after 2000 would required additional capacity of about 540 GW, plus replacements, to be committed for operation by 2020. If half of this is LWR's then by 2010 about 4.6 million tons of uranium would have been committed for a 30 year life. If the life is 40 years, then 4.9 million tons would have been committed by 2010. (With a 40 year life there would be fewer replacements by 2020.)

According to a recent DOE report, there is a 95 percent confidence that there is 3,875,000 tons of U_3O_8 in the U.S., at a forward cost of $100 per pound. This includes reserves as well as probable, possible and speculative reserves.

Forward costs are operating and capital costs in 1980 dollars that would be incurred in producing the uranium; they exclude income taxes, profits, cost of money and sunk costs. The market price that would support a 15 percent rate of return has been estimated to be 1.4 - 1.6 times the forward cost per pound of U_3O_8.

It should be remembered that if there is the demand for uranium that approaches the amount potentially available the price rises accordingly.

The U.S. also has to a considerable degree a contractual, political and moral obligation to supply a considerable amount of uranium to industrial and developing nations.

The breeder should start being deployed in a significant way by 2010 or before as it is by no means assured that we would otherwise have the uranium required.

If reactors can be built in the time that is technically possible and if fewer design changes are made during construction, costs can be drastically reduced. This would make them the clear choice from the point of view of economics. To be able to take advantage of this may require deployment of breeders by 2010.

Even if breeders are not required due to the lack of uranium for LWR's, it may well be desirable to deploy them on economic grounds. The economics of the LMFBR compared to the LWR using break-even analysis has been extensively examined by various U.S. groups. The majority conclusion is that the break-even could occur around the year 2000 at an equivalent 30 year levelized price of uranium of about $50 - $150 per pound, in 1980 dollars.

The capital cost of breeders is higher than that for LWR's but the fuel cost is lower. This provides a good hedge against inflation as the capital costs will be a larger fraction of the kilowatt-hous cost and will remain constant. The longer the lifetime used in the evaluation, the more favorable for the breeder.

Recent cost benefit studies, using econometric models, have shown that benefits measured in hundreds of billions of dollars would accrue from early as opposed to late introduction of the LMFBR.

There has been no even marginally commercially successful reactor without a previous demonstration plant having been built. Those involved with the reactor development program believe that a demonstration plant is essential. There will be many things that will not work as well as would be desired when they are put together in a complete reactor system. The information learned from such a demonstration will lead to far better second and subsequent generation plants.

No U.S. reactor has even been built with a single scale up as large as would be represented by the scale up from FFTF to a 1000 MW reactor.

The major reason for success in both the Naval nuclear and the LWR program was that in each case there was a reactor being built which provided a focus for the research effort.

The refocusing of a broad range R&D program, even one already focused on the needs to build a plant, will be greatly improved as the result of data obtained in the design, construction and operation of a demonstration plant.

One of the principal reasons for the success on the LWR's has been the infrastructure, suppliers of equipment and services, that had been created and nurtured. Cancellation of the CRBR will cause a break in the industry continuity and many suppliers may be reluctant to get back into the breeder business.

If CRBR is not continued, then it will have to be replaced by another demonstration plant. The size could be somewhat but not much larger. This would require many additional years and far more money. If CRBR is completed the next plant can be built for considerably less than it would otherwise cost.

To date, there has been $1.148 billion spent on CRBR, $246 million of components have been delivered and $352 million more are on order. There are 3200 people working on this project and design is 86 percent completed.

The design of CRBR is as advanced as any in the world. The design techniques and safety studies are more advanced than those in any other country. The CRBR can accommodate changes required to demonstrate the LMFBR system, including alternate fuel systems.

In fact, the recently completed conceptual design study (CDS) by the DOE which assumes construction and operation of CRBR, contains relatively modest changes to the basic CRBR design. For example, the 1000 MW CDS plant would have the same core and IHX design concepts, and its containment would be based on the same design philosophy as CRBR.

Although the fuel handling systems of each plant are quite different, other CDS reactor components only reflect modest extension of CRBR design experience, such as reactor vessel piping with internal downcomers; shutdown heat removal system within the reactor vessel; four loops vs three; two stage coolant pump which retains the hotleg feature of CRBR; and flexibility to accommodate any one of three steam generator designs.

The CRBRP will serve as an important step in beginning the transition of the fast breeder reactor program from the technology development stage to the decision point of large-scale commercial utilization. The major objectives of the project are: 1) to demonstrate the technical performance, reliability, maintainability, safety, environmental acceptability and economic feasibility of the LMFBR central station electric power plant in a utility environment, and 2) to confirm the value of this concept for conserving important non-renewable natural resources.

Although paper studies, laboratory experiments, and component testing are essential steps in developing complex new technology, only the practical demonstration of the fully integrated systems can move it nearer to readiness for commercial use. The history of light water reactor development suggests that CRBR would be the first of probably two demonstration plants built in tandem before there can be sufficient investor confidence to make commercial deployment possible. Such tandem demonstrations will require about 25 years for design, licensing, construction, testing and demonstration of operating reliability and maintenance requirements. This would bring us to about the year 2007 before our nation is postured to commit additional breeders that would then begin to make their first energy contribution in about 2020. If Clinch River should be terminated, the entire program will stretch out at least an additional ten years.

With the risks of oil supply, the uncertainties of the environmental acceptability of massive additional use of coal, and the unknown about future uranium for LWR's, our nation can ill afford the risk of arriving at 2007 and not have the capability to deploy the breeder. It may not be needed until later, but if it should be needed then and not available, the consequences could be severe. Breeders will multiply the energy recoverable from our nation's uranium reserves by a hundredfold or more.

In dissenting from the majority vote of ERAB, the undersigned also feel that Clinch River suffered from the criteria used in voting and weighing procedures. Clinch River cannot possibly save energy by 2000, it will not replace oil by then, it has no economic potential during this century, all of which cause CRBR to receive low ratings in these categories. We do feel that it is an essential and integral part of the on-going LMFBR program which received high ratings, and CRBR should proceed with dispatch.

Respectfully submitted: John W. Simpson
Roland W. Schmitt
William S. Lee
Louis H. Roddis

ENERGY RESEARCH ADVISORY BOARD
ADDITIONAL REMARKS BY THOMAS B. COCHRAN
WITH REGARD TO THE CLINCH RIVER BREEDER REACTOR

In its initial evaluation of DOE energy R&D programs, at least two-thirds of the members of the ERAB agreed that the Clinch River Breeder Reactor (CRBR) has low urgency, low economic potential, low benefit-to-cost ratio and that funding should be reduced. In the final analysis three-quarters of the ERAB members recommended that the "[breeder reactor] demonstration be delayed until a future time" -- a statement which clearly implies termination of the present CRBR project.

Four ERAB members have attached a six page dissent to the five sentences devoted to the CRBR*/ in this 61 page report, which evaluates 52 program areas covering all DOE energy R&D. Under normal circumstances, the report of the majority should respond to the points raised by the minority. Because ERAB was under an extremely tight schedule to complete this exercise, no time was made available to provide for a majority discussion of the minority view. Consequently, the following comments by one member of the majority are presented in order to provide some balance to the discussion of the CRBR issue.

URANIUM SUPPLY

In order to counter the majority view that "sufficient... uranium supplies exist to satisfy projected levels of electric demand for at least 40 years and possibly well beyond" (p. 56), the minority states that "no one can adequately predict what course the future will take with respect to energy" and then proceeds to present its own high nuclear growth scenario.**/ This has the effect of exhausting low cost uranium resources sooner than otherwise projected, thus making an earlier commitment to a breeder demonstration plant more persuasive.

The simple response to this argument is that when one is not ordering any new reactors, one is not going to run out of uranium. This, the current reality, is consistent with the low nuclear growth scenario

*/ Three of these five sentences (at pages 3, 27, and 56) summarize statements in the other two.

**/ If this approach were applied to all energy R&D activities it would make orderly program planning and this ERAB exercise meaningless.

of the most recent energy projection of the DOE Energy Information Agency's (EIA). It assumes no nuclear plants will be constructed beyond those where construction is already 10 percent complete. While this will probably be the most accurate of the EIA projections,*/ the following table shows that the minority estimate of nuclear plants built by 2020 (committed by 2010) is almost 2.5 times the EIA intermediate growth scenario and more than twice the nuclear capacity in EIA's highest nuclear scenario.

YEAR	DOE-EIA INTERMEDIATE-CASE GWE	DOE-EIA HIGH-CASE GWE	ERAB MINORITY GWE
1981	60	60	60
2000	175	195	200
2020	290	350	713

With its very high nuclear growth after 1990, the minority then argues that we will have committed 4.6 million tons of uranium by 2010 -- exceeding the domestic resources at a forward cost of $100/lb. The minority has conveniently ignored a) any reduction in LWR uranium requirements through increased fuel-use efficiency and reduced enrichments tails with advanced technology (30% to 50% improvements have been projected);**/ b) any improvements in uranium mining technology over the next 30 to 60 years; c) the more robust world uranium resource pictures;***/ and d) the availability of higher cost (lower grade) resources, domestic and foreign.

To further exacerbate the uranium supply picture, the minority implies that utilities will not build a nuclear plant in 2010 unless the uranium for all plants operating in 2020 is assured through 2050. This conveniently ignores the world experience with breeders that will be

*/ It should be noted that DOE and its predecessor agencies have consistently overestimated total energy, total electric, and nuclear electric energy growth during the past eight years.

**/ DOE, NASAP Report, DOE/NE-0001, Executive Summary, June 1980, p. 11.

***/ Two of our closest allies, Canada and Australia, are major export countries. In part because of competition from cheaper, higher grade foreign uranium resources, the domestic uranium producers are currently seeking protective import restrictions.

accumulated between now and 2010 that will permit prudent decision making regarding the need for and timing of commercial breeder introduction.*/

Properly framed, the uranium supply argument is subsumed in the larger question of when the breeder will become economically competitive with the LWR. The minority claims "most US groups estimate the uranium break-even price at about $50-$150/lb (1980 dollars." This claim is incorrect. The range in the most recent analyses is $150/lb to $400/lb.**/ With more credible assumptions regarding the growth rate in nuclear capacity and the capital cost difference betrween LMFBRs and LWRs, the breeder is unlikely to be economically competitive with conventional reactors until well into the next century, if ever.

More important than the issue of whether the breeder will ever be economical is whether the US can afford to wait a decade before reassessing whether to commit to a demonstration plant. The current economic outlook of the breeder strongly favors delay.***/

SUNK COSTS VS. FORWARD COSTS

The minority argues that cancellation of CRBR will result in the loss of over $1 billion investment already incurred. This is a familiar argument, but one based on bad economic theory. One should weigh forward benefits against forward costs and not sunk cost to evaluate the wisdom of proceeding.****/ Current estimates of the total project cost are in

*/ The French will have operated the commercial size Super Phenix breeder reactor for some 25 years by 2010. Also, the US breeder program, even without the CRBR, would be one of, if not the, largest energy R&D efforts in the world.

**/ DOE, NASAP Report, DOE/NE-0001/5, June 1980, p. 42 gives $120 to $200/lb as the indifference price for LMFBR costing 1.25-1.5 times LWR as compared with a 15% improved LWR. Brian G. Chow, "Economic Comparison of Breeders and Light Water Reactors, Pan Heuristics, 23 July 1979, p. 74, projects $150 to $438/lb.

***/ In 1990, we will be in a far better position to judge the economic outlook for breeders based in part on the additional French experience. We will know also whether the "second coming" of nuclear power in the US is real or imaginary.

****/ The minority also takes no credit for R&D benefits obtained from $1.03 billion sunk of which only $608 million represents hardware completed or on order. Furthermore, if the project were cancelled part of $353 million (for hardware on order) would be recoverable.

the range of $3.2 billion (1981 dollars) making the forward cost in excess of $2 billion,*/ an amount well worth saving, or applying to other more cost effective energy R&D programs. Furthermore, the $2 billion forward cost estimate is unrealistically low.**/

DEMONSTRATION OF SAFETY AND LICENSING

The minority claims that "even if one accepts the argument that the breeder reactor would only provide a useful option in the future it is still necessary to complete the Clinch River Project in order to actually demonstrate this technology in the US licensing and safety environment."***/ Safety and licensing requirements, however, are evolving and would likely change drastically by the time the breeder is commercialized.****/ There is little to be gained by demonstrating present breeder technology in the current licensing and safety environment. Even if one accepted the minority view that one might wish to deploy breeders in 2010, it would make far more sense to demonstrate licensing in 2000, some 20 years hence.

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*/ The latest total CRBR project cost estimate is $2.88 billion (1980 dollars), based on 8% escalation rate and a completion date of 1988. By way of comparison the entire project was estimated in 1973 to cost $700 million.

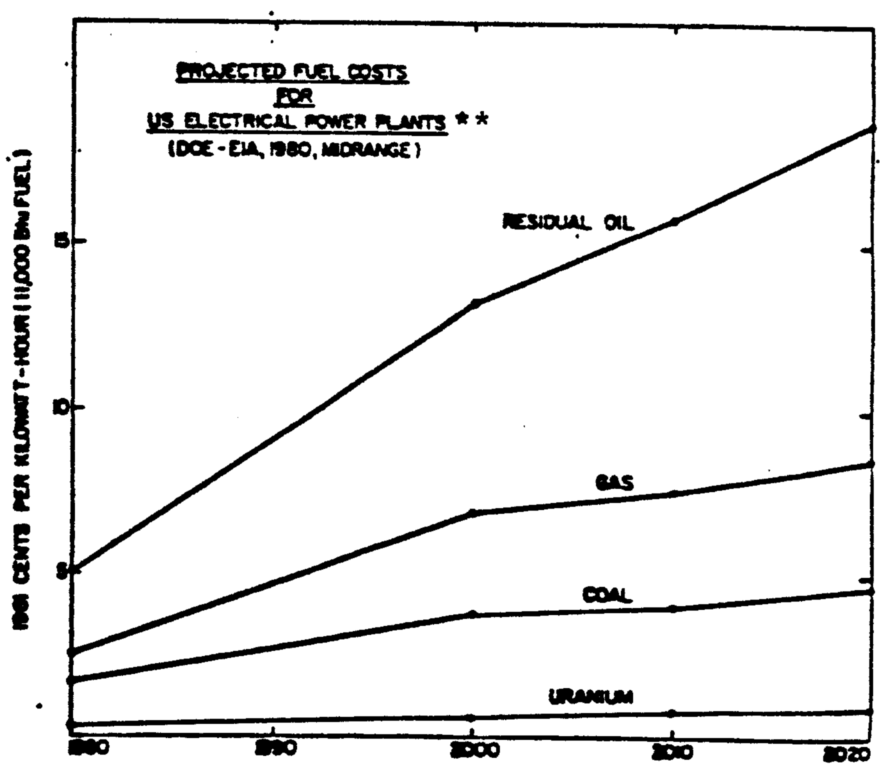
**/ It is based on a) the unlikely prospect that DOE will obtain approval from NRC to begin site work prior to completion of safety and environmental reviews, b) estimates of the construction schedule and cost that do not reflect the experience of most nuclear projects of this type, and c) the assumption that the Clinch River site is suitable. With regard to the last, NRC may require an alternate site, in part because of unfavorable meteorology and post TMI limits on population density. In this event the project would be set back an additional 4 years at an added cost of $1.7 billion.

***/ This argument would have been a bit more persuasive were it not for the fact that DOE has just requested a licensing exemption for the NRC (Letter from DOE Secretary Edwards to Nunzio Pallidino, Chairman NRC, Nov. 30, 1981) in order to commence early site preparation work prior to completion of the required safety and environmental reviews and hearings. This request, if granted, would enable DOE to initiate site work prior to the next CRBR budget review by the Congress.

****/ Anyone who seriously questions this need only examine the effect the TMI accident has had on the licensing requirements in effect just two years ago.

CONCLUDING REMARKS

The ERAB report raises the question of whether "federally-sponsored nuclear programs are receiving a larger portion of funding completely out of line with the expected nuclear share of the US energy mix during the next few decades." In the President's FY 1982 energy R&D budget $875.6 million -- some 31% of all R&D funds exclusive of the Science and Technology Base (see Table III-D) -- is devoted to breeders and advanced uranium enrichment technologies.*/ These activities can be seen, as viewed from the market place, as attempts to reduce the impact of rising uranium prices. The figure on the next page suggests that the problem is not with the uranium but with oil. When one also realizes that a) we can safely defer a commitment to the CRBR, b) the LMFBR base program expenditures can be substantially reduced once the program is refocussed for the longer term, c) a 50% reduction in the price of uranium enrichment will reduce electricity prices by only 0.1¢/kwh, d) our national security problem is with oil, not uranium, and e) improvements in energy productivity have proven to be the more cost effective means of providing additional "supplies," there can be little doubt that DOE energy R&D priorities are misplaced.



*/ $875.6 million represents the sum of the budgets for the LMFBR Base, CRBR, Breeder Fuel Cycle R&D, Uranium Enrichment R&D (Centrifuge and AIS), and the LWBR (See Table IV-A, pp. 26).

**/Frank von Hippel, Testimony before the Subcommittee on Energy Conservation and Power, of the House Committee on Energy and Commerce, October 5, 1981.

DISSENT TO THE RECOMMENDATION WITH
RESPECT TO ELECTRIC AND HYBRID VEHICLES

Electric and hybrid vehicle technology is high risk, but promising, and its continued development would well serve the long term national interest. The technology is high risk because the economic viability of electric and hybrid vehicles has not been demonstrated. It is promising because of the rapid advances in the offing for performance improvements and cost reductions of electric drive systems based on power semiconductor devices, and because of continued progress in battery technology. And, it would serve the long term national interest because it directly addresses the problem of total dependence of the US on liquid fuels for personal transportation services.

Under normal circumstances it would be expected that development of electric vehicle technology would be pursued at a reasonable level by the automobile industry. However the present condition of the industry is such that it cannot be expected to pursue this high risk development without some Federal support. Termination or sharp reduction of the Federal program at the present time would significantly delay electric vehicle development and substantially increase the risk that this technical option would not be ready at the time when it might be needed.

Respectfully submitted: Roland W. Schmitt