ERDA 76-1

A NATIONAL PLAN FOR ENERGY RESEARCH, DEVELOPMENT & DEMONSTRATION: CREATING ENERGY CHOICES FOR THE FUTURE 1976

VOLUME 1: THE PLAN

ENERGY RESEARCH & DEVELOPMENT ADMINISTRATION
USA

UNITED STATES
ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION
WASHINGTON, D.C. 20545

April 15, 1976

The President of the United States

The President of the Senate

The Speaker of the House of Representatives

Sirs:

I enclose for your consideration Volume I of ERDA 76-1, "A National Plan for Energy Research, Development, and Demonstration - Creating Energy Choices for the Future" containing the Plan. Volume II, the Program Implementation (including both nonnuclear and nuclear programs) will be forwarded under separate cover at a later date, expected to be within the next 30 days.

This is the first annual update of the initial report submitted to you in June 1975 (ERDA-48), and complies with the requirements of Section 15 of the Federal Nonnuclear Energy Research and Development Act of 1974.

This report represents an evolution in approach over the previous document. ERDA's proposed National Plan has been expanded in scope and depth of coverage and the basic goals and strategy are refined, but remain essentially intact. The Plan summarizes ERDA's current views on the energy technologies the Nation will need to achieve longer-term energy independence, specifically:

- The paramount role of the private sector in the development and commercialization of new energy technologies is addressed.
- Conservation (energy efficiency) technologies are singled out for increased attention and are now ranked with several supply technologies as being of the highest priority for national action.
- The President's 1977 budget requests a large increase - 30% over 1976 - in funding for energy RD&D with particular emphasis on:
  - accelerating energy RD&D programs directed at achieving greater long-term energy independence,

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- encouraging cost-sharing with private industry and avoiding the undertaking of RD&D more appropriately the responsibility of the private sector,

- supporting the commercial demonstration of synthetic fuel production by providing loan guarantees beginning in FY 76.

o Federal programs to assist industry in accelerating the market penetration of energy technologies with near-term potential are a key element of the Plan.

The Executive Summary outlines specific conclusions and recommendations that are presented more fully in the body of the report.

I believe it is important that we achieve extensive Congressional and public discussion of the national energy research, development and demonstration considerations and recommendations contained in ERDA-48 and described in further detail in the present report. Such public discussion is an essential part of the common effort to arrive at an effective approach to the solution of our energy problem - an approach that in terms of research, development and demonstration is based on the concept of creating energy choices for the future.

Sincerely,

Robert C. Seamans, Jr.
Administrator

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DEVELOPING THE PLAN

Preface

In the 1975 State of the Union message, President Ford enunciated three national energy policy goals necessary for the Nation to regain energy independence. These goals are reiterated in the 1976 Energy Message:

—"First, to halt our growing dependence on imported oil during the next few critical years.

—"Second, to attain energy independence by 1985 by achieving invulnerability to disruptions caused by oil import embargoes. Specifically, we must reduce oil imports to between 3 and 5 million barrels a day, with an accompanying ability to offset any future embargo with stored petroleum reserves and emergency standby measures.

—"Third, to mobilize our technology and resources to supply a significant share of the free world's energy needs beyond 1985."

The following principles guided the development of the program. These principles are still sound today:

—"Provide energy to the American consumer at the lowest possible cost consistent with the need for secure energy supplies.

—"Make energy decisions consistent with our overall economic goals.

—"Balance environmental goals with energy requirements.

—"Rely upon the private sector and market forces as the most efficient means of achieving the Nation's goals, but act through the government where the private sector is unable to achieve our goals.

—"Seek equity among all our citizens in sharing of benefits and costs of our energy program.

—"Coordinate our energy policies with those of other consuming nations to promote interdependence, as well as independence."

New technology that will help expand domestic energy supplies and improve the efficiency of energy use is an essential tool in achieving the President's energy goals. The introduction of new technology requires, in turn, a major national effort in research, development and demonstration (RD&D), carried out largely in the private sector but supplemented by government-sponsored RD&D where necessary.

In June 1975, the Energy Research and Development Administration (ERDA) submitted to the President and the Congress a report entitled **A National Plan for Energy Research, Development and Demonstration: Creating Energy Choices for the Future (ERDA–48).**

Within the context of the President's goals for energy independence, the 1975 plan:

—Recommended energy R&D goals and objectives for the Nation.

—Examined the potential timing and contribution of major energy technology options.

—Ranked major technologies and related them to their potential energy contribution in the near, mid and long-term.

—Discussed Federal and private sector roles in energy RD&D and described the Federal energy RD&D effort.

The Plan also served as an important input to the development of the President's amended 1976 and the 1977 budget request for energy RD&D funding.

While ERDA's proposed plan is national in scope, the Federal Government can neither unilaterally plan the course of national action nor accomplish all the necessary actions defined by such a plan. This planning process is a useful mechanism because the Federal Government can use such an approach as one context for its own actions and as a way to promote consensus on the Nation's approach to energy RD&D. In this regard ERDA–48 contributed to this planning process in the following three ways:

1. By establishing a likely order of technology introduction from the near to the long term, ERDA–48 identified current major guideposts for measuring and assessing the rate of technology introduction. These guideposts can be useful in evaluating whether enough new technologies are being introduced to solve the Nation's

energy problem, and in identifying possible compensatory government action.

2. ERDA–48 proposed national energy RD&D priorities linked directly to this order of technology introduction. These national priorities are intended to be generally helpful in evaluating the national energy RD&D effort. In particular, the priorities bear on the allocation of government RD&D resources.
3. It stimulated debate on the technological options open to the Nation in the context of the total energy problem. ERDA believes this context, which forces the weighing of all alternatives together, facilitates the objective evaluation of individual technologies. It is a debate that should be encouraged.

Accomplishment of the activities identified in the proposed national plan needs: 1) agreement of the private sector and the public on the planning approach, and 2) acceptance of both the role and the sets of actions set forth in the plan to be carried out by these entities. Thus, the development of a national planning approach must be iterative and dynamic. Newly discovered energy supplies, changes in energy policy, scientific successes and failures, economic conditions, actual progress in introducing new technology—all these and more will change the Plan. Recognizing these dynamics, the Congress instructed ERDA to report annually on its progress during the past year, and to revise annually its Plan and program.

This document is the first such annual report and Plan revision. Because it ranges widely, although not exhaustively, across the energy problem and energy RD&D, this revised Plan carries many themes. However, it returns repeatedly to the central theme that the development and introduction of new energy technology requires the interaction of many programs, institutions, and individuals.

Accordingly, **Chapter I** of ERDA 76-1 presents an overview of the energy problem and the major requirements for its solution. It then describes at some length the relative roles of the participants in the solution and why—and how—the players must work together.

The next two chapters present the revised Plan and program. **Chapter II** describes the Plan—a likely ordering of technology introduction and the related national RD&D priorities. This revised Plan is not much different from ERDA–48. Substantively, the higher national priority assigned to conservation is the major revision. Additionally, this chapter restates and attempts to clarify some of the ERDA–48 material.

Chapter III summarizes the Federal energy RD&D program, which, of course, is only one part of the national activity under way. This chapter develops two important points. First, it discusses Federal RD&D program strategies, emphasizing programs nearing the point of market penetration. The interaction of Federal RD&D with the private market is a unique and crucial aspect of ERDA's mission. Second, this chapter presents the FY 1977 Federal energy RD&D budget. (Volume II of this Plan, published separately, contains more detail on last year's progress and future prospects for each of the energy RD&D programs.)

Chapters IV and V turn to the institutional mechanics necessary to implement the Federal RD&D and program. **Chapter IV** discusses the interactions between ERDA and the public, the private sector, state and local government agencies, other Federal Government agencies, and other countries. Successful interaction will increase the likelihood of early development and implementation of new energy technologies and realization of the Nation's energy goals. **Chapter V** describes the key elements of the analysis and planning system being developed and implemented by ERDA.

The final chapters of this report will be of special interest to those who want to follow closely the analytic foundations of the Plan. **Chapter VI** discusses the events, public comments, and new analytic results that have impact on or have shaped the Plan, and explains why Plan revisions were made; similar material will be included in all future editions of the Plan. **Chapter VII** looks to the future, presenting ERDA's current views of priority matters to be treated in greater depth in the next Plan update.

Executive Summary

Key Points of The Summary

Representing an evolution in approach over the initial planning of June, 1975, this National Plan expands the scope and depth of coverage of the earlier Plan. The basic goals and strategy are refined, but remain essentially intact.

Significant points of emphasis in this report are as follows:

- The paramount role of the private sector in the development and commercialization of new energy technologies is addressed.
- Conservation (energy efficiency) technologies are singled out for increased attention and are now ranked with several supply technologies as being of the highest priority for national action. The primary responsibility for developing and bringing into use improved technologies for energy efficiency rests with the private sector but the Federal Government is increasing its funding for this area to provide encouragement and stimulus to the total national effort.
- Federal programs to assist industry in accelerating the market penetration of energy technologies with near-term potential are a key element in the Plan.
- The close coordination of technology development with socioeconomic and environmental factors, at regional as well as national levels, is provided.
- The President's 1977 Budget recognized the high priority of energy RD&D by proposing a greatly expanded program at a level appropriate to the responsibilities of the Federal Government. Specifically, it:
  —Accelerated energy RD&D programs directed at achieving greater long-term energy independence.
    ——Expanded efforts to assure the safety, reliability, and availability of commercial nuclear power plants.
    ——Placed greatest funding on technologies with the highest potential payoff in terms of recoverable resources (i.e., nuclear and fossil).
    ——Greatly increased the Federal investment in conservation technologies.
    ——Continued to expand the investigation of other technologies where they can make significant contributions to meeting the long-term energy requirements of the U.S. (i.e., solar, and fusion).
  —Encouraged cost-sharing with private industry (e.g., coal liquefaction demonstrations) and avoided undertaking RD&D more appropriately the responsibility of the private sector (e.g., in areas of conservation technology).
  —Supported the commercial demonstration of synthetic fuel production from coal, oil shale, and other domestic resources by providing loan guarantees beginning in FY 1976.
- A new short-term, five-year-forward planning category is added to the Plan to focus attention on opportunities for technology development that may have effect within five years.

National priorities for energy RD&D are not the same as priorities for the allocation of *Federal* funds for energy RD&D. In many cases, Federal spending for the development of a particular energy technology may not be justified because:

—the RD&D function can better be performed by the private sector,
—the objective can better be achieved by some means other than RD&D, or
—the funding required is not sufficiently high in priority compared to other demands for Federal funds.

Furthermore, the level of Federal resource commitment for any particular area of energy technology is also influenced by the stage of technology development as a technology moves from the less expensive research phase to the more expensive pilot and demonstration plant phases.

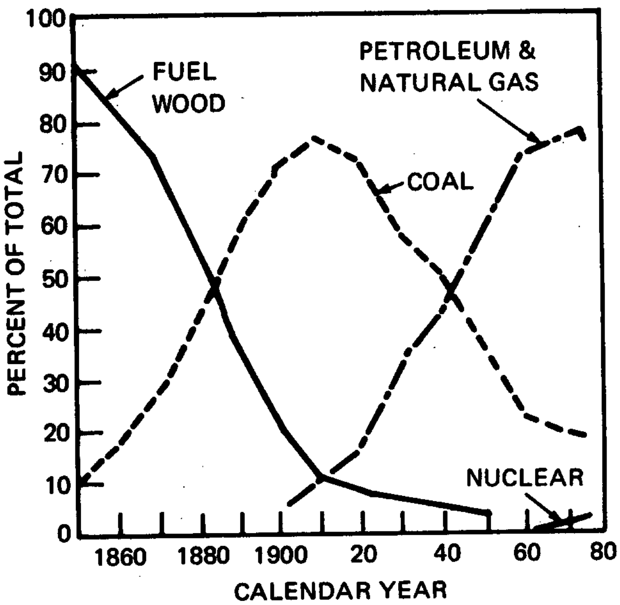
While ERDA's proposed plan is national in scope, the Federal Government can neither unilaterally plan the course of national action nor accomplish all the necessary actions defined by such a plan. This planning process is a useful mechanism because the Federal Government can use such an approach as one context for its own actions and as a way to promote consensus on the Nation's approach to energy RD&D.

Background of the Plan

The Nation faces a serious and continuing energy problem characterized by limited energy choices and increasing dependence on diminishing oil and gas resources. This problem is currently exemplified by an undue reliance upon imported fuels.

This serious energy problem has come about because most of the fuel currently used by the Nation is in the form of petroleum and natural gas, and these fuel resources are becoming rapidly depleted. Actions must be initiated to prepare for a transition from dependence on oil and gas to reliance on alternative energy sources, particularly coal and nuclear in the near and mid term. Historically, however, such transitions, as illustrated in Figure I, have required more than half a century.

To provide alternatives to undesirable dependence on oil and gas, the Nation must undertake a program of technology development which will be technologically difficult and costly, and will require time.



SOURCE: HISTORICAL STATISTICS OF THE UNITED STATES BUREAU OF THE CENSUS; U.S. BUREAU OF MINES, 1974

Figure I U.S. Energy Consumption Patterns

The problems of transition to new energy sources are difficult. New domestic energy sources are potentially available—indeed, solar energy and nuclear fission (breeder) and fusion represent essentially inexhaustible energy sources—but there are significant economic, environmental, social and technological problems to be solved before these new energy sources can become adequate supplements for oil and gas. Meanwhile, existing domestic alternatives in such forms as abundant coal resources, and the full benefit of nuclear light water reactors cannot be completely realized without further technological improvements.

Figure II presents current potentially recoverable resource estimates for key domestic fuels. Shaded areas indicate the additional resources that may become recoverable if the necessary technology and utilization techniques can be developed. In addition, Figure II illustrates the relative paucity of domestic oil and gas resources compared to the estimated cumulative energy demand from now until the end of the century. Coal and nuclear represent the major exploitable resources to supplement oil and gas over the next several decades. Geothermal, oil shale, and solar energy in the form of solar heating and cooling represent supporting resources to ease overall supply problems in that same time period. Nuclear breeders, solar electric, and fusion represent technologies that can exploit major resources for the next century. These latter three technologies differ significantly as to the status of their development and demonstration, the severity of the economic, environmental, social and technological challenges to be overcome and their potential for meeting energy needs within given time frames. With respect to the latter point, the first two of these have the potential to contribute to meeting energy needs during the later part of this century.

In summary, even though the Nation is blessed with abundant energy resources, it is currently dependent upon a narrow base of diminishing resources.

This Plan is designed to describe likely options for the introduction of new technology that will assist the changeover from dependence on this narrow base of diminishing domestic resources to reliance on a broader range of less limited alternatives.

The transition to less limited resources poses substantial technological and environmental problems. Of equal importance are the difficult economic, social, and institutional problems that will be associated with this transition. These problems must be addressed more intensively than ever before and a RD&D program, however successful technically, can fail because of failure to solve any one of these problems.

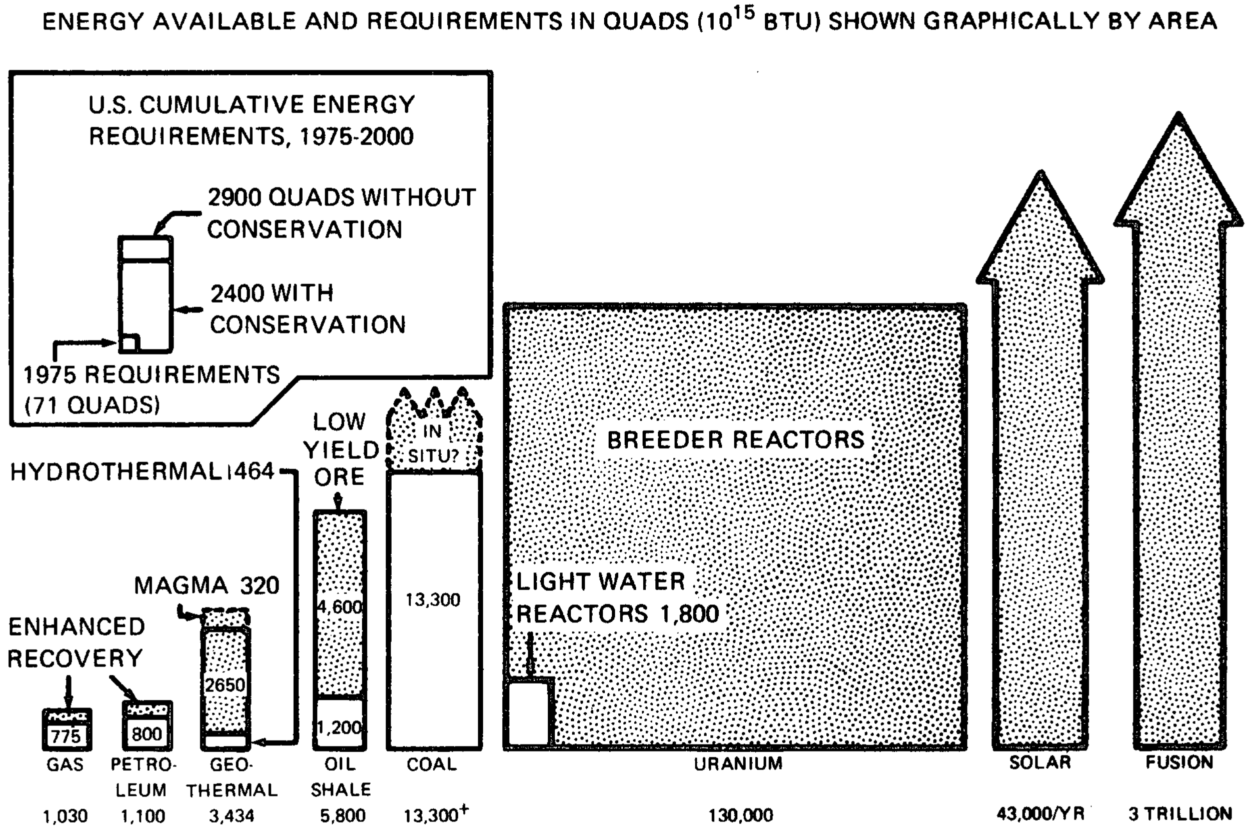


Figure II Potentially Recoverable Domestic Energy Resources

Technology development is made more difficult by uncertainty as to how the future will evolve with respect to energy demand, energy costs and many other factors. There is, today, uncertainty as to the future of energy demand; the relative economics of energy technologies; the interplay with the environment; the choice of preferred energy systems; the date of introduction or the rate of implementation of a particular energy technology; the international aspects of the world-wide energy problem; and other factors affecting solution to the domestic energy problem.

While technological development is a necessity for almost every aspect of the energy problem, the design of a program for technology development must remain responsive to such factors as:

- How much domestic oil and gas is actually found and produced
- The availability of imports from secure sources, plus the backup protection against supply disruption that can be gained from stockpiling policy
- The rate of implementation and level of development of both existing and emerging new technologies
- The degree of protection afforded human health and the physical environment
- The degree of modification of life styles which the Nation finally adopts
- The end-use energy efficiencies that may be finally attained
- The level of effort that can be placed in the development of new technology
- The economic and technical success finally achieved by new technologies
- The impact of economic and sociopolitical considerations.

Even though this list is not exhaustive, it is illustrative of the difficulties in dealing with the energy problem. Decisions on this development must be made today in the face of uncertainty, without foreclosing future options. Indeed, the basis for undertaking a program of energy RD&D is to broaden the Nation's range of available energy options—**to create energy choices for the future.**

While RD&D is clearly needed, an insufficient amount is being conducted in the private sector because of uncertainties with respect to future profitability; environmental standards and other regulatory policies; the magnitude of technological risks being faced; the lack of present institutional organizations to undertake the effort; or simply because of the sheer size of the effort or investment. Energy RD&D

is one element of the total National policy which must seek to reduce these risks and uncertainties and improve the economic and regulatory climate for private action.

The starting point for this Plan for technology development is the broader concept of national energy goals and principles.

Ultimately, decisions as to which technologies are found to be acceptable have wide-ranging implications for the country's security, and involve the future environmental and economic well-being of all citizens. The process of developing alternatives to the present energy system needs to be carried out in a context which continually considers the broader issues of public concern.

The programs to achieve Energy Independence were guided by the following principles: These principles are still sound today:

- "Provide energy to the American consumer at the lowest possible cost consistent with the need for secure energy supplies.
- "Make energy decisions consistent with our overall economic goals.
- "Balance environmental goals with energy requirements.
- "Rely upon private sector and market forces as the most efficient means of achieving the Nation's goals, but act through the government where the private sector is unable to achieve our goals.
- "Seek equity among all our citizens in sharing costs and benefits of our energy program.
- "Coordinate our energy policy with those other consuming nations to promote interdependence, as well as independence."

In keeping with the above principles, the President set forth the following goals for a comprehensive national energy effort in the 1976 Energy Message:

—First, to halt our growing dependence on imported oil during the next few critical years.

—Second, to attain energy independence by 1985 by achieving invulnerability to disruptions caused by oil import embargoes. Specifically, we must reduce oil imports to between 3 and 5 million barrels a day, with an accompanying ability to offset any future embargo with stored petroleum reserves and emergency standby measures.

—Third, to mobilize our technology and resources to supply a significant share of the free world's energy needs beyond 1985.

It is the purpose of the National Plan for Energy RD&D to translate these principles and goals into specific Federal programs for technology development, recognizing that industry initiatives in implementing this development will be of paramount importance and that the public's support as citizens and consumers is essential.

A basic premise in national energy policy and planning for RD&D is that the private sector has the primary role in creating new energy alternatives; the Federal Government's role is to assist the private sector in the development and market penetration of new energy technologies.

With few exceptions, the private sector is the main producer and consumer of energy. The role of the private sector is therefore paramount in the accelerated introduction of energy technology, and in the solution of the Nation's energy problem.

In part, this is so because the private sector is motivated and prepared to take the risks involved in developing and introducing new energy technologies. In addition, the private sector has the inherent flexibility to act; the preponderant share of new investment funds; and the managerial capabilities for carrying out most of the RD&D and virtually all of technology introduction. Moreover, market forces as they are perceived by decision-makers in the private sector will determine the economically optimal mix of alternative energy technologies to displace the undue reliance on petroleum and natural gas.

Therefore the establishment of the Federal program and activity levels, the objectives are:

- To assist and reinforce private sector actions rather than to compete with them
- To ensure relevance of governmental activity by achieving extensive private sector involvement at the earliest possible moment in the development cycle.

An important theme of this report is that the private sector and market forces are the most efficient means of achieving the Nation's energy goals.

The role of the public sector, especially that of the Federal Government, is therefore supplementary—to do what cannot otherwise be done privately. The Federal role, in turn, divides into three parts: Government can establish an appropriate policy climate for private sector action, share risks, and conduct a complementary RD&D program.

In general, a preferred role of government is to establish an appropriate climate for private introduction of energy technology, such as:

- **Leadership and assistance:** establishing a consistent and stable policy and regulatory network.
- **Management of energy resources located in Federal lands:** making available these resources for use over time with due regard to environmental, aesthetic, conservation, land-use, or other factors of national interest.
- **Economic and anti-trust regulation:** making energy decisions consistent with national economic goals; providing energy consistent with the need for secure energy supplies; and assisting in the devel-

opment of standards, criteria, and certification procedures.

- **Human health, safety, and environmental Protection:** ensuring the protection of the Nation's environment and the public's health and safety.
- **International policy:** coordinating our energy policies with those of other consuming and producing nations to promote interdependence as well as independence.

Within the Federal Government, ERDA has specific leadership responsibility in energy RD&D.

Energy RD&D is an important component of the total Federal role, and ERDA plays a leadership role here in three ways.

First, ERDA develops and updates the National Plan for Energy RD&D. This Plan cannot, and is not intended to, represent technology as a total solution to the energy problem, nor can it predict certain success for any particular program, ensure immediate results, or preselect a single energy future. Rather, the Plan performs three principal functions:

1. Establishes a likely order of technology introduction from the near to the long term, and identifies current major guideposts for measuring and assessing the rate of technology introduction. These guideposts are useful in determining whether enough new technologies are being introduced to solve the Nation's energy problem, and in identifying possible compensatory government action.
2. Proposes national energy RD&D priorities linked directly to the order of technology introduction. These priorities are intended to be generally helpful in evaluating the national energy RD&D effort. In particular, the priorities bear on the allocation of government RD&D resources.
3. Stimulates debate on the technology options open to the Nation in the context of the total energy problem. ERDA believes this context, which forces the weighing of all alternatives together, facilitates the objective evaluation of individual technologies. It is a debate that should be encouraged.

Second, ERDA has the responsibility to monitor and report on the entire Federal energy RD&D effort. In this way, a coordinated program aimed at common objectives is more likely to emerge. Volume II of this Plan summarizes the activities of 23 Federal agencies as they relate to the total RD&D program.

Finally, ERDA is itself the principal sponsor of Federal energy RD&D, including programs involving risk-sharing with the private sector.

Fundamentals of the Plan

To propose effective solutions to the Nation's current energy problem, the National Plan for Energy RD&D addresses technology development from the standpoint of both private sector and Federal Government activities, and also proposes approaches to incorporate pertinent nontechnological considerations which can affect the results of RD&D.

The National Plan for Energy Research, Development and Demonstration is an integral part of an overall approach for addressing the Nation's energy needs. It is responsive to the national energy policy goals and principles enunciated in the President's 1975 State of the Union Message, and reiterated in the 1976 Energy Message. While its emphasis is on technological development, it is consistent with and reflects broader policy concerning import levels, foreign relations, the needs of industry and consumers, fiscal policy, environmental protection, and human health and safety concerns.

In its initial response to the Nation's energy needs, the Energy Research and Development Administration (ERDA) formulated the first National Plan for Energy RD&D, which proposed national priorities for the development of new energy technologies. That approach, published in June 1975, remains the basis for this first annual update.

The dual emphasis of this updated Plan is:

- The further refinement of priorities and strategic approaches identified in the initial National Plan for Energy RD&D
- The integration of the critical nontechnological aspects of energy development into RD&D consideration.

Technological Emphasis

The overall emphasis of this Plan is to support the private sector in the development and implementation of energy technologies that can begin to reduce the demand for oil and gas significantly in the balance of this century, and, where possible, in the near term.

To accomplish this, the Plan:

- Singles out conservation (energy efficiency) technologies for increased attention and ranks them with several supply technologies as being of the highest priority for national action
- Identifies six key supply technologies which can enter the market penetration phase in the near term
- Outlines initial program steps to overcome technological barriers to the rapid implementation of key technologies with near-term potential
- Adds a short-range planning category to focus attention on opportunities for technology development that may have effect within five years.

To balance these initiatives, the Plan also develops in further detail the longer-range programs given priority in ERDA's initial Plan.

Nontechnological Emphasis

The nontechnological emphasis of this Plan is to ensure that RD&D has taken account of all those factors which can facilitate the rapid integration of new energy technologies into the framework of the society.

To accomplish this, the Plan outlines approaches to:

- Government support to the private sector to accelerate market acceptance of key technologies after technological barriers to market penetration have been removed
- Integration of environmental planning at each stage in the process of technology development
- Interaction of public and private sectors at national, state, regional and local levels to ensure appropriateness of energy RD&D
- Development of a management process within ERDA to provide overall guidance and coordination of both technological and nontechnological aspects of energy development.

These approaches will be summarized and the basis for their emphasis will be explained in greater detail below.

The foundation of the National Plan is a set of recommended national energy technology goals, a strategy for achieving these goals, and a proposed set of national priorities for energy technology development.

To provide a basis for setting priorities in technology development and developing strategies for implementation, the Plan identifies eight national energy technology goals:

I. Expand the domestic supply and economically recoverable energy producing raw materials
II. Increase the use of essentially inexhaustible domestic energy resources
III. Efficiently transform fuel resources into more desirable forms
IV. Increase the efficiency and reliability of the processes used in energy conversion and delivery systems
V. Transform consumption patterns to improve energy use
VI. Increase end-use efficiency
VII. Protect and enhance the general health, safety, welfare and environment related to energy
VIII. Perform basic and supporting research and technical services related to energy

The Plan then develops a strategy for attaining these national goals:

NEAR TERM (Now to 1985 and beyond)	• Increase the efficiency of energy used in all sectors of the economy and extract more usable energy from waste materials • Preserve and expand major domestic energy systems: coal, light water reactors, and gas and oil from new sources and by enhanced recovery techniques.
MID TERM (1985 to 2000 and beyond)	• Accelerate the development of new process for producing synthetic fuels from coal and extracting oil from shale • Increase the use of fuel forms such as geothermal energy, solar energy for heating and cooling, and extraction of more usable energy from waste heat.
LONG TERM (Beyond 2000)	• Permit the use of the essentially inexhaustible resources: nuclear breeders; fusion; and solar electric energy from a variety of options including wind power, thermal and photovoltaic approaches, and ocean thermal gradients • Provide the technologies to use the new sources of energy, which may be distributed as electricity, hydrogen, or other forms throughout all sectors of the economy.

Initial ERDA analyses have led to the preliminary conclusions that only the successful development and implementation of a number of these technologies in a combination of approaches can provide adequate solutions to the present energy problem. All the national energy technology goals must therefore be pursued together. However this does not mean that every conceivable technology approach can or should be pursued with equal vigor or at all.

Although the proposed strategic approach is broad in scope, it recognizes the existence of limited resources, and consequently, the importance of setting priorities.

All appropriate technologies will be drawn upon to some extent in achieving the national technology goals. However, the development of some technologies is absolutely essential, while the development of others is more supportive and complementary. This distinction is based on six criteria:

- How substantial an energy contribution would successful development of the technology make possible?

Table I Technologies Now Available for Pursuing Major Energy Technology Goals

The last column of this table presents data from ERDA–48. It represents the maximum impact of the technology in any scenario measured in terms of additional oil which would have to be marketed if the technology were not implemented. Basis for the calculation is explained in Appendix B of ERDA—48. These data are being reexamined, and changes will be made when analysis is completed. In a number of cases, revised projections of impacts will be lower.

Technology	Term of Impact*	Direct Substitution For Oil & Gas**	RD&D Status	Impact in Year 2000 in Quads
GOAL I: Expand the Domestic Supply of Economically Recoverable Energy Producing Raw Materials				
Oil and Gas—Enhanced Recovery	Near	Yes	Pilot	13.6
Oil Shale	Mid	Yes	Study/Pilot	7.3
Geothermal	Mid	No	Lab/Pilot	3.1-5.6
GOAL II: Increase the Use of Essentially Inexhaustible Domestic Energy Resources				
Solar Electric	Long	No	Lab	2.1-4.2
Breeder Reactors	Long	No	Pilot/Demo	3.1
Fusion	Long	No	Lab	—
GOAL III: Efficiently Transform Fuel Resources Into More Desirable Forms				
Coal—Direct Utilization Utility/Industry	Near	Yes	Pilot/Demo	24.5
Waste Materials to Energy	Near	Yes	Comm	4.9
Gaseous & Liquid Fuels from Coal	Mid	Yes	Pilot/Demo	14.0
Fuels from Biomass	Long	Yes	Lab	1.4
GOAL IV: Increase the Efficiency and Reliability of the Processes Used in the Energy Conversion and Delivery Systems				
Nuclear Converter Reactors	Near	No	Demo/Comm	28.0
Electric Conversion Efficiency	Mid	No	Lab	2.6
Energy Storage	Mid	No	Lab	—
Electric Power Transmission and Distribution	Long	No	Lab	1.4
GOAL V: Transform Consumption Patterns to Improve Energy Utilization				
Solar Heat & Cooling	Mid	Yes	Pilot/Demo	5.9
Waste Heat Utilization	Mid	Yes	Study/Demo	4.9
Electric Transport	Long	Yes	Study/Lab	1.3
Hydrogen in Energy Systems	Long	Yes	Study	—
GOAL VI: Increase End-Use Efficiency				
Transportation Efficiency	Near	Yes	Study/Lab	9.0
Industrial Energy Efficiency	Near	Yes	Study/Comm	8.0
Conservation in Buildings and Consumer Products	Near	Yes	Study/Comm	7.1

* Near—now through 1985
Mid—1985 through 2000
Long—Post-2000
** Assumes no change in end-use device.

- In which time frame does the technology produce its initial energy impact?
- Does the energy output of the technology substitute directly for oil and gas supplies?
- What is the economic status and potential of the technology?
- What are the environmental and human health implications of the application of the technologies?
- What is the stage of development of the technology in the spectrum from the laboratory to the marketplace?

Table I summarizes the key characteristics of each technology with respect to some of these factors. These considerations and the strategic considerations discussed provide a basis for the priority ranking of the technology categories, listed in Table II.

Priority Ranking of Conservation Now Significantly Increased

Conservation (energy efficiency) technologies are singled out for increased attention and are now ranked with several supply technologies as being of the highest priority for national action. This ranking represents a major change from the initial Plan and reflects observations of only moderate progress to date on supply technologies, evaluation of public

Table II Proposed National Ranking of RD&D Technology Categories*

HIGHEST PRIORITY DEMAND	
NEAR-TERM CONSERVATION (EFFICIENCY) TECHNOLOGIES	• CONSERVATION IN BUILDINGS & CONSUMER PRODUCTS • INDUSTRIAL ENERGY EFFICIENCY • TRANSPORTATION EFFICIENCY • WASTE MATERIALS TO ENERGY
HIGHEST PRIORITY SUPPLY	
NEAR-TERM MAJOR ENERGY SYSTEMS	• COAL-DIRECT UTILIZATION IN UTILITY/INDUSTRY • NUCLEAR-CONVERTER REACTORS • OIL AND GAS ENHANCED RECOVERY
NEW SOURCES OF LIQUIDS AND GASES FOR THE MID TERM	• GASEOUS AND LIQUID FUELS FROM COAL • OIL SHALE
"INEXHAUSTIBLE" SOURCES FOR THE LONG TERM	• BREEDER REACTORS • FUSION • SOLAR ELECTRIC
OTHER IMPORTANT TECHNOLOGIES	
UNDER-USED (LIMITED APPLICATION) MID-TERM TECHNOLOGIES	• GEOTHERMAL • SOLAR HEATING AND COOLING • WASTE UTILIZATION
TECHNOLOGIES SUPPORTING INTENSIVE ELECTRIFICATION	• ELECTRIC CONVERSION EFFICIENCY • ELECTRIC POWER TRANSMISSION AND DISTRIBUTION • ELECTRIC TRANSPORT • ENERGY STORAGE
TECHNOLOGIES BEING EXPLORED FOR THE LONG TERM	• FUELS FROM BIOMASS • HYDROGEN IN ENERGY SYSTEMS

* Individual technologies are not ranked within the technology categories.

comment on the initial Plan, and further analysis of conservation opportunities. Specific reasons for assigning this higher priority to energy efficiency technologies are identified below.

Many of the technologies to improve energy efficiency currently appear to share one or more of the following characteristics:

- A barrel of oil saved can result in reduced imports.
- It typically costs less to save a barrel of oil than to produce one through the development of new technology.
- Energy conservation generally has a beneficial effect on the environment in comparison to energy produced and used.
- Capital requirements to increase energy use efficiency are generally lower than capital needs to produce an equivalent amount of energy from new sources since most new supply technologies are highly capital intensive.
- Conservation technologies can generally be implemented at a faster rate and with less government involvement in the near term than can new supply technologies.
- Energy efficiency actions can reduce the pressure for accelerated introduction of new supply technologies. Since the actions persist over time, the benefits are continuing.

These reasons deal generally with conservation technologies. The rate of application and introduction of conservation technologies in specific instances will be determined by the comparative economics and social acceptability of the available alternatives.

Because conservation technologies are characterized by their large number, their diversity, and the relatively small energy contribution of any one—in contrast to major supply technologies—a broad, general strategic approach is required to stimulate the market introduction and implementation of these more diverse technologies. Supportive of this approach, the new short-range planning category initiated in this Plan is particularly appropriate.

In addition to the near- (1985), mid- (1985-2000), and long-term (post-2000) planning horizons established by ERDA's enabling legislation, a new planning horizon—0 to 5 years—will be included in the National Plan for Energy RD&D. The 5-year forward focus is intended to roll forward each year, and will be institutionalized and monitored for successes and failures.

While opportunities to be considered within this focus are sought throughout the entire ERDA program, and nuclear, fossil, and solar and other technical areas are being included, it is likely that the predominant opportunities will be identified within the conservation program. Opportunities for fuel substitution are also being sought because of their beneficial impact on oil imports and relief of gas shortages.

While technologies such as geothermal and solar heating and cooling are assigned only a moderate priority in the ranking, because of projected limitations in their application, both technologies can have an impact on the Nation's energy demand in the mid term if the institutional infrastructures to support their market penetration can be established. These technologies are important because they are sufficiently well developed to be employed on a regional basis when the resources can be exploited economically. The geothermal resources and technologies included in this category are limited to hydrothermal and geopressurized applications, and the solar heating and cooling technologies may be limited to areas that enjoy high levels of insolation and experience relatively high costs for alternative fuels.

The Plan and The Federal Energy RD&D Program

Federal budget allocations are designed to encourage and support private sector initiatives in energy RD&D; national energy technology priorities do not, therefore, translate directly to the ERDA energy budget for any one year for several reasons:

- Differences exist in the scope of effort and the extent of funding required at different phases in the maturing of energy technologies. In general, earlier research efforts require a lower level of funding than, say, demonstration phases.
- Many of the technologies will be developed in the private sector and the distribution of necessary effort between the private sector and the Federal Government will vary tremendously.
- The nature of government involvement may differ for different technologies. RD&D is only one mechanism for government involvement.
- Other government agencies also have responsibilities in energy RD&D. These are reflected in the total Federal budget and in ERDA's planning process, but do not appear in the ERDA budget.

The 1977 Federal budget and the Administration's legislative program provide strong support for energy RD&D. The total allocation for energy RD&D has been increased by more than 30 percent. The Federal budget for 1977 demonstrates the Administration's commitment to the importance of energy research, development, and demonstration as stressed in the Plan which was a key input to the President's budget process. In this year's budget, the amount earmarked for energy research, development, and demonstration represents a 30 percent increase in budget outlays over the previous year. Significant budget increases this year occur in many energy RD&D areas.

Among the specific budget decisions, the President has placed emphasis on closing the fuel cycle in the nuclear light, water reactor program by providing a substantial increase for management of nuclear waste and chemical reprocessing. The increased funding in nuclear waste management represents a recognition on the part of the Administration that safe and environmentally sound nuclear waste disposal, which is a responsibility of the Federal Government, should be demonstrated on an expedited basis. To encourage and enable private sector to build, own, and operate additional U.S. enrichment capacity, the Nuclear Fuel Assurance Act was proposed to Congress in June 1975. The Act will provide ERDA necessary authority to negotiate cooperative agreements with private firms which, after Congressional approval, would provide temporary financial assurances to these firms.

Conservation, recommended in the Plan for accelerated development, has also received an increase in FY 1977 over FY 1976 of 64 percent, or essentially a rate of increase two times the overall program average.

The budget also provides funds to initiate a synthetic fuel program in 1976 as an essential part of a national RD&D effort. Its purpose would be to provide assistance to the private sector to encourage the development of both conventional energy technology (e.g., fossil fuel and nuclear power plants) and emerging technologies (e.g., synthetic fuel from coal, oil shale, and other domestic resources).

Even with the energy conservation measures outlined in this Plan, the demand for oil and gas is expected to outstrip the combined domestic supply and the current level of imports. Moreover, the gap between demand and domestic production is widening.* Over the next 25 years, synthetic fuels offer a domestic energy alternative to imported oil and natural gas.

A program of legislative, budgetary, and administrative actions to undertake a Federally supported synthetic fuels initiative was considered by Congress in the fall of 1975 and, although the program was not authorized during that session, the 1977 Budget provides funds to implement during 1976, a $2 billion loan guarantee program in ERDA. With the

* This relationship is graphically portrayed in Figure III–3.

enactment of EIA, this program would be transferred to EIA and expanded from $2 to $6 billion in loan guarantees, to meet the current 1985 objectives of 350,000 barrels of oil per day of synthetic fuel production capacity.

In Tables III, IV and V, growth of Federal energy RD&D programs is depicted. Table III lists budget outlays of all Federal agencies performing RD&D and Tables IV and V show ERDA budget amounts. Figure III illustrates percentage increases in ERDA's major program areas.

Volume II of this Plan (published separately) describes in detail the Federal programs for development of the technologies.

Table III Federal Energy R&D (in millions)

	FY 75		FY 76*		FY 77	
	BA	BO	BA	BO	BA	BO
Direct Energy R&D						
ERDA	$1,317.0	$1,011.0	$1,657.0	$1,427.0	$2,435.0	$2,009.0
DOI	89.9	54.2	104.0	93.3	98.3	96.3
EPA	80.8	18.2	56.8	76.6	55.4	76.6
NRC	58.9	51.7	87.5	76.9	104.0	98.2
NASA	0.8	0.8	1.7	1.0	-0-	0.8
Subtotal	1,547.4	1,135.9	1,907.0	1,674.8	2,692.7	2,280.9
Supporting R&D						
ERDA	362.0	313.0	403.0	373.0	430.0	404.0
DOI	33.2	30.9	59.0	56.7	66.8	65.2
EPA	53.2	5.0	43.2	43.4	41.6	43.4
NRC	2.3	2.1	9.6	9.1	5.3	5.0
NSF	103.2	65.9	114.6	74.2	123.4	106.9
Subtotal	553.9	416.9	629.4	556.4	667.1	624.5
Total Federal Energy R&D	$2,101.3	$1,551.9	$2,536.4	$2,231.2	$3,359.8	$2,905.4

* Funds for FY 76 Transition Quarter are not included.

Table IV ERDA Energy R&D Budget (Outlays in millions)

	FY 75	FY 76†	FY 77	FY 76 to FY 77 percent change*
Direct Energy R&D				
Nuclear Fuel Cycle and Safeguards	$ 120	$ 163	$ 282	73
Conservation	21	55	91	64
Geothermal	21	32	50	57
Fusion	151	224	304	36
Fission	538	522	709	36
Solar	15	86	116	35
Fossil	138	333	442	33
Environmental Control Tech.	7	12	15	24
Subtotal	1,011	1,427	2,009	
Supporting Research				
Basic Energy Sciences	165	188	205	9
Environmental Research	148	185	199	7
Subtotal	313	373	404	
Total ERDA Energy RD&D	$1,324	$1,800	$2,413	

† Funds for FY 76 Transition Quarter are not included.
* Percentage change calculated prior to rounding outlays.

Table V ERDA Energy R&D Budget (Authority in millions)

	FY 75	FY 76†	FY 77	FY 76 to FY 77 percent change*
Energy RD&D Programs				
Nuclear Fuel Cycle and Safeguards	$ 118	$ 173	$ 347	101
Conservation	36	75	120	60
Geothermal	28	31	100**	223
Fusion	183	250	392	57
Fission	567	602	823	37
Solar	42	115	160	39
Fossil	335	398	477	20
Environmental Control Tech.	8	13	16	23
Subtotal	1,317	1,657	2,435	
Supporting Research				
Basic Energy Sciences	191	210	227	8
Environmental Research	171	193	203	5
Subtotal	362	403	430	
Total ERDA Energy RD&D	$1,679	$2,060	$2,865	

† Funds for FY 76 Transitional Quarter are not included.
* Percentage change calculated prior to rounding authority.
** Includes $50 Million for Geothermal Loan Guarantee Program.

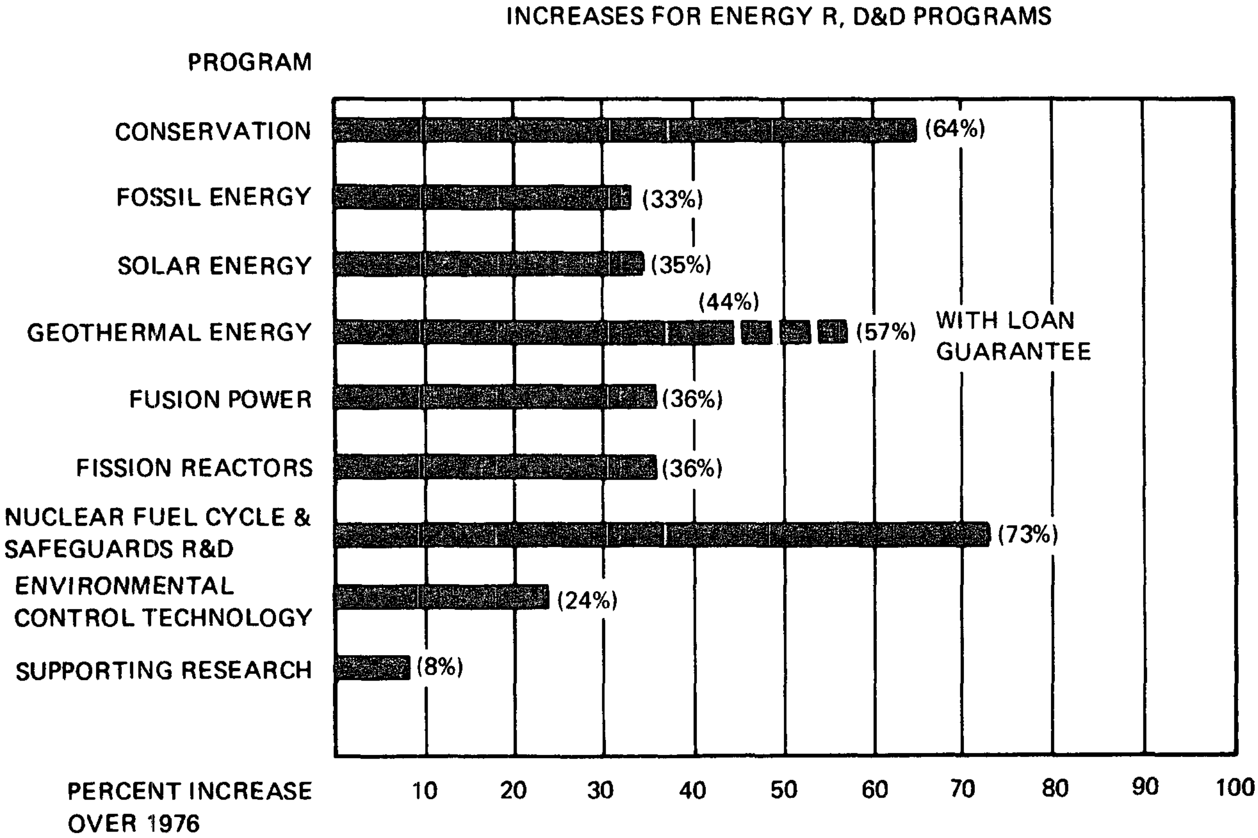


Figure III Energy Research and Development Administration FY 1977 Budget

This Plan focuses on a set of technologies (involving both supply and demand) and a related set of operational approaches. If successfully pursued, these approaches could result in significant market penetration of technologies that could ease the overall energy problem within the next critical decade.

The Plan therefore identifies seven high-priority technologies that have the potential for making significant energy contributions in the near term and mid term. They are:

- Conservation (energy efficiency)
- Light water reactors
- Enhanced oil and gas recovery
- Direct utilization of coal
- Synthetic fuels
- Geothermal energy
- Solar heating and cooling

The Plan develops a preliminary strategic approach for each, analyzing its marketability and a strategic approach to support its commercialization by the private sector.

The Plan also identifies strategies for the development of three high-priority programs with longer-term potential:

- Breeder reactors
- Solar electric
- Fusion

To be effective in supporting the private sector in the development and commercialization of energy technologies, the Federal Government must take the lead in helping to create mechanisms for interaction between ERDA and other public and private sector groups. Introduction of new energy technologies will directly or indirectly touch all Americans and all private institutions, and will require the concrete action of all—Congress, Federal Government agencies, state and local governments and regional groups, and the private sector.

An important operational element of the Plan, therefore, is to ensure the participation of each of these groups and to promote interaction among them, so that RD&D program planning can be responsive to the international, national, regional, and local objectives. To this end, the Plan outlines initiatives designed to:

- Promote and support cooperative international efforts to develop solutions to common energy problems

- Improve interaction among Federal agencies involved in energy RD&D
- Strengthen interfaces between ERDA and industry, state and local governments, universities, and the public
- Capitalize on ERDA's existing regional structure to coordinate research, development and demonstration of energy technology with local economic, environmental, and social concerns.

ERDA is developing an internal management system for analysis, resource allocation, implementation, and evaluation of its programs to ensure the most effort to complement the private sector in meeting national energy goals. The implementation of this system will take time, will be difficult, and will require the assistance of the private sector. It is vital that ERDA develop a well-coordinated and integrated system for program planning, budgeting, and review (PPBR system). Such a system is needed to provide a framework for:

- Analyzing the Nation's energy needs
- Formulating Federal plans for addressing those needs.
- Designing programs to carry out specific objectives.
- Allocating resources consistent with the Plan and programs
- Ensuring that the programs are effectively designed and managed.

For example, it is necessary in developing an energy plan to be able to determine which technologies are likely to be developed by the private sector with minimal government involvement and which will require more specific government assistance. To make these projections, planners must be familiar with industry criteria for market penetration and must be able to anticipate probable private sector behavior in terms of investor and consumer acceptance of new technology. If a technology is judged to be a poor commercial risk in the private sector, a judgment must be made as to whether the potential public benefits are sufficient to justify a government role. Inputs to determine this must come from interaction with industry and with the public (e.g., consumers, local and regional entities, environmental groups). This logic is presented in Figure IV.

Through the use of PPBR, the current process of establishing priorities among technologies in the Plan can be vastly improved. The PPBR system is being designed to develop an energy system option which can evaluate public and private rates of return and develop measures of relative value among technology programs.

It is anticipated that for each technology program, the system will develop five basic documents:

1. **Program Strategy:** This document will explore the need, if any, for a Federal role and the effectiveness of RD&D and other potential programmatic solutions as illustrated by Figure II. It will present a program strategy and establish the major goals and milestones for the program.
2. **Program Plan:** The program plan will chart the detailed course of the program, typically over a several-year period leading to a major programmatic decision (e.g., should a demonstration phase be undertaken?). The basis for the program plan is the program strategy, but the plan would be more specific in assigning program responsibility and developing management structure and will seek to define the most cost-effective Federal program to achieve the agreed objectives.
3. **Environmental Development Plan:** The plan for environmental development will be a companion document to the program plan, detailing the program of environmental research that must parallel technology development. Environmental issues involved in developing the technology are identified and a program outlined for resolving these issues in a time period consistent with the rate of technology RD&D.
4. **Program Approval Document:** This is an internal ERDA document that will present in some detail the activities to be conducted and milestones to be achieved within approved budgets for a given fiscal year. Its purpose is to provide a baseline for monitoring program operations.
5. **Environmental Impact Statement (EIS):** Within the structure of the National Environmental Policy Act, ERDA intends to use the EIS as a major input to decision processes. Where required, an EIS will be prepared to illuminate a major "go/no go" program decision. It summarizes the information developed by the Environmental Development Plan and uses it to address the issues raised. In this way, ERDA hopes that these issues can be identified at the start of an appropriate program phase, so that they can be systematically addressed.

Developing the Plan

Because the nature of the energy problem is dynamic, the annual revisions of this Plan can be expected to evolve in response to changes and to new information.

The National Plan for Energy RD&D is required to be updated annually to remain responsive to continuous changes in the external environment, both with regard to energy and non-energy events and policies. Technical and nontechnical

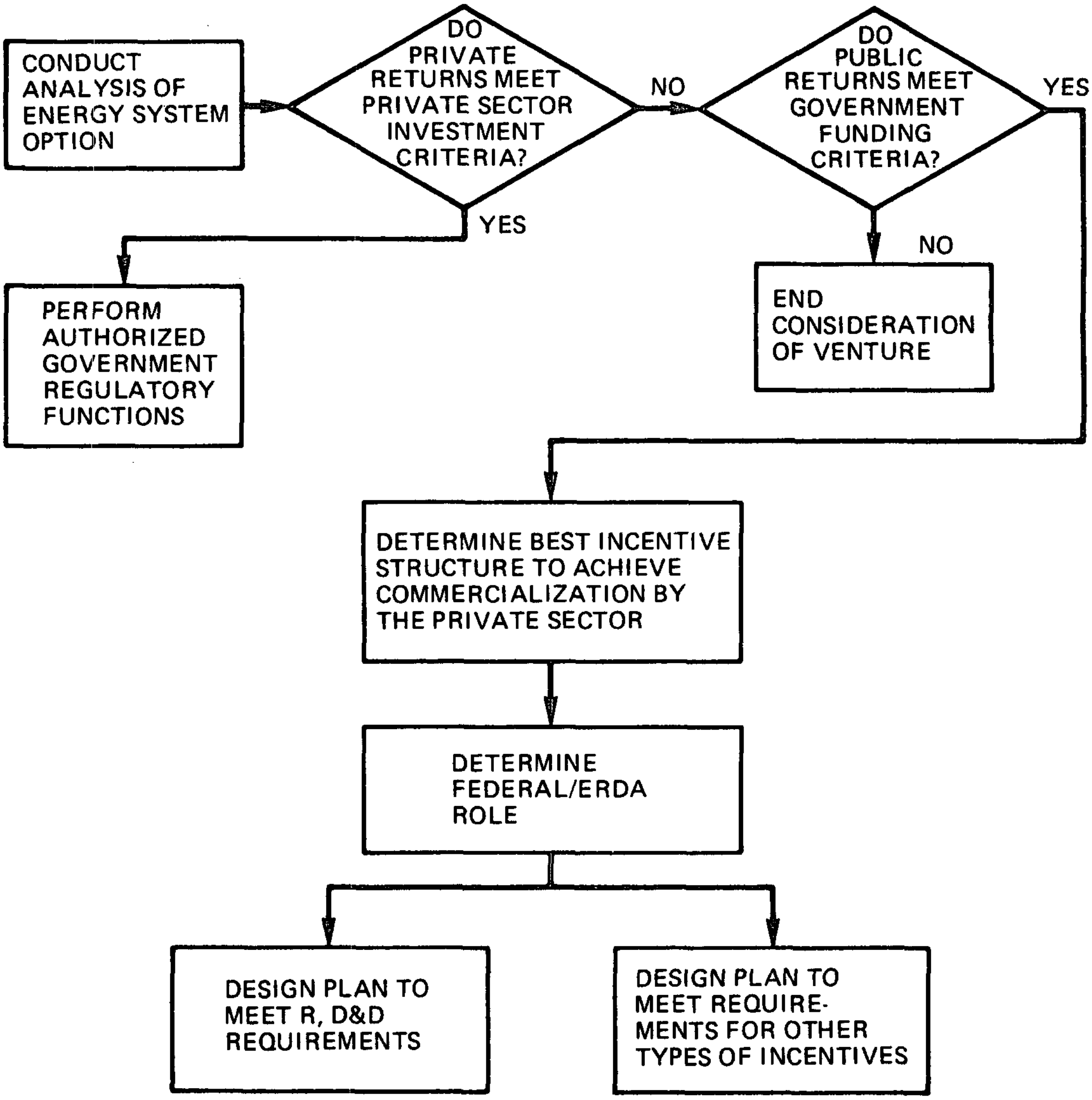


Figure IV Strategic Planning Logic

factors which constitute these changes and influence the evolution of this Plan can be characterized as:

- Assessments of international and domestic events and their effect on the Plan
- Assessments of the National Plan for Energy RD&D based on the viewpoints and insights of others
- Assessments of the results of energy systems analysis studies and their effect on the Plan
- Assessment of RD&D activities in the private sector.

An integral part of this Plan is a detailed program for improving the informational base for these assessments, facilitating ERDA's access to this information, and developing the tools to better analyze the implications of new energy technologies in terms of economic growth, environmental impact, and public policy.

Decisions on the adequacy of energy RD&D programs are being continually refined on the basis of improved analyses and evaluation mechanisms being developed within ERDA.

Successful implementation of new energy technologies will produce changes in the underlying economic and institutional systems of this country. To provide information to the public as a basis for wise energy choices, analyses of energy systems attempt to identify these changes and assess their potential impacts.

This update draws from preliminary conclusions from three selected areas of analysis aimed at:

- Understanding the relationships among energy, economic growth, and environmental impact as a result of the introduction of new energy technologies and other energy policy initiatives
- Calculating the net energy aspects of energy technologies
- Supporting market penetration initiatives through specific market studies (e.g., the Electric Utility Study mentioned in Chapter VI).

Most of these studies are not yet complete. It appears, however, that they will be useful in selecting promising energy technologies and in clarifying the degree of Federal participation—if any—required to develop and introduce new technologies. Analyses to date do not yet suggest the need for a sharp revision in the basic goals and strategies in this Plan.

Although it is too early to state with certainty what will be included in future reports, the results of three efforts essential to ERDA's own planning will probably be included and help to shape the next annual Plan.

These activities are:

- Developing benefits and costs of energy RD&D
- Establishing priorities for component programs
- Analyzing energy RD&D activities in the private sector.

During 1976, it is ERDA's goal to apply the tools of energy systems analysis to the quantification of costs and benefits of selected energy technologies and to report on this work in the next Plan.

Using its developing PPBR system, ERDA expects in the coming year to be able to extend the process of priority-setting to a much greater level of detail than is presently possible. The PPBR can make program priorities and the bases for resource allocations more explicit which, in turn, will help to delineate the implications of various alternatives.

Finally, as an essential means to reinforce and support private sector activities, it is ERDA's goal to initiate an analysis of ongoing and anticipated RD&D efforts in the private sector and to provide an interim report in the 1977 Plan.

Chapter I—The National Energy Problem and the Nature of Its Solution

The United States is a nation rich in domestic energy resources, yet depends on the importation of large quantities of fossil fuels. This is the essential paradox of the Nation's energy problem.

Today, over 75 percent of the Nation's energy demand is filled by petroleum and natural gas. These energy resources are in dwindling supply domestically and, ultimately, worldwide. Indeed, domestic production of these fuels has declined since the embargo of October 1973. On the other hand, coal, the most abundant domestic fossil fuel, supplies less than 20 percent of current energy needs, uranium provides only about 2 percent of the Nation's energy, and alternative sources such as solar or geothermal energy provide little or no energy. Clearly, the Nation relies most on the least plentiful domestic energy resources and least on the most abundant resources.

The present level of petroleum and natural gas use reflects their relative cost and abundance in the past. As a result, this Nation has not sought, until recently, as a matter of national policy either to explicitly limit the rate of energy growth or to develop an adequate range of readily available alternative energy supply systems for the future. Instead, the Nation has built up over the last half century a large infrastructure based on the production and use of petroleum and natural gas. The cost of this infrastructure exceeded $150 billion, and the Nation cannot afford to loose the value of this investment.

As a result of reliance on petroleum and natural gas and of the continuing decline of domestic production, the proportion of energy needs met by imports has remained at approximately 20 percent since the oil embargo, even despite the decreases in U.S. energy demand associated with the recent recession. The annual cost of this imported energy has risen from about $3 billion in 1970 to about $27 billion today. The difference in cost is mostly attributable to increases in price rather than absolute levels of imports. Most critically, foreign sources of these energy supplies have become less certain. Canada has restricted its exports to the U.S.; the Organization of Petroleum Exporting Countries (OPEC) cartel has exhibited cohesion and purpose in controlling prices and production in the face of weakened world demand; and the Middle East remains politically unstable.

But even if none of these things had happened, the long-term problem of a diminishing petroleum and natural gas resource base, both domestic and worldwide, remains. As standards of living increase throughout the world, the demand for petroleum and natural gas will increase for many countries. But the resource base will continue to decrease. The events of the last few years have served, importantly, to dramatize the resource problem. They create serious present difficulties, but they are only short-term manifestations of the longer term problem.

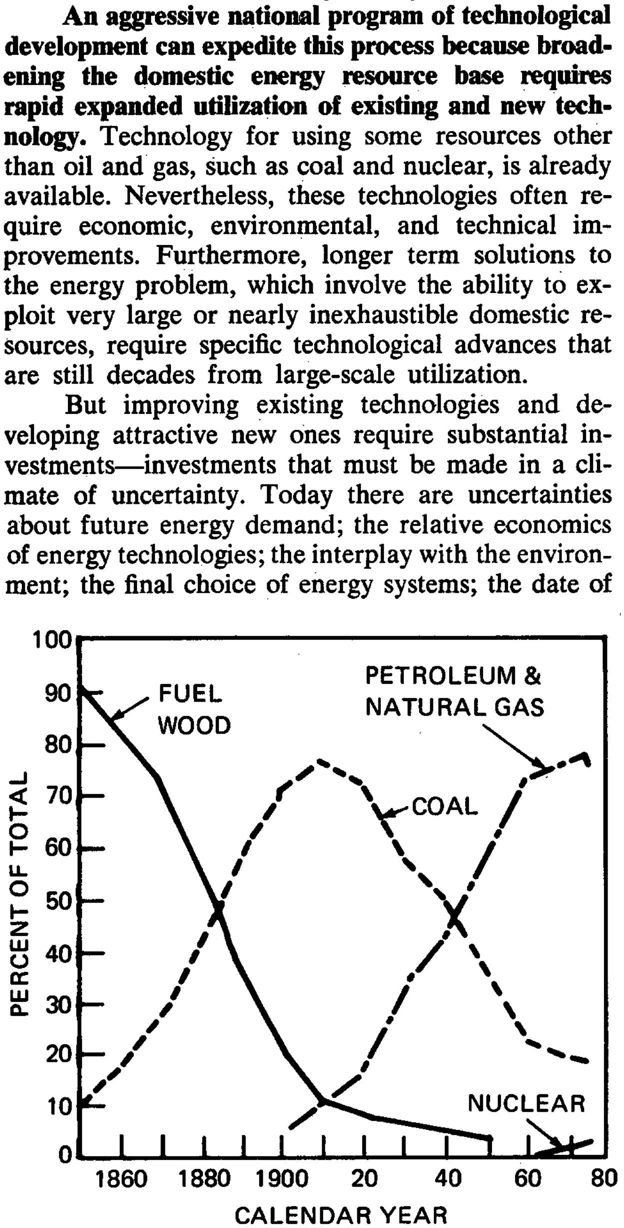
Solving the energy problem requires broadening the base of domestic energy resources and adapting to the new resource base more quickly than ever before.

A variety of domestic energy resources should be developed because it would reduce our excessive reliance on one form of energy—a reliance that has at times severely constrained national policy—and because social choice is likely to be best served by a range of energy choices. It is not possible to predict what the Nation's interests and its people's desired life style will be at the end of this century. But whatever those interests and desires are, a sufficient supply of affordable energy should be available to serve them. The social decisions on which technologies will be chosen for implementation and on the degree to which they will be employed can best be made if alternative energy forms are available.

The urgency of solution should also be stressed. Historical perspectives (Figure I-1) show that in the past it has taken about 60 years to move from reliance on one major energy resource to reliance on another. Domestic production of petroleum and natural gas now appears to have reached or passed its peak. The relative domestic market shares of these two energy supplies are expected to decrease with time. A transition to new energy resource bases must be accomplished, but this transition from dependence on a narrow base of diminishing resources to reliance on a broader range of less limited or unlimited alternatives must be made more swiftly than ever before. The Nation does not have 60 years this time if growth in the energy sector is to be supported without undue reliance on foreign energy sources.

An aggressive national program of technological development can expedite this process because broadening the domestic energy resource base requires rapid expanded utilization of existing and new technology. Technology for using some resources other than oil and gas, such as coal and nuclear, is already available. Nevertheless, these technologies often require economic, environmental, and technical improvements. Furthermore, longer term solutions to the energy problem, which involve the ability to exploit very large or nearly inexhaustible domestic resources, require specific technological advances that are still decades from large-scale utilization.

But improving existing technologies and developing attractive new ones require substantial investments—investments that must be made in a climate of uncertainty. Today there are uncertainties about future energy demand; the relative economics of energy technologies; the interplay with the environment; the final choice of energy systems; the date of



SOURCE: HISTORICAL STATISTICS OF THE UNITED STATES BUREAU OF THE CENSUS; U.S. BUREAU OF MINES, 1974

Figure I–1 U.S. Energy Consumption Patterns

introduction or the rate of implementation of a particular energy technology; developments that might impact on the worldwide energy problem; and other factors that affect the solution to the domestic energy problem.

Despite these uncertainties, decisions must be made today, without foreclosing future options, even though important information may be unavailable or analyses may be incomplete. Functioning effectively in this environment necessitates continuous feedback and readjustments which are necessary elements of planning under conditions of uncertainty.

The Role of the Private and Public Sectors

With few exceptions, the private sector is the main producer and consumer of energy. The role of the private sector is therefore paramount in the accelerated introduction of energy technology, and thus to the solution of the Nation's energy problem.

Specifically, the private sector is prepared to take risks, has the inherent flexibility to act, controls the preponderant share of new investment funds, and possesses the necessary managerial capabilities for carrying out most of the RD&D and virtually all of technology introduction. Moreover, market forces as they are perceived by decision-makers in the private sector will determine the economically optimum mix of alternative energy technologies to displace the undue reliance on petroleum and natural gas. **Thus, an important theme of this report is that the private sector and market forces are the most efficient means of achieving the Nation's energy goals.**

The role of the public sector, especially that of the Federal Government, is therefore supplementary —to do what cannot otherwise be done privately. The Federal role, in turn, divides into three parts. Government can establish an appropriate policy climate for private sector action, share risks with the private sector, and conduct a complementary RD&D program. Of course, all three may be required to introduce any single technology.

Establishing an Appropriate Climate

The preferred role of government is to establish an appropriate policy climate for technology introduction. In a few situations—notably uranium enrichment—the government is the sole commercial agent because of earlier activities growing out of its national security responsibilities. Current government initiatives in uranium enrichment would decrease the government's control and contribute to commercialization efforts by the private sector. In other situations, the government's regulatory role greatly affects the introduction of technologies. For example, changed government price regulations on oil and gas could make conservation technologies and more expensive enhanced-recovery techniques for oil and gas more attractive. Similarly, changing regulation of nuclear plants and other major installations could speed construction and lower the cost of the technologies. Such activities need to be continually assessed to ensure that a proper balance is maintained among various governmental objectives.

Other examples of government roles that can stimulate or inhibit private action are energy pricing policy and strategic storage (Federal Energy Administration); energy regulation (Federal Power Commission); investment tax credit (Department of the Treasury); environmental regulation (Environmental Protection Agency); Federally owned resource management (Department of the Interior); and siting standards (state and local governments).

In general, then, the preferred role for government is to establish an appropriate climate for private introduction of energy technology by:

- **Providing leadership and assistance:** Establishing a consistent energy policy and regulatory network
- **Managing energy resources located in Federal lands:** Making these resources available for use over time with due regard to environmental, aesthetic, conservation, land use, or other factors of national interest
- **Establishing and enforcing economic and antitrust regulation:** Making energy decisions consistent with national economic goals; providing energy to the American consumer at the lowest possible cost consistent with the need for secure energy supplies; assisting the development of standards, criteria, and certification procedures
- **Protecting human health and the environment:** Ensuring the protection of the Nation's environment and the public's health and safety
- **Coordinating Federal policy with international policy:** Coordinating the Nation's energy policies with those of other consuming and producing nations to promote interdependence as well as independence.

Sharing Risks

Even with a regulatory and policy climate more conducive to private investment, private action may fail to follow because risks remain excessive. Both technological uncertainty and the difficulty of projecting future economic conditions contribute to excessive risk, even when technical feasibility is known.

In these cases, government can stimulate private-sector action by sharing risks—that is, by absorbing the greater-than-commercially-acceptable risk of investing in energy technology.*

This relatively new government role has the advantage of producing a self-liquidating government interest in successful projects. It is a technique contemplated by the Federal Nonnuclear Energy Research and Development Act** and by other legislation administered by ERDA and other agencies.

At least four specific risk-sharing ventures are already in place or in the formative stage:

- The proposed Nuclear Fuel Assurance Act, designed to move a hitherto Government monopoly in uranium enrichment production into the private sector by temporary financial assurance to private enrichment firms
- The proposed synthetic fuels commercial demonstration program, aimed at constructing a first round of commercial-scale synthetic fuel plants (ERDA)
- The geothermal loan guarantee program,*** which will assist both RD&D and introduction of new geothermal technology (ERDA)
- The loan program to open new coal mines**** (FEA)

Beyond these specific ventures, the President has proposed the Energy Independence Authority (EIA). The EIA would have at its disposal a variety of tools to share the risks on many types of energy projects.

Conducting RD&D

Increasingly, RD&D is required to develop new technology that can subsequently be introduced to develop new domestic energy resources, or to exploit old resources more cleanly and safely. Much of this kind of RD&D is already being carried out by the private sector. But the private sector cannot conduct **all** the necessary RD&D; Federal help is necessary. However, a Federal RD&D program should neither act as a substitute for private funds nor invest too heavily in speculative projects that may never capture a place in the market.

The choice is difficult, but the Federal Nonnuclear Energy Research and Development Act† of 1974, one of the acts that establishes the basis for ERDA's programs, addresses this question. The relevant text states:

> "In determining the appropriateness of Federal involvement in any particular research and development undertaking, the Administrator shall give consideration to the extent to which the proposed undertaking satisfies criteria including, but not limited to, the following:
>
> (A) "The urgency of public need for the potential results of the research, development, or

* See Chapter V for a discussion of the criteria for government investment.

** Public Law 93–577, Section 7.

*** Title 2, Public Law 93–410, "Geothermal Energy Research, Development and Demonstration Act of 1974."

**** Public Law 94–163 "Energy Policy and Conservation Act."

† Public Law 93–577, Section 5(b)(2).

demonstration effort is high, and it is unlikely that similar results would be achieved in a timely manner in the absence of Federal assistance.

(B) "The potential opportunities for non-Federal interests to recapture the investment in the undertaking through the normal commercial utilization of proprietary knowledge appear inadequate to encourage timely results.

(C) "The extent of the problems treated and the objectives sought by the undertaking are national or widespread in their significance.

(D) "There are limited opportunities to induce non-Federal support of the undertaking through regulatory actions, end-use controls, tax and price incentives, public education, or other alternatives to direct Federal financial assistance.

(E) "The degree of risk of loss of investment inherent in the research is high, and the availability or risk capital to the non-Federal entities which might otherwise engage in the field of the research is inadequate for the timely development of the technology.

(F) "The magnitude of the investment appears to exceed the financial capabilities of potential non-Federal participants in the research to support effective efforts."

This legislative mandate fits closely with the nature of the technology-introduction problem discussed in this chapter. Sections (A) and (B) of the Act recognize the urgency of obtaining the results of RD&D—an urgency that may mandate government involvement. Similarly, Section (C) stresses the importance of the national benefits to be obtained and recognizes that local efforts may not produce them. Coal and nuclear energy are good examples of nationally important energy sources that may not be able to be tapped fully by local or regional efforts. Section (F) notes that some energy technology development is just too expensive for the private sector; fusion power illustrates this case.

At the same time, the Act infers that other avenues should be explored before deciding on direct Federal involvement. Section (D) suggests that obstacles to private action should first be removed, and Section (E) recognizes the potential value of risk-sharing.

The Role of Federal Agencies

When government needs to play any of its three roles, it requires the action of numerous Federal agencies:

- Various Federal agencies are responsible for recommending comprehensive national energy policy that is in balance with other national policies and priorities. Among these agencies are:
  —Energy Resources Council
  —Council of Economic Advisers
  —Council on Environmental Quality
  —Domestic Council
  —Water Resources Council
  —Federal Energy Administration.
- Various Federal agencies are directly involved in managing the expenditures of energy or related RD&D resources. Among these agencies are:
  —Energy Research and Development Administration
  —Department of the Interior
  —Environmental Protection Agency
  —Nuclear Regulatory Commission
  —National Science Foundation
  —National Aeronautics and Space Administration.
- Several agencies are involved in the regulatory aspects of environmental protection and human health and safety. Chief among these are:
  —Environmental Protection Agency
  —National Institute of Environmental Health Sciences
  —National Institute for Occupational Safety and Health
  —Department of Labor (Occupational Safety and Health Administration)
  —Occupational Safety and Health Review Commission.
- Other agencies are involved in setting standards and regulations for energy-related organizations. Among these are:
  —Federal Energy Administration
  —Federal Power Commission
  —Nuclear Regulatory Commission
  —Department of Commerce (National Bureau of Standards)
  —Department of Transportation
  —Federal Trade Commission
  —Interstate Commerce Commission
  —Federal Maritime Commission.
- Other agencies work with the private sector to assist the market penetration of key energy technologies. Among these are:
  —Department of Housing and Urban Development
  —Department of Commerce
  —Department of the Interior
  —Small Business Administration
  —Department of Transportation
  —General Services Administration.
- Finally, there are agencies that deal with other areas that have direct energy implications. Among these are:
  —Department of State
  —Department of the Treasury

—Department of Defense
—Department of Health, Education and Welfare.

The Role of ERDA

Energy RD&D is an important component of the total Federal role, and ERDA plays a leadership role here in three ways.

First, ERDA develops and updates this Plan. The Plan cannot, and is not intended to, represent technology as the total solution to the energy problems, predict certain success for any particular program, ensure immediate results, or preselect a single energy future. Rather, the Plan performs three principal functions:

1. Establishes a likely order of technology introduction from the near- to the long-term, and identifies current major guideposts for measuring and assessing* the rate of technology introduction. These guideposts can be useful in evaluating whether enough new technologies are being introduced to solve the Nation's energy problem, and in identifying possible compensatory government action.
2. Proposes energy RD&D priorities linked directly to the order of technology introduction. These national priorities are intended to be generally helpful in evaluating the national energy RD&D effort. In particular, the priorities bear on the allocation of government RD&D resources.
3. Stimulates debate on the technology options open to the Nation in the context of the total energy problem. ERDA believes this context, which forces the weighing of all alternatives together, facilitates the objective evaluation of individual technologies. It is a debate that should be encouraged.

Second, ERDA is responsible for monitoring and reporting on the entire Federal energy RD&D effort. In this way, a coordinated program aimed at common objectives is more likely to emerge. Volume II of this Plan summarizes the activities of 23 Federal agencies as they relate to the total RD&D program.

Finally, ERDA is the principal sponsor of Federal energy RD&D as well as of several risk-sharing programs.

This chapter has examined the energy problem and the nature of its solution, a sketch not so very different from that drawn in ERDA-48. More importantly, it has attempted to set forth the institutional structure in which the energy problem must be solved. Specifically, it has spelled out the division of responsibility between the private and the public sectors, as well as the three supportive roles played by the Federal Government. Similarly, the functions of the several Federal agencies, and especially ERDA, have been clarified, and the cooperation of the Federal energy RD&D program has been emphasized. However, a discussion of the crucial role to be played by state and local governments has been postponed until Chapter IV to simplify this discussion.

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* These assessments, which will be regularly included in subsequent editions of this document, are based on:
- How much domestic oil and gas is actually found and produced
- The availability of imports from secure sources, plus the backup protection against supply disruption that can be gained from stockpiling
- The degree and rate of implementation of both existing and emerging technologies
- The degree of modification of life styles the Nation finally adopts
- The degree of end-use efficiencies that may finally be attained
- The level of effort that can be allocated to the development of new technology by the public and private sectors
- The economic and technical success finally achieved by new technologies
- The extent of environmental, economic, and sociopolitical considerations.

Chapter VI discusses such assessments more fully.

THE PLAN

Chapter II—Fundamentals of the Plan

The National Plan for Energy Research, Development and Demonstration has been formulated as an integral part of the overall policy for addressing the Nation's energy needs. It is responsive to the national energy policy goals and principles enunciated by the President (see Preface). While its emphasis is on technological development, it is consistent with and reflects broader policy concerning import levels, foreign relations, the needs of industry and consumers, fiscal policy, environmental protection, and human health and safety.

This chapter presents the fundamentals of the National Plan for Energy RD&D:

- National policy goals related to energy
- National energy technology goals
- Strategy and priorities for RD&D.

In addition, the final section of the chapter discusses specific supporting technologies, basic energy science, and environmental research.

National Policy Goals Related to Energy

The National Plan for Energy RD&D is based on five national goals formulated to guide the introduction of new technology:

- Maintain the security and policy independence of the Nation
- Maintain a strong and healthy economy, providing adequate opportunities and allowing fulfillment of economic aspirations (especially in the less affluent parts of the population)
- Provide for future needs so that future life styles remain a matter of choice and are not limited by the unavailability of energy
- Contribute to world stability through cooperative international efforts in the energy sphere
- Protect and improve the Nation's environmental quality by assuring that the preservation of land, water, and air resources is given high priority.

These goals express ERDA's current understanding of the national interest with respect to energy technology, and should therefore serve as the basis for energy RD&D in both the private and public sectors. Because of their fundamental importance, these goals merit continued scrutiny and debate.

The Need for Choices

To achieve the national policy goals related to energy, the U.S. must have the flexibility of a broad range of energy choices.

It is not possible to predict now what our Nation's interests and its people's desired life style will be at the end of this century. Whatever those interests and desires are, however, energy should be available to serve them. The present situation, in which national policy and social choices are constrained by overreliance on increasingly scarce forms of energy, cannot be allowed to recur.

It would be presumptuous now for the Nation to select a single technological course of action toward long-term energy independence. The successful exploitation of new energy sources and the reduction of the growth rate of energy demand require a broad range of approaches. Central among these is the development and deployment of new technology; that is the focus of this Plan. Because technology development is uncertain, commitment now to one set of technologies for the future would ignore the possibility of failure. Even if technological success were guaranteed, it would be impossible to ensure that the resulting technology would be best suited for future conditions.

Finally, it is reasonably certain that the Nation would be better served by leaving to the future the ultimate choices of how much energy is consumed, which technologies are actually implemented, and to what degree. To provide limited options for the future would undermine the strengths of the market place and individual choices of life style.

Responding to the Problem

In its immediate response to the energy situation, the Nation is currently limited to two choices: importing more oil and natural gas or making do with less energy. Successful achievement of national goals, however, mandates a more positive policy aimed at exploitation of domestic resources and reduction of unnecessary waste in energy consumption.

The Nation has several possible courses of technological development that can assist in solving the energy problem. The first course of action is to produce more of the major fuels in use today. Secondly, new technologies to expedite the transition to resources that are presently under-used (e.g., solar energy for heating, geothermal) or essentially inexhaustible (e.g., fertile uranium for breeding, fusion fuels, solar energy for electrical generation) can be developed and introduced. Thirdly, to make better use of more plentiful resources, actions can be taken to alter present patterns of end-use consumption. These actions can facilitate the shift of major end-use sectors from dependence on scarce fuels to more plentiful resources. As an example, electrification of land transportation would terminate present dependence on oil and gas and allow needs to be met by any of the basic resources, all of which can be used to generate electricity. Finally, efficiency improvements can be made both in the conversion of resources into energy and in the end-use devices that use this energy to meet societal needs.

All these desirable courses of action, if they are to achieve their full potential, require the development and implementation of new or improved technology.

National Energy Technology Goals

The framework for organizing a National Plan for energy RD&D must be established in relation to the five national policy goals and must permit a positive response to the energy problem. To provide this framework, the four courses of technological development discussed above have been expanded into a set of national technology goals. Two additional goals have been added to cover activities that support all technological approaches. The set of national energy technology goals is as follows:

I. Expand the domestic supply of economically recoverable energy-producing raw materials
II. Increase the use of essentially inexhaustible domestic energy resources
III. Efficiently transform fuel resources into more desirable forms
IV. Increase the efficiency and reliability of the processes used in energy conversion and delivery systems
V. Transform consumption patterns to improve energy use
VI. Increase end-use efficiency
VII. Protect and enhance the general health, safety, welfare, and environment related to energy
VIII. Perform basic and supporting research and technical services related to energy.

These goals emphasize not only the development of technologies related directly to the energy supply, but also the development of technologies that focus on the:

- Crucial importance of reducing energy waste and increasing the efficiency of energy use in all sectors of the economy through the application of existing and new technologies
- Major role of technologies in protecting and enhancing the quality of the human and physical environment, a concept that must be fully integrated into all aspects of energy production and use
- Need for basic research and technology transfers from other high-technology areas to support and stimulate continuing innovation in the energy technology area.

The supply and demand technologies related to goals I through VI are listed in Table II-1. The table also shows the best estimates (developed last year) of the energy impact in the year 2000 of an aggressive but potentially attainable rate of introduction of each technology, and indicates the time frame in which each technology would begin to have an impact. This table summarizes the current spectrum of technology options from which the Nation may select and introduce new energy technology if economic and other criterias are met. Before a strategy for achieving these goals can be developed, however, it is necessary to examine the Nation's energy resource base—the resources presently available to address the Nation's energy problem.

The Importance of Resources

A crucial requirement in the development of a National Plan for Energy RD&D is an understanding of the Nation's energy resource base. That understanding must begin with knowledge of those resources currently in widespread use and known to exist, and those currently unused or under used. Despite the great visibility of new and exotic energy forms in both general and technical literature, the fact remains that the U.S. currently depends on coal, petroleum gases and liquids, hydroelectricity, and nuclear power to meet 99 percent of its energy needs. More critically, 75 percent of these needs are met solely by petroleum and natural gas, both of which are in limited domestic supply.

The following discussion of the Nation's resources will develop and illustrate two key points:

- The Nation possesses very large domestic fuels resources that are under-used or not used at all.
- The magnitude of the recoverable resources and, in many cases, even their availability are dependent upon technology.

Reliance on a Narrow and Declining Resource Base

The urgency of the need for transition to new energy sources emerges clearly from the intensive reappraisal of the Nation's oil and gas resources performed by the United States Geological Survey (USGS) and independently supported in a study by the National Academy of Science (NAS). These esti-

Table II–1 Technologies Now Available for Pursuing Major Energy Technology Goals

The last column of this table presents data from ERDA–48. It represents the maximum impact of the technology in any scenario measured in terms of additional oil which would have to be marketed if the technology were not implemented. Basis for the calculation is explained in Appendix B of ERDA–48. These data are being reexamined, and changes will be made when analysis is completed. In a number of cases, revised projections of the impacts will be lower.

Technology	Term of Impact*	Direct Substitution for Oil & Gas**	RD&D Status	Impact in Year 2000 in Quads
GOAL I: Expand the Domestic Supply of Economically Recoverable Energy Producing Raw Materials				
Oil and Gas—Enhanced Recovery	Mid	Yes	Pilot	13.6
Oil Shale	Near	Yes	Study/Pilot	7.3
Geothermal	Mid	No	Lab/Pilot	3.1-5.6
GOAL II: Increase the Use of Essentially Inexhaustible Domestic Energy Resources				
Solar Electric	Long	No	Lab	2.1-4.2
Breeder Reactors	Long	No	Pilot/Demo	3.1
Fusion	Long	No	Lab	—
GOAL III: Efficiently Transform Fuel Resources Into More Desirable Forms				
Coal—Direct Utilization Utility/Industry	Near	Yes	Pilot/Demo	24.5
Waste Materials to Energy	Near	Yes	Comm	4.9
Gaseous & Liquid Fuels from Coal	Mid	Yes	Pilot/Demo	14.0
Fuels from Biomass	Long	Yes	Lab	1.4
GOAL IV: Increase the Efficiency and Reliability of the Processes Used in the Energy Conversion and Delivery Systems				
Nuclear Converter Reactors	Near	No	Demo/Comm	28.0
Electric Conversion Efficiency	Mid	No	Lab	2.6
Energy Storage	Mid	No	Lab	—
Electric Power Transmission and Distribution	Long	No	Lab	1.4
GOAL V: Transform Consumption Patterns to Improve Energy Utilization				
Solar Heat & Cooling	Mid	Yes	Pilot/Demo	5.9
Waste Heat Utilization	Mid	Yes	Study/Demo	4.9
Electric Transport	Long	Yes	Study/Lab	1.3
Hydrogen in Energy Systems	Long	Yes	Study	—
GOAL VI: Increase End-Use Efficiency				
Transportation Efficiency	Near	Yes	Study/Lab	9.0
Industrial Energy Efficiency	Near	Yes	Study/Comm	8.0
Conservation in Buildings and Consumer Products	Near	Yes	Study/Comm	7.1

* Near—now through 1985
Mid—1985 through 2000
Long—Post-2000
** Assumes no change in end-use device.

mates were used in ERDA–48 to project domestic petroleum and natural gas production.

The amount of oil and gas considered to be economically recoverable is subject to wide variations, reflecting different assumptions about undiscovered resources, technology, and price. Responsible estimates of remaining recoverable resources vary by a factor of two or more. All major estimates agree, however, that at current levels of use, domestic supplies of oil and gas cannot support projected energy demands for very long.

The implication of the USGS and NAS estimates is that current rates of oil and gas production by conventional methods will be difficult to maintain, even with additional Outer Continental Shelf and Alaskan production. Without enhanced recovery, the USGS estimates indicate that production of domestic oil and natural gas will begin to drop rapidly in the mid 1980's. It is unlikely that major new energy sources will be ready by that time.

New estimates of domestic recoverable resources may present a more optimistic picture. However, for purposes of planning for alternative RD&D programs, it is more prudent to use the lower band of existing estimates. In either case, as Dr. McKelvey, Director of the USGS, has said:

> . . . higher and lower estimates still carry the same message on several important policy questions. All indicate that substantial amounts of fluid hydrocarbons remain to be discovered if exploration is encouraged. All indicate that one of the largest

targets for future production is the oil presently remaining in place that might be available if recovery technology is advanced. All emphasize the importance of frontier areas, and all show that it is necessary soon to develop other sources of energy as the mainstay of our future energy supply.*

Specific Changes in Resource Estimates Since ERDA–48

Estimates of the major recoverable domestic resources are shown in Figure II-1. The shaded areas in this figure indicate the additional resources that may become recoverable if the technology can be developed to make this feasible. The figure and the estimates are identical to those presented in ERDA–48 with the following exceptions:

- **An increase in the estimate of coal resources.** The recoverable resource level, estimated at 12,000 quads in ERDA–48, has been increased to 13,300 quads (an 11 percent increase) to reflect a new resource assessment by USGS.** The new USGS estimate showed an overall 25 percent increase in total coal resources (including resources not currently considered economically recoverable).
- **The addition of solar energy to the recoverable resource base.** The estimate shown in the chart (43,000 quads per year) represents the average solar flux incident on the U.S. per year, and indicates the high contribution **potential** of this resource. However, significant technical problems are associated with the use of solar energy. Since energy flux is relatively low in energy value and is intermittent in a terrestrial application, the practical application of solar energy requires the availability of large collecting structures and energy storage. (For example, 20,000 to 30,000 acres of thermal collector area are required for a 1,000 megawatt electric plant at today's collection efficiences.) Furthermore, solar energy technologies and their applications will require varying degrees of further development before they can become economically viable. Some water and space heating systems are being introduced in the U.S.; however, considerable technological development is required before solar energy in other forms can be used efficiently and economically.
- **The addition of fusion to the recoverable resource base.** The estimate of 3 trillion quads reflects the

* Department of the Interior News release, May 1975.
** See Chapter VI for a more detailed assessment of this new assessment.

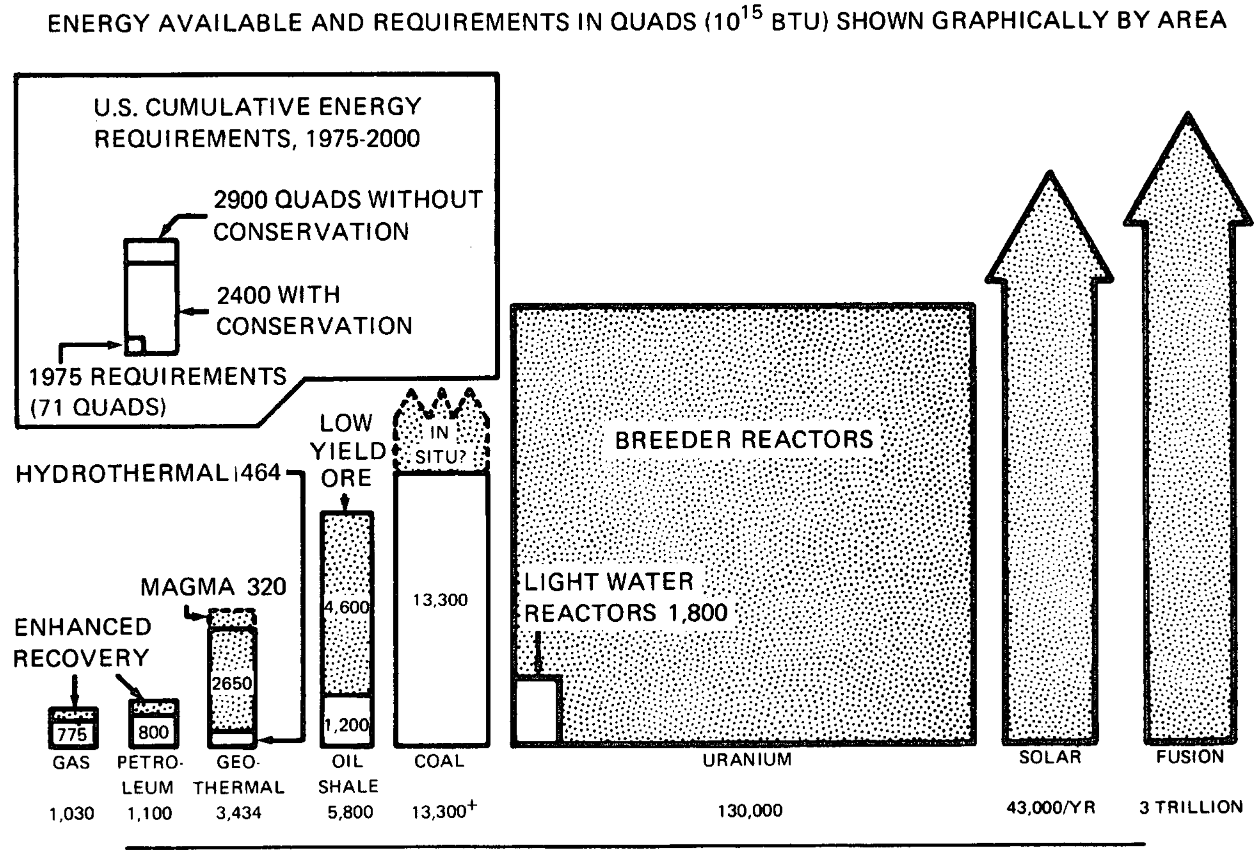


Figure II–1 Recoverable Domestic Energy Resources

potential energy that can be derived from the deuterium in the oceans. In theory, fusion energy is capable of providing all the energy needed for an indefinite period. Through the RD&D process, scientists are attempting to translate that theory into practice. Difficult scientific, engineering, and economic problems will have to be solved even after success has been achieved in producing the necessary controlled thermonuclear reaction. Nevertheless, the resource base is so large that success will ensure a virtually limitless energy source.

- **The addition of geothermal energy to the recoverable resource base.** The geothermal estimate is based on a new assessment of resources* that considers utilization of present or near-term technology without regard to cost. Most important currently is the recoverable heat portion of hydrothermal convective resources. In the mid term (1985–2000), the liquid-dominated hydrothermal resources and the geopressured resources (including dissolved methane) could become viable options, for both electric power generation or direct use as heat. The mid- to long-term (2000 and beyond) geothermal potential of the total heat resource within the earth's crust is undoubtedly very large, in the forms of hot dry rock, heat flows evidenced by temperature gradients that are either "normal" or enhanced by natural radioactive decay, and ultimately even magma (molten rock).
- **The addition of energy demand estimates (1975–2000) with and without conservation.** Energy conservation is shown to reduce the cumulative requirements by over 15 percent. The demand estimates are based on the scenarios contained in ERDA–48.

Implications of the Resource Estimates

Figure II-1 shows the relative paucity of domestic oil and gas resources compared to the estimated cumulative energy demand from now until the end of the century. Coal and nuclear represent the major exploitable resources to supplement oil and gas over the next several decades. Geothermal, oil shale, and solar energy (in the form of solar heating and cooling) represent supporting resources to ease overall supply problems during that time period. Nuclear breeders, solar electric, and fusion represent technologies that can exploit major resources for the next century; these technologies also have the potential to contribute to meeting energy needs during the latter part of this century.

In summary, even though the Nation is blessed with abundant energy resources, it is presently dependent upon a narrow base of diminishing resources. Accordingly, the National Plan for Energy RD&D describes likely options for introducing new technology that will assist the changeover from dependence on this narrow base of diminishing domestic resources to reliance on a broader range of less limited alternatives.

The transition to less limited resources poses substantial technological and environmental problems. Of equal importance are the difficult economic, social, and institutional problems that will be associated with this transition. An RD&D program, however successful technically, can fail because of failure to solve any one of these problems. These problems are addressed in later sections of this report.

Strategy and Priorities for RD&D

A National Plan for Energy RD&D should be guided by the policy and technology goals established. It must also reflect the reality of available domestic energy resources and the developmental status of technologies needed to use these resources. To translate the understanding developed thus far into an RD&D program, however, it is necessary to compare the potentials of the wide spectrum of technology options currently under investigation. Definitions of major technological options to be considered in the Plan are presented in the Glossary. Twenty-one major RD&D technologies and 14 supporting technologies are described.

ERDA–48 examined a number of combinations from the spectrum of technology options to establish both an overall strategy and specific energy RD&D priorities for the principal supply and demand technologies. Subsequent analysis, described in Chapter VI, has changed the strategy and priorities of ERDA–48 in one important respect:

Priority Ranking of Conservation now significantly increased. This major change from ERDA–48 reflects observation of only moderate progress to date on supply technologies, public comment on ERDA–48, and further analysis of conservation opportunities. Specific reasons for assigning higher priority to energy efficiency technologies are identified below. Many of the technologies to improve energy efficiency currently appear to have one or more of the following characteristics.

- A barrel of oil saved can result in reduced imports. Conservation combined with fuel substitution efforts reduces dependence on foreign oil. The focus is on cost-effective approaches since not everything that saves energy should be implemented at this time. Technology development should increase the number of cost-effective approaches available.
- It typically costs less to save a barrel of oil than to produce one through the development of new technology.

* See Chapter VI for a more detailed discussion of this new assessment.

- Energy conservation generally has a more beneficial effect on the environment than does energy produced and used.
- Capital requirements to increase energy-use efficiency are generally lower than capital needs to produce an equivalent amount of energy from new sources since most new supply technologies are highly capital-intensive.
- Conservation technologies can generally be implemented at a faster rate and with less government involvement in the near-term than can supply technologies.
- Energy efficiency actions can reduce the pressure for accelerated introduction of new supply technologies. Since the actions persist over time, the benefits are continuing in nature.

These reasons deal generally with conservative technologies. The rate of application and introduction of conservation technologies in specific instances will be determined by the comparative economics and social acceptability of the available alternatives.

Strategy of Energy Technology

With this revision, ERDA now views the likely order of technological change in energy supply and demand as follows:

For the near-term (now to 1985) and beyond, technology will help to:

- Increase the efficiency of energy used in all sectors of the economy and extract more usable energy from waste materials
- Preserve and expand major domestic energy systems: coal, light water reactors, and gas and oil from new sources and by enhanced recovery techniques.

For the mid-term (1985–2000) and beyond, technology will help to:

- Accelerate the development of new processes for producing synthetic fuels from coal and extracting oil from shale
- Increase the use of fuel forms such as geothermal energy, solar energy for heating and cooling, and extraction of more usable energy from waste heat.

For the long-term (past 2000), technology will help to:

- Permit the use of the essentially inexhaustible resources: nuclear breeders; fusion; and solar electric energy from a variety of options including wind power, thermal and photo-voltaic approaches, and ocean thermal gradients
- Provide the technologies to use the new sources of energy, which may be distributed as electricity, hydrogen, or other forms throughout all sectors of the economy.

Table II-2 presents the spectrum of technology options listed in Table II-1 in these strategic terms.

Table II–2 The Strategy of Technology Introduction

Time of Impact	Strategic Element	Technology	Impact in Year 2000 (Quads)
Near-term (now to 1985 and beyond)	Increase efficiency of energy use and convert waste to energy	Conservation in Buildings and Consumer Products	7.1
		Industrial Energy Efficiency	8.0
		Transportation Efficiency	9.0
		Waste Materials to Energy	4.9
	Preserve and expand oil, gas, coal, and nuclear	Coal-Direct Utilization in Utility/Industry	24.5
		Nuclear-Converter Reactors	28.0
		Oil & Gas Enhanced Recovery	13.6
Mid-Term (1985-2000 and beyond)	Accelerate development of synthetic fuels from coal and shale	Gaseous and liquid fuels from Coal	14.0
		Oil Shale	7.3
	Increase use of under-used (limited application) fuel forms and extract more usable energy from waste heat	Geothermal	3.1–5.6
		Solar Heating & Cooling	5.9
		Waste Heat Utilization	4.9
Long-Term (past 2000)	Develop the technologies necessary to use the essentially inexhaustible fuel resources	Breeder Reactors	3.1
		Fusion	—
		Solar Electric	2.1–4.2
	Develop the technology necessary to change the existing distribution systems to accommodate the distribution of new energy sources.	Electric Conversion Efficiency	2.6
		Electric Power Transmission & Distribution	1.4
		Electric Transport	1.3
		Energy Storage	—
		Hydrogen in Energy Supplies	—
		Fuels from Biomass	1.4

Table II-3 presents the strategy in more concrete terms—the numbers of energy facilities that would be built if all the technologies were successfully introduced. These estimates are not additive, since not all technologies must be introduced fully to satisfy demand in the year 2000.

While these tables are not prescriptive, they potentially provide a set of yardsticks useful in assessing the actual rate of technological introduction. Such assessments are essential to shaping the Federal role in developing energy* technology to fit progress being made in the private sector.

National RD&D Priorities

Based on an understanding of the strategic role of technology in solving the Nation's energy problem, it is possible to suggest what type of energy RD&D is most important. Several observations are helpful in understanding the nature and use of these priorities, presented in Table II-4.

1. **The highest supply and demand technology priorities stem directly from the strategic assessment described in the preceding section.**

Table II–3 Numbers of Major Facilities Potentially Required by Year 2000

Type of Energy Facilities	Number of Equivalent Facilities: Potentially Required in 2000	Existing in 1975
Fossil Power Plants (1000 MWe equivalent)	500–800	400
Nuclear Power Plants (1000 MWe equivalent)	450–800	37
Geothermal Power Plants (1000 MWe equivalent)	40–100	0.5
Solar Electric Power Plants (1000 MWe equivalent)	50–100	0
Coal Mines (one million tons/year equivalent)	1600–2370	640
Coal Liquefaction or Gasification Plants (50,000 b/d oil equivalent)	70–140	0
Oil from Shale Plants (50,000 b/d oil equivalent)	40–80	0
Buildings (millions) Solar Heated and Cooled	13–22	negligible
Heat Pumps (millions)	13–26	0.2
Electric Automobiles (millions)	10–20	negligible

Notes
- The list is non-additive because different technologies serve the equivalent energy markets in different scenarios.
- Source for the date is the ERDA–48 scenarios.
- MWe = megawatts electric
- b/d = barrels per day

2. **Under-used (limited application) mid-term technologies such as geothermal and solar heating and cooling are assigned only a moderate priority in the ranking.** However, certain applications of these technologies can have an impact on the Nation's energy demand in the mid term with the establishment of an industrial base. These technologies are important because they are sufficiently well-developed to be employed on a regional basis where the resources can be exploited economically. The geothermal resources and technologies included in this category are limited to hydrothermal and geopressurized applications, and the solar heating and cooling technologies may be limited to areas that enjoy high levels of insolation and experience relatively high costs for alternative fuels.

3. **A lower priority is assigned to technologies supporting intensive electrification, and to hydrogen and biomass systems.** Electrification technologies and hydrogen systems are likely to be very important to an economy powered by breeders, solar electricity, and fusion power. As the importance of electrification increases over time, the priorities for these technologies should also be increased. Further study may also reveal specific applications within the broad technologies that should receive a high priority now.

4. **Notwithstanding the differences in priorities, some work on all the energy technologies is appropriate now.** A number of factors support this conclusion:

- A specific RD&D can fail entirely, or can produce results much later than expected. It would thus be unwise to restrict the number of RD&D efforts on the assumption that anyone will be successful.
- The long lead times characteristic of the technologies for using inexhaustible resources require that RD&D be undertaken now to ensure their timely availability. Figure II-2 summarizes this problem.
- Only the successful development and implementation of a number of technologies in a combination of approaches can provide adequate solutions to the present energy problem.
- Curtailment of any major existing energy source (e.g., nuclear power) places heavy demands on all the remaining options.

These overall RD&D priorities have a number of uses, as well as some limitations. Both their uses and limitations are important to a proper understanding of the priorities.

- **The priorities help in assessing progress toward the energy technology goals.** RD&D is a precursor of technology introduction. Therefore, RD&D progress, or lack of it, provides early indications of whether the technological strategy is proceeding as planned.
- **The priorities form the basis for Federal action.** When any of the three Federal roles is justified, the priorities help determine its urgency.

Table II-4 Proposed National Ranking of RD&D Technologies*

HIGHEST PRIORITY DEMAND	
NEAR-TERM CONSERVATION (EFFICIENCY) TECHNOLOGIES	• CONSERVATION IN BUILDINGS & CONSUMER PRODUCTS • INDUSTRIAL ENERGY EFFICIENCY • TRANSPORTATION EFFICIENCY • WASTE MATERIALS TO ENERGY
HIGHEST PRIORITY SUPPLY	
NEAR-TERM MAJOR ENERGY SYSTEMS	• COAL-DIRECT UTILIZATION IN UTILITY/INDUSTRY • NUCLEAR-CONVERTER REACTORS • OIL AND GAS ENHANCED RECOVERY
NEW SOURCES OF LIQUIDS AND GASES FOR THE MID TERM	• GASEOUS AND LIQUID FUELS FROM COAL • OIL SHALE
"INEXHAUSTIBLE" SOURCES FOR THE LONG TERM	• BREEDER REACTORS • FUSION • SOLAR ELECTRIC
OTHER IMPORTANT TECHNOLOGIES	
UNDER-USED (LIMITED APPLICATION) MID-TERM TECHNOLOGIES	• GEOTHERMAL • SOLAR HEATING AND COOLING • WASTE UTILIZATION
TECHNOLOGIES SUPPORTING INTENSIVE ELECTRIFICATION	• ELECTRIC CONVERSION EFFICIENCY • ELECTRIC POWER TRANSMISSION AND DISTRIBUTION • ELECTRIC TRANSPORT • ENERGY STORAGE
TECHNOLOGIES BEING EXPLORED FOR THE LONG TERM	• FUELS FROM BIOMASS • HYDROGEN IN ENERGY SYSTEMS

*Individual Technologies are not ranked within the technology categories.

The priorities are not simply related to the allocation of ERDA RD&D resources. As outlined in Chapter I and discussed in detail in Chapters III and V, the chain of events from national priorities to ERDA programs is a long one. A Federal role must first be justified, and the relative importance of Federal RD&D—as opposed to other Federal actions—assessed. When Federal RD&D is indicated, ERDA may not be the appropriate agency to conduct the related programs. Further, the level of ERDA resource commitment is also influenced by the stage of technology development and the overall size of ERDA's budget.

Despite their limitations, these RD&D priorities should serve as a useful tool in linking both private and public RD&D to the national interests in energy technology.

Specific Supporting Technologies

Successful implementation of the RD&D strategy to develop and implement the primary RD&D technologies requires the concurrent development of technologies that provide specific support. The priority and status of these technologies, listed in Table II-5, derive from the technologies to which they relate.

The following list, originally included in ERDA-48, presents specific supporting technology activities:

- More rapid and complete assessment of domestic uranium resources

Table II-5 Supporting Technologies

Specific Supporting Technologies:	Exploration and Resource Assessment Mining and Beneficiation Environmental Control Technology Nuclear Safeguards Support to the Nuclear Fuel Cycle Uranium Enrichment Fossil Fuel Transportation Waste Management

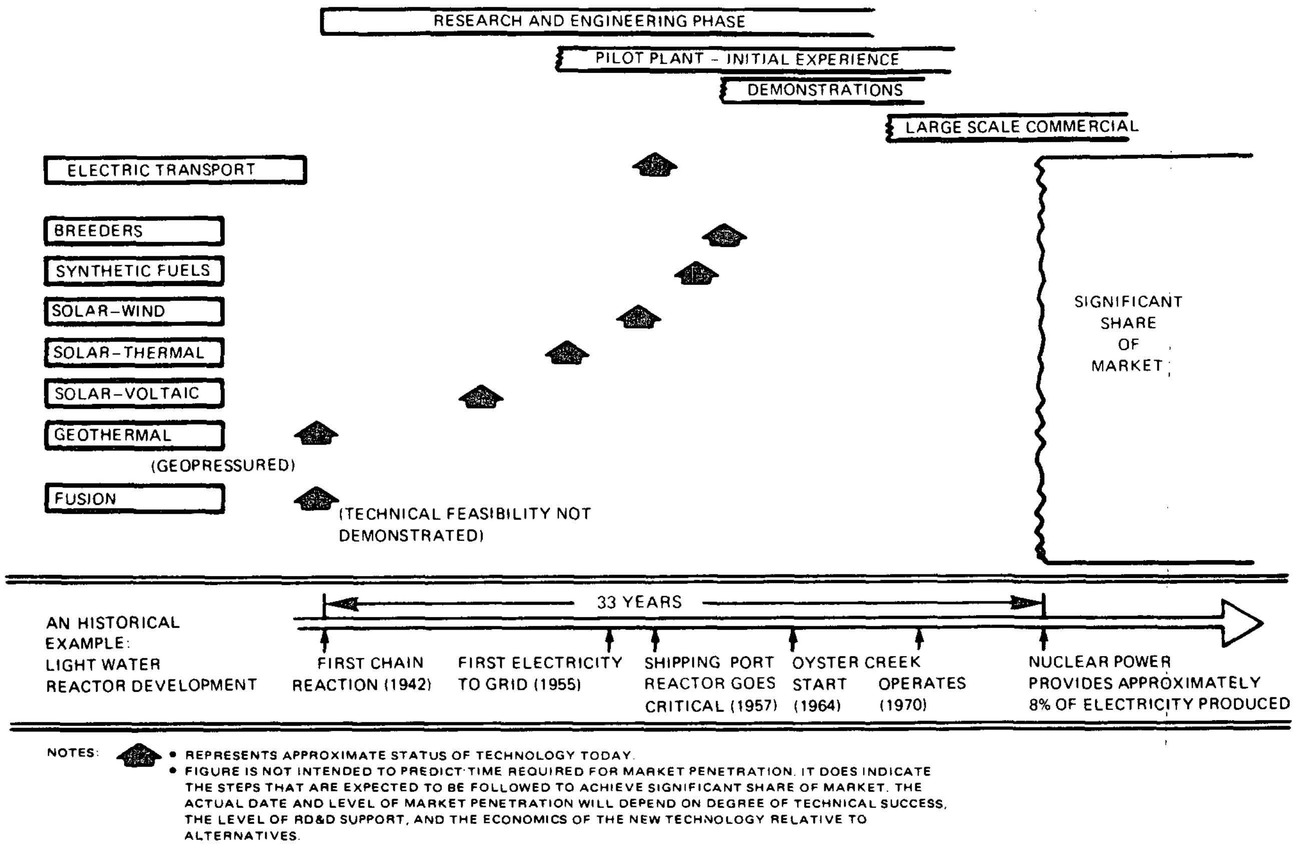


Figure II–2 Status of Longer Range Technologies

- Expansion of coal availability and use through improved mining and environmental control technologies
- Increased effort toward understanding biomedical and environmental consequences of waste products generated and dispersed by fossil energy technologies
- Emphasis on resolution of nuclear safeguard issues to strengthen the viability of the nuclear option
- Increased effort on light water reactor fuel cycle technology where information and experience are required to resolve issues of chemical processing, plutonium recycling, and waste management
- Early expansion of the U.S. nuclear fuel enrichment capacity through diffusion, centrifuge, and other techniques.

Basic Energy Science and Environmental Research

Two of the energy technology goals do not involve direct supply and demand energy technology. They do, however, encompass two critical technological activities: basic energy science and environmental research.

Basic Energy Science

Basic energy science provides the seeds for future technological advances. The basic strategy of the National Plan for Energy RD&D is that the Nation must rapidly change to new energy technologies and new resource bases. Much of the research to accomplish this massive task will be developmental and applied, and will be performed by the private sector or in certain cases by the government.

To develop new knowledge relevant to the Nation's energy goals, an accompanying program of longer range, more fundamental research must also be established. Only by gaining new insights can major improvements be made in existing technologies, and entirely new concepts developed. Since the results of research cannot be predicted with any certainty, the apropriate level of support is based on subjective judgments of the possible future significance of technology needs and the nature of the uncertainties to be resolved rather than on objective analysis.

Fundamental research has to be supported largely by public funds. The private sector can and does perform excellent basic research in selected areas, but in general there is insufficient incentive for it to invest heavily in activities that can pay off only in the long term. The return from research is unpredictable, and the results may not accrue to those making the initial investment.

A national program of basic energy science must include two types of research. One type addresses topics where the results, if successful, can be expected to form the foundation on which new or improved environmentally acceptable technologies can be built. For example, improved understanding of the strength and corrosion of structural materials, the fracture of rocks, or chemical reactivities and kinetics may have major impacts on many different development programs. Within ERDA, the focus is on those areas where the development of future energy technologies requires increased understanding.

The second type of research implicit in the overall national program is that directed toward the discovery of fundamental laws and principles. While past experience has indicated that the results of such research will probably be useful ultimately, this cannot be predicted except in the most general terms. The ERDA programs in medium and high energy physics are of this type. Both seek a deeper understanding of matter and energy at the most fundamental level. The research seeks to enhance man's culture and understanding of nature, which are values of great but intangible benefit.

Placing basic energy science in agencies responsible for meeting development and demonstration goals produces an element of conflict. Some feel that basic research thrives in an environment not dominated by demands for short-range applications; however, the ultimate usefulness of basic research is typically its primary justification. If rapid application of results is to occur, there must be a conscious effort to transfer fundamental results and insights to those responsible for development and demonstration.

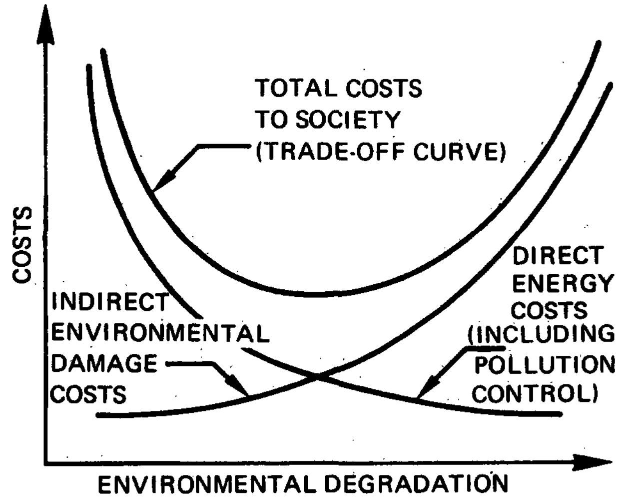
To effect this transfer of results, each federally supported technology program must have a component whose primary function is to bridge the basic-to-applied gap, serving as the point of contact between programs and the basic research activity. In this way, program requirements are translated into needed fundamental knowledge by the researcher, and new fundamental knowledge is translated into engineering concepts in the development and demonstration programs.

Environmental Research

Quality of life is measured not only in terms of the goods and services that an abundant and cheap energy supply can provide, but also in terms of human health and a clean environment. An energy future that promises inexpensive goods and services but that neglects the cost of damage to man and the environment is a poor bargain. Generally, however, the adverse impacts of technology can never be totally eliminated. Thus, the challenge is to create energy futures that are environmentally acceptable as well as technologically and economically viable.

"Environmental acceptability" implies a trade-off between the energy benefits sought, the consumer cost of energy, and the social cost of damages to human health and the environment. Environmental considerations are among the many factors that contribute to the need for alternative technology approaches; accordingly, they must be weighed carefully in the decision processes leading to the adoption, rejection, or modification of these alternatives. This integration of environmental considerations into the ERDA decision-making process is discussed further in Chapter V of this report. However, it must be recognized that major environmental issues will be resolved not through technology alone, but also through social processes. Hence, public dissemination of the implications of technology alternatives is mandatory to permit socially optimal choices.

In general, at a given level of energy production, the direct cost of supplying energy to the consumer decreases as such associated processes as land reclamation, waste disposal, and air and water pollution control are minimized or neglected. Thus, the direct cost of energy decreases as environmental restrictions are eased. At the same time, indirect social and environmental costs (e.g., pollutant-induced diseases, disabilities, shortened lifespans, deterioration of buildings, reduced productivity) increase as environmental degradation increases. These trends are shown in Figure II-3.



NOTE: DIRECT ENERGY COSTS + INDIRECT ENVIRONMENTAL DAMAGE COSTS = TOTAL COSTS TO SOCIETY.

Figure II–3 Conceptual Environment/Cost Trade-Off Curve at a Fixed Level of Energy Production

The sum of the direct energy costs and the indirect social and environmental costs represents the total cost to society. In theory, this curve should exhibit a minimum cost value. Society may choose to pay more than this minimum cost in one of two ways. The first, to the right of the trade-off curve, is the historical approach in which the direct energy costs to a particular consumer are minimized, and the increased indirect environmental and social costs are either spread over the whole society, or worse, paid for by a different element of the public. The other approach, to the left of the curve, is when society decides to reduce environmental degradation still further. It seems reasonable that society's choice would be to the left of the minimum cost as long as society believes that the marginal benefit exceeds or equals the marginal cost.

While the curves shown in Figure II-3 are illustrative only, they represent the technology/environment trade-off relationship. The responsibility of energy RD&D is to change the shape of the trade-off curve over time to afford the public greater environmental protection for the same cost or equal protection at less cost. A number of Federal agencies, including ERDA, have been assigned responsibility to pursue RD&D to accomplish this result.

Addressing the energy/environment trade-off from the social rather than RD&D viewpoint, a relationship can also be established among the level of energy production, direct energy costs, and indirect environmental costs. In brief, if either the direct energy costs or indirect environmental costs become too great, society can either invest in new technologies and/or resource bases with lower penalties or settle for a lower level of energy production.

This analysis highlights a real responsibility to identify available energy alternatives and to improve knowledge of their environmental implications. Extensive research must be conducted if the public is to be informed of the true nature of trade-offs and the implications of the various choices. This approach is expected to be one way in which environmental perspectives can be introduced into the ERDA decision-making process. Insights derived therefrom can affect ERDA's view of priorities in both technology development and environmental research.

Strategic Elements of Environmental Policy

The overriding challenge to energy RD&D is thus to establish a spectrum of technology options capable of significantly reducing the social costs of energy production while providing economically attractive benefits for energy suppliers and consumers. To meet this challenge, the environmental RD&D strategy developed must contain the following elements:

- Early identification and characterization of the environmental issues and public concerns associated with the commercial operation of energy systems
- Establishment of standards of environmental performance for each technology concept to spur innovations aimed at reducing the severity of environmental impacts and the cost of their control
- Continuous interaction with the public, private organizations, and other governmental agencies to ensure current awareness of public concerns regarding energy developments and environmental RD&D, as well as wide dissemination of information on environmental problems and progress.

Within ERDA, the following operational philosophy guides environmental RD&D:

- Environmental performance is considered an integral part of energy technology performance and is assigned competitive priority within each technology program. Environmental activities thereby command sufficient resources to achieve major program milestones.
- Protection of the health and safety of workers and the general public from potentially adverse impacts of energy is a basic performance standard for all energy technologies.
- In conformance with the spirit of the National Environmental Policy Act,* detailed environmental planning focused on key decision points constitutes an essential part of every program plan. An agency-wide environmental and safety overview function assesses changes in resource priorities, scheduling, and environmental performance goals.
- Public involvement programs and environmental RD&D coordination activities at both the agency and the technical program level are conducted to ensure that: (1) technical and policy decision-makers are fully informed about related external activities, perceptions, and problems, (2) environmental activities are coordinated effectively, and (3) all outside groups gain a realistic view of ERDA's and the Nation's environmental progress and problems related to energy.

It will take some time before the environmental RD&D strategy is fully implemented either nationally or within ERDA for all near-, mid-, and long-term technologies. First priority must be assigned to achieving market penetration of near-term technologies, as discussed in Chapter III. In recognition that decisions concerning the benefits and risks of the immediate energy future must be made soon, environmental activities in ERDA and throughout the Federal RD&D establishment reflect this near-term emphasis. Chapter III includes a discussion of the

* Public Law 91–190.

major health and environmental problems affecting market penetration of near-term technologies and the approaches the Federal RD&D establishment is pursuing to resolve those problems.

Since knowledge of the identity, character, and methods for mitigating near-term environmental risks is far from complete, RD&D planning must place heavy emphasis on the rapid acquisition of environmental information and innovation in the near-term. The planning process, however, cannot neglect mid- and long-term environmental problems. Environmental planning and implementation must therefore ensure support for long-term environmental RD&D in the face of pressures to turn full attention to near-term demands.

To ensure that appropriate environmental RD&D priorities are maintained and that ERDA resources are allocated to produce environmentally acceptable energy technology options over the long-term, a formal environmental planning process is being structured within ERDA. Chapter V includes a description of this ERDA environmental planning process.

Chapter III—The Plan and The Federal Energy RD&D Program For FY 1977

Laying out the fundamentals of the Plan, as was done in the preceding chapter, in terms of the objectives and goals to be attained and the programmatic priorities for action is the first step in building the National Plan for Energy RD&D. To be complete, however, a plan needs to indicate how the objectives it has set are to be achieved—i.e., how resources are to be deployed, how problem areas are to be addressed, and how responsibilities are to be assigned.

As indicated earlier, the private sector must play the predominant role in market penetration of new energy technologies. The energy situation is thus completely unlike the Manhattan Project or the Apollo Program in that in those cases, virtually all activities were undertaken or directed by the Federal Government.

This chapter, therefore, focuses on the narrower set of activities that the Federal Government can appropriately undertake, within our Nation's free enterprise system, to carry forward its portion of the total national effort. Accordingly, this chapter covers: (1) the budgetary decisions made by the Federal Government to support specific energy technologies; and (2) the overall programmatic approaches to be adopted for each of those technologies. The two subsequent chapters deal with the institutional mechanisms and decision-making processes that appear central to carrying out the Plan.

The FY 1977 Budget

The ERDA National Energy RD&D Plan served as an important input to the development of the President's amended 1976 and 1977 budget requests for energy RD&D funding.

Table III–1 President's National Energy Program FY 1977 Budget

	(Outlays in millions of dollars) FY 1976		FY 1977†		
	$	%	$	%	Percent Change
Program Activities					
Domestic energy resource development, conservation and petroleum storage (e.g., FEA, Energy Independence Authority, TVA & power administration, uranium enrichment)*	5,516	69%	7,259	70%	+32%
Energy research, development and demonstration (e.g., ERDA, Interior, NRC, et al.)	2,231	28%	2,905	28%	+30%
Regulation (REA, FPC, MESA, NRC)*	234	3%	244	2%	+ 4%
Total outlays	7,981	100%	10,408	100%	+30%
Less: Receipts (TVA, NPR, uranium enrichment)*	–3.385		–4,355		+29%
Net outlays	4,596		6,053		+32%

† Funds for FY 76 Transition Quarter are not included.
* Based on: "Seventy Issues—Fiscal Year 1977 Budget," OMB

Table III-1A Federal Energy R&D (Dollars in millions)

	FY 75		FY 76*		FY 77	
	BA	BO	BA	BO	BA	BO
Direct Energy R&D						
ERDA	$1,317.0	$1,011.0	$1,657.0	$1,427.0	$2,435.0	$2,009.0
DOI	89.9	54.2	104.0	93.3	98.3	96.3
EPA	80.8	18.2	56.8	76.6	55.4	76.6
NRC	58.9	51.7	87.5	76.9	104.0	98.2
NASA	0.8	0.8	1.7	1.0	–0–	0.8
Subtotal	1,547.4	1,135.9	1,907.0	1,674.8	2,692.7	2,280.9
Supporting R&D						
ERDA	362.0	313.0	403.0	373.0	430.0	404.0
DOI	33.2	30.9	59.0	56.7	66.8	65.2
EPA	53.2	5.0	43.2	43.4	41.6	43.4
NRC	2.3	2.1	9.6	9.1	5.3	5.0
NSF	103.2	65.9	114.6	74.2	123.4	106.9
Subtotal	553.9	416.9	629.4	556.4	667.1	624.5
Total Federal Energy R&D	$2,101.3	$1,552.8	$2,536.4	$2,231.2	$3,359.8	$2,905.4

* Funds for FY 76 Transition Quarter are not included.

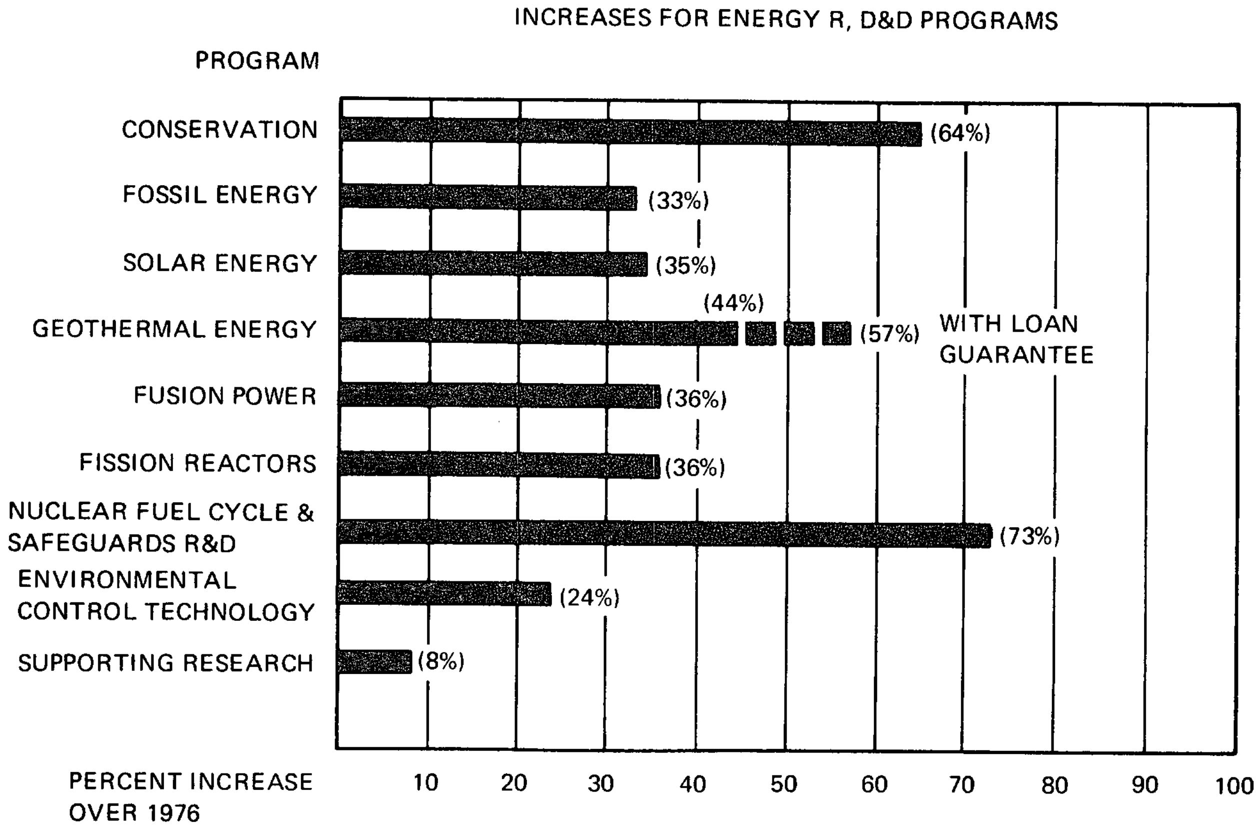


Figure III–1 Energy Research and Development Administration FY 1977 Budget

Table III-2 Federal Energy R&D Budget Exclusive of ERDA (Authority in millions)

	FY 75	FY 76*	FY 77
Energy RD&D Programs			
Nuclear Fuel Cycle and Safeguards	6.6	14.4	25.0
Conservation	4.1	5.7	1.2
Geothermal	10.9	12.2	5.9
Fusion	-0-	-0-	-0-
Fission	57.6	78.7	85.0
Solar	0.8	1.7	-0-
Fossil	69.6	80.0	84.7
Environmental Control Tech.	80.8	57.3	55.9
Subtotal	230.4	250.0	257.7
Supporting Research			
Basic Energy Sciences	84.6	95.8	103.6
Environmental Research	107.3	130.6	133.5
Subtotal	191.9	226.4	237.1
Total Non-ERDA Energy RD&D	422.3	476.4	494.8

* 76 dollars do not include transition quarter.

Table III-4 ERDA Energy Related Budget FY 75–76–77 (Authority in millions)

	FY 75	FY 76†	FY 77	FY 76 to FY 77 percent change*
Energy RD&D Programs				
Nuclear Fuel Cycle and Safeguards	$ 118	$ 173	$ 347	101
Conservation	36	75	120	60
Geothermal	28	31	100**	223
Fusion	183	250	392	57
Fission	567	602	823	37
Solar	42	115	160	39
Fossil	335	398	477	20
Environmental Control Tech.	8	13	16	23
Subtotal	$1,317	$1,657	$2,435	
Supporting Research				
Basic Energy Sciences	191	210	227	8
Environmental Research	171	193	203	5
Subtotal	362	403	430	
Total ERDA Energy RD&D	$1,679	$2,060	$2,865	

† 76 dollars do not include transition quarter.
* Percentage change calculated prior to rounding authority.
** Includes $50 Million for Geothermal Loan Guarantee Program.

Table III-3 Federal Energy R&D Budget Exclusive of ERDA (Outlays in millions)

	FY 75	FY 76†	FY 77
Direct Energy R&D			
Nuclear Fuel Cycle and Safeguards	6.3	13.7	23.9
Conservation	1.3	7.0	1.9
Geothermal	10.7	10.1	5.8
Fusion	-0-	-0-	-0-
Fission	50.6	68.7	80.2
Solar	0.8	1.0	0.8
Fossil	37.0	70.2	82.2
Environmental Control Tech.	18.2	77.1	77.1
Subtotal	124.9	247.8	271.9
Supporting Research			
Basic Energy Sciences	55.5	62.8	89.7
Environmental Research	48.4	120.6	130.8
Subtotal	103.9	183.4	220.5
Total Non-ERDA Energy RD&D	228.8	431.2	492.4

† Funds for FY 76 Transitional Quarter are not included.

Table III-5 ERDA Energy R&D Budget (Outlays in millions)

	FY 75	FY 76†	FY 77	FY 76 to FY 1977 percent change*
Direct Energy R&D				
Nuclear Fuel Cycle and Safeguards	$ 120	$ 163	$ 282	73
Conservation	21	55	91	64
Geothermal	21	32	50	57
Fusion	151	224	304	36
Fission	538	522	709	36
Solar	15	86	116	35
Fossil	138	333	442	33
Environmental Control Tech.	7	12	15	24
Subtotal	$1,011	$1,427	$2,009	
Supporting Research				
Basic Energy Sciences	$ 165	$ 188	$ 205	9
Environmental Research	148	185	199	7
Subtotal	$ 313	$ 373	$ 404	
Total ERDA Energy RD&D	$1,324	$1,800	$2,413	

† Funds for FY 76 Transition Quarter are not included.
* Percentage change calculated prior to rounding outlays.

In FY 1977, as compared with FY 1976, Federal outlays for all energy activities combined have increased about 30 percent to a net level of $6 billion. Similarly, the energy RD&D portion of this total has also increased over 30 percent, to a level of over $2.9 billion. Table III-1 and III-1A summarize this information as adapted from the January 21, 1976 document, **Seventy Issues—Fiscal Year 1977 Budget,** prepared by the Office of Management and Budget. Tables III-2 and III-3 are a breakdown of the energy RD&D portion of the Federal energy budget by agency. Table III-4 and III-5 and Figure III-1 are a breakdown of the ERDA energy RD&D budget by technology area, showing percentage changes for FY 1977 of selected major programs.

Although the year-to-year percentage changes reflect program priority, they also reflect program **status.** Thus a new program, such as Conservation, may receive a lower absolute level of funding, but a level significantly higher than the preceding year or years. On the other hand, older programs may require very expensive technology and large demonstration plants, which entail large absolute expenditures but not necessarily a level of expenditure significantly higher than the preceding year. Budget decisions are designed also to encourage cost-sharing with private industry (e.g., coal liquefaction demonstration) and to avoid undertaking shorter term RD&D that is more appropriately the responsibility of the private sector (e.g., in areas of conservation technology). The extent to which the current budget has been successful in sharing the cost of programs with non-Federal organizations is shown in quantitative form in Table III-6. Specifically, of the total expected costs over $5 billion for ERDA cost-shared programs, non-Federal organizations are prepared to bear about 30 percent of the funding burden. This funding will facilitate a broad range of activities, including demonstration of a fission power breeder reactor, electric energy systems, solar heating and cooling of buildings, conservation techniques in operating commercial restaurants, and coal liquefaction.

Table III-6—ERDA Cost-Shared Program Areas with Non-Federal Organizations
(in $ millions)

	ERDA Estimated Investment	Non-Federal Organizations Investment	Total Estimated Cost (TEC)	Non-Federal Cost as Percent of TEC
Fossil*	1967	1257	3224	39
Geothermal**	7	5	12	42
Conservation	94	116	210	55
Fusion (Only Laser)	15	33	48	69
Fission***	1967	283	1981	14
Total	3780	1694	5475	31

* Does not include demonstration plants
** Funding of most plants yet to be determined
*** Primarily Clinch River Breeder Reactor

The major thrusts of ERDA's Energy RD&D budget for FY 1977, discussed in the order of program priority ranking laid out in Chapter II, can be summarized as follows:

—**Conservation** received a substantial funding increase from FY 1976 amounting to 64 percent. Conservation together with gradual deregulation of oil prices was an important element of the Energy Policy and Conservation Act. This funding supports a greatly expanded program to improve technology and encourage conservation of energy in buildings, industry and transportation.

—**Light Water Reactor Fuel Cycle** funding was increased by 73 percent from the previous year to assist the private sector in "closing the fuel cycle"—i.e., reprocessing and refabrication of nuclear fuel; developing acceptable technical and environmental approaches for the long-term storage of commercial reactor wastes; and insuring safeguards of nuclear materials.

—**Coal Direct Utilization** program funding was increased from past levels to support the continuing program and to permit construction of additional demonstration plants.

—**Enhanced Oil and Gas Recovery** program funding provides for continuation of ongoing programs and additional field demonstrations in partnership with industry.

—**Synthetic Fuels** program funding will be requested in a supplemental FY 1976 budget request to provide financial incentives to develop a synthetic fuels industry.

—**Essentially Inexhaustible Energy Technologies,** i.e., breeder reactor, fusion, and solar electric—all had their funding increased upwards of 30 percent reflecting the critical long-term need for these programs.

As can be seen, the ERDA FY 1977 Energy RD&D budget reflects the major objectives set forth in the President's 1976 Energy Message; the national priorities in the National Plan for Energy RD&D; the application of criteria for determining the appropriate Federal role as set forth in Chapter II; and the principles set forth directly above to arrive at appropriate budget levels for the Federal Program.

The overall Federal budget strategy is best captured by quoting selected portions relating to energy RD&D directly from the OMB document **Seventy Issues:**

"The Nation has undeveloped reserves of coal, oil, gas and uranium. There are also many opportunities to conserve energy. A solution to the dependence problem can be achieved with a longer term effort directed toward increasing domestic energy supplies and achieving greater conservation. The

President's national energy program is a comprehensive approach designed to achieve a capability for energy independence by 1985. The program includes both short-term and longer term initiatives but places basic reliance on the private sector to carry out expanded domestic energy supply production and conservation, and by developing a strategic storage petroleum system that will be capable of easing the impact of any embargo.

"The 1977 budget outlay estimates reflect the President's strong emphasis on domestic energy production, conservation and petroleum storage programs and massive R&D efforts to develop new energy technologies.

Domestic Energy Resource Development, Conservation and Storage

"Development and conservation of energy resources are essential to achieving greater independence from foreign petroleum supplies. These programs encourage the development of oil, gas, coal and uranium reserves, energy production, strategic petroleum storage, and more energy efficient process. Highlights contained in the FY 1977 budget include:

- **"Energy Resource Development, Production, Conservation**
  —**"Energy Independence Authority**—Proposed establishment of an Energy Independence Authority with $100 billion in equity and funding authority to provide assistance (mainly loans and loan guarantees) to the private sector to encourage the development of energy projects using conventional technology (e.g., fossil and nuclear power plants) and emerging technologies (coal to gas plants, oil shale to oil). The Authority will also work to shorten the time required for energy projects to obtain clearances and permits from Federal regulatory agencies.

  * * * * *

  —**"Uranium Enrichment**—Uranium enrichment is one of the processes required to convert uranium ore into usable fuel for nuclear power plants. At the present time, this activity is carried out in three Government-owned production facilities originally built for defense purposes.
  —"In order to relieve the taxpayer of the financial burden of funding the construction of additional uranium enrichment facilities and to assure the availability of fuel for nuclear power plants, the President has proposed legislation required to foster the creation of a private competitive uranium enrichment industry in the U.S.
  —"To produce a large enough stockpile to meet potential future needs, the FY 1977 budget will provide a substantial increase for (a) the production of enriched uranium and (b) the continuation of the previously approved expansion of the capacity of the current ERDA plants. However, the Administration believes that future expansion of enrichment capacity should be financed by the private sector with necessary Government cooperation and temporary assurance under the proposed Nuclear Fuel Assurance Act.

  * * * * *

  —**"Energy Conservation**—Conservation proposals to: provide $55 million in financial assistance to low-income homeowners for insulation, establish thermal efficiency standards for new residential and commercial buildings, encourage appliance manufacturers to improve energy efficiency and to label appliances, and encourage auto manufacturers to increase fuel economy. The Energy Policy & Conservation Act makes the appliance labeling and auto fuel economy standards mandatory.
  —**"Energy/Environment** — Amendments to the Clean Air Act to provide a needed balance between environmental and energy goals.
  —**"Energy Tax Expenditures**—Tax expenditures to encourage the development and production of energy and mineral resources. Exploration and development expenses (mostly for oil and gas) may be treated as current costs rather than as capital investments, which are depreciated over a number of years. This provision is expected to provide a $1 billion incentive to develop energy resources in 1977. Another tax provision allows the use of percentage depletion rather than actual cost depletion. Although sharply curtailed for oil and gas in 1975 legislation, it is still expected to offer a $1.6 billion tax incentive for mineral production in 1977, with most of that amount for fossil fuel production. The Administration has proposed a package of tax aids for electric utilities that will especially help generating facilities not using oil or gas as fuels. It is estimated to provide $0.8 billion of tax relief in 1977.

  * * * * *

Energy Research, Development and Demonstration

"The Energy Research and Development Administration, proposed by the Administration, was established in January 1975 to be the major Federal agency for the conduct of energy research and development. In FY 1977 ERDA will provide 83% of the total Federal funding [outlays] for energy R&D. It also provides a central Federal agency for the planning and coordination of Federally sponsored energy research and development.

* * * * *

- **"Overall Energy R&D Budget Strategy**
  —"Accelerate energy research and development

programs directed at achieving greater long-term energy independence.

—"Expand efforts to assure the safety, reliability, and availability of commercial nuclear power plants by increasing R&D on the long-term storage of radioactive wastes, fuel reprocessing, and safeguards against theft of nuclear materials.

—"Place greatest funding on technologies with the highest potential payoff in terms of recoverable resources (i.e., nuclear and fossil).

—"Continue to expand the investigation of other technologies where they can make significant contributions to meeting the long-term energy requirements of the U.S. (i.e., solar, geothermal, and conservation R&D).

—"Encourage cost-sharing with private industry (e.g., coal liquefaction demonstrations) and avoid undertaking shorter term R&D more appropriately the responsibility of the private sector (e.g., in areas of conservation technology).

—"Support the commercial demonstration of synthetic fuel production from coal, oil shale, and other domestic resources by providing loan guarantees during FY 1976 (upon enactment of the Energy Independence Authority legislation in FY 1977, transfer these projects to EIA).

- **"Non-nuclear Energy R&D**

—**Balance between nuclear and non-nuclear energy R&D**—The table of direct ERDA spending indicates more effort on nuclear than non-nuclear energy R&D. However, direct ERDA spending is not a true measure of the total national effort on non-nuclear energy R&D and greatly understates the effort being made to develop and commercialize non-nuclear energy technologies.

—"Although specific data is not available, private industry is known to be spending much more on non-nuclear energy R&D than on nuclear energy R&D (which has higher technical and regulatory uncertainties).

—"The Administration plans to support legislation which is expected to provide about $6 billion of loan guarantees in FY 1976–1978 to enable industry to construct facilities for producing synthetic fuels.

—"About $50 million per year will also be provided for loan guarantees for geothermal production projects.

—**"Fossil energy development**—Accelerate the development and demonstration of technology to (a) enable plentiful domestic coal resources to be substituted for increasingly scarce supplies of oil and natural gas; (b) increase the efficiency of the use of fossil fuels through advanced power conversion systems; and (c) increase the recovery of oil and natural gas from fields in the U.S.

—**"Solar energy development**—Increase the development and demonstration of solar energy applications, including 226 [awards involving 325 to 480] units to demonstrate solar heating and cooling in residential and commercial buildings and acceleration of technology for the conversion of solar energy to electricity.

—**"Geothermal energy development** — Expand R&D required for the utilization of U.S. geothermal resources including improving the capability for defining the extent and availability of such resources, developing advanced engineering techniques and building pilot plants. Provide $50 million in FY 1977 for loan guarantees to enable industry to proceed with geothermal production projects which would otherwise not be undertaken because of current technical and economic uncertainties.

—**"Conservation R&D**—Provide an expanded program to improve technology and encourage conservation of energy in buildings, industry, and transportation.

- **"Nuclear Energy R&D**

—**"Fusion**—Continue research to determine the scientific feasibility of obtaining virtually unlimited power for the long-term (beyond the year 2000) from the controlled thermonuclear fusion reaction. In FY 1977 continue construction on the $215 million Tokamak Fusion Test Reactor at Princeton, N.J., which will represent a major milestone.

—**"Fuel Cycle and Safeguards**—Improve the use of current commercial nuclear reactors.

—**"Commercial waste management**—Greatly accelerate the conduct of R&D to provide the technology for the terminal storage of radioactive wastes from commercial power plants by demonstrating this technology at several sites.

—**"Nuclear fuel reprocessing**—Assist industry by conducting R&D on the technology for reprocessing and reusing spent nuclear fuel discharged from commercial nuclear power plants.

—**"Safeguards** — Demonstrate techniques for safeguarding nuclear materials against theft.

—**"Uranium enrichment R&D** — Develop and demonstrate improved techniques for uranium enrichment which offer the promise of more efficient production and cheaper electricity for consumers.

- **"Other Direct Energy R&D**

—"Significantly increase outlays for the Nuclear Regulatory Commission's safety research program and the Department of Interior's mining R&D program.

—"Reduce outlays for the Environmental Protection Administration's development of environmental control technology because of the completion of portions of major contracts and the increasing responsibility of other agencies in this area.

- **"Supporting Energy R&D**

—"Continue the FY 1976 level of effort on programs to (a) determine the biomedical and environmental effects of nuclear and non-nuclear energy sources to assure development of safe energy technologies and (b) solve fundamental scientific and engineering problems that constrain the development of energy technologies.

- **"Synthetic Fuels**

—"Support legislation to provide $2 billion in loan guarantees for industry ($500 million of Budget Authority) during 1976 for the commercial demonstration of synthetic fuel production from coal, oil shale, and other domestic resources. A total of $6 billion in loan guarantees is expected to be necessary over the 1976–1978 period in order to reach the 1985 objectives of 350,000 barrels per day of synthetic fuel production capacity. . . .

* * * * *

- **"Nuclear Regulation**—Funding for the Nuclear Regulatory Commission will increase 15% because of the important role NRC plays in ensuring that nuclear power continues to be a safe and environmentally acceptable means of generating electricity. The United States needs additional nuclear power plants in order to achieve more energy independence from foreign suppliers and to provide consumers with cheaper electricity than alternative sources can provide. The additional resources for NRC will help enable the U.S. to achieve the benefits of nuclear power by assuring adequate attention to the problems of safety, environmental effects, and safeguarding nuclear materials against theft.
- **"Nuclear Licensing**—A legislative proposal to streamline the NRC procedures for licensing nuclear power plants to reduce the amount of time required to process applications while maintaining safety and environmental standards.

Need for Initiative to Develop Domestic Energy Resources

"It is essential that the Nation move promptly to develop domestic energy resources to assure that needed supplies are available in the long run to avoid a growing dependence on foreign energy supplies. The Nation's energy situation continues to deteriorate.

* * * * *

Presidential Proposal for Energy Independence Authority

"To encourage needed domestic energy development and conservation, the President has proposed the establishment of a government corporation, the Energy Independence Authority (EIA) with $100 billion in financial resources to help achieve greater energy independence.

* * * * *

"Specific types of projects which EIA could provide financial and regulatory assistance would be limited to commercialization of:

—"Emerging energy technologies, such as synthetic fuels, not yet in widespread domestic commercial operation.

—"Technologies essential to production of nuclear power.

—"Conventional or emerging technologies for production and transmission of electric power generated by sources other than oil and gas.

—"Conventional energy technologies for the production or transportation of energy that are of such size or scope that they would not otherwise be financed by the private sector.

* * * * *

1977 Budget
ERDA Synthetic Fuels Commercial Demonstration Program
($ millions)

	1976* Budget Authority	1976* Outlays	1977 Budget Authority	1977 Outlays
Loan Guarantee Fund	500	—	—	—
Administrative Expenses	3	3	—	—
Total	503	3	—	—

* The loan guarantee fund will cover $2 billion in guarantees to initiate the program in 1976. The guarantee program will be transferred to the Energy Independence Authority in 1977 upon its enactment.

Need for the Program

- "U.S. dependence on foreign sources of oil and gas continues to grow with domestic production having fallen in the last several years.
- "Even using advanced oil and gas recovery techniques, extensive production from the Outer Continental Shelf and Alaska, improved energy conservation, expansion of nuclear power facilities, and greater direct burning of coal, oil imports will continue to rise substantially if synthetic fuel production capacity is not available by the middle 1990's. Synthetic gas and liquid fuels can be obtained from the processing of coal, oil shale, biological waste, and other domestic resources not now being fully utilized.
- "Initiating a synthetic fuels industry capable of

providing about 5 million barrels/day of production capacity (i.e., about 100 major plants) by 1995 will require early resolution of a number of uncertainties related to regulation, environment, financing, labor and transportation. The lead time to initiate such an industry requires the construction and operation, over the next 5 to 10 years, of a variety of synthetic fuel plants to obtain the needed data and information.

The President's Proposal

- "In his 1975 State-of-the-Union message, the President proposed the first important step toward the development of a synthetic fuels industry—a federally sponsored Synthetic Fuel Commercial Demonstration Program. An extensive interagency study concluded that the synthetic fuels program should proceed in two phases, the first of which would involve the construction and operation of about 12–15 commercial-size plants and would result in total synthetic oil and gas production equivalent to 350,000 barrels per day of oil. The second phase might begin in 1978 or 1979 and raise production to 1 million barrels per day, but this depends on the results of R&D efforts, additional information on environmental impacts, and the private sector's response to the first phase.
- "Although a $6 billion program of loan guarantees to implement aspects of the President's proposal was passed by the Senate during the last session, it failed to pass the House of Representatives.

Support for the Program in the 1977 Budget

- "The President is again supporting immediate creation, in 1976, of a synthetic fuels commercial demonstration program in the Energy Research and Development Administration. This program will be carried forward in ERDA until such time as the Energy Independence Authority is enacted and the program can be incorporated under that Authority.

—"As a first step in implementing this program, the 1977 budget provides for FY 1976 supplemental funding of $503 million in budget authority to cover $2 billion in loan guarantees for the remainder of 1976.

—"Additional budget authority to cover the full $6 billion loan guarantee program for Synthetic Fuels, which the Administration supported in 1975, is included in the 1977 Budget under the Energy Independence Authority.

Need for the Program

—"The U.S. needs more nuclear power.

- "Although domestic coal supplies are extensive and accessible, their use is severely limited by environmental constraints. Widespread use of coal without relaxing environmental standards will require new clean conversion technologies (e.g., gasification or liquefaction of coal) or those permitting direct use of coal (e.g., sulphur removal from exhaust gases).
- "Recovery of potentially significant solar and geothermal resources is currently limited by technological and economic uncertainties. Their economical use will require development of new or improved technologies.
- "The U.S.'s most plentiful domestic resources are coal and nuclear. Neither one alone could be sufficiently developed to meet all our energy needs over the next few decades due to limitations on required transportation and other supporting facilities and equipment manufacturing capacity. Both coal and nuclear must be exploited to achieve energy independence from foreign suppliers.
- "Furthermore, compared to coal-fired power plants, the price for electricity generated by nuclear power plants is significantly cheaper for the consumer in most parts of the country.

—"But nuclear plants and their associated service facilities also have problems that must be addressed

- "Nuclear plants must be carefully designed, constructed, and operated so that none of the radioactive materials contained deep inside the plant can ever be released to the environment.
- "An independent Government agency (the Nuclear Regulatory Commission) regulates the safety of nuclear power plants at every stage.
- "A recent report by a group of safety experts has concluded that nuclear power plants are very safe (the chance of any member of the

FY 1977 Budget (ERDA)
R&D To Improve Commercial Use of Nuclear Power

Summary Table Research and Development Programs	(Outlays $ Millions) 1976	1977	% of change 1976–1977
Nuclear power plant safety*	60	89	49%
Safeguarding nuclear materials	15	27	80%
Nuclear fuel reuse	13	30	131%
Management of commercial wastes	12	63	425%
Total	100	209	109%

* Most of these funds are included in the budget of the Nuclear Regulatory Commission (NRC).

public being killed in a nuclear plant related accident is one in 5 billion which is slightly less likely than the chance of being struck by a meteor. And over 2000 times less likely than being struck by lightning).

- "The nuclear materials that serve as fuel for the power plant must be protected against theft.

* * * * *

- "Nuclear fuel discharged from power plants must be reused or recycled and radioactive waste material must be safely managed and disposed of."

* * * * *

Chief Programmatic Thrusts

Because Volume II of the Plan is designed to present programmatic efforts in considerable detail, the remaining section of this chapter concentrates on those broad areas critical to achieving energy goals. For most of the high-priority programs to be pursued in the near- and mid-term, these critical areas involve: (1) accelerating the market penetration of energy supply and conservation technologies in or entering commercial status; and (2) ensuring the environmental acceptability of these technologies (including health, safety, social, and aesthetic factors). For high-priority programs in the longer term, i.e., chiefly those for the essentially inexhaustible energy sources, the critical area is identifying and overcoming technical and environmental problems in the earlier research, development, and demonstration program phases.

In each of these two groups, the Plan considers:

- **The critical problems of each technology that prevent market penetration and environmental acceptability for the near-term and technological success for the longer term programs.** The former aspects of technology development tend to be the ones that have received the least attention in the past, are likely to pose the greatest hurdles to be overcome, and will require the closest coordination between the government and the private sector. Consequently, they receive more extended treatment in the technology discussions.
- **The strategic approach to be taken by the government—within the context of the Plan—and the larger, complementary role the private sector is expected to play.** Each technology requires a program designed to meet its particular development needs. As discussed in Chapter I, a government role is justified under selected conditions—e.g., when a low or uncertain level of private return on investment bars private action even though significant social (public) benefits could be achieved, or where the rate of implementation of the private sector would desirably be accelerated through assistance in addressing key uncertainties and/or institutional obstacles. If the Nation's overall efforts are to mesh effectively, each sector needs to understand the current approach to introducing the technologies and the roles expected of each.
- **The specific programmatic efforts being considered or already under way to implement the strategic approach.** In some areas, current efforts are extensive; in others, they are minimal in the expectation that normal market forces will cause the implementation of the technologies; and, in still others, efforts are contingent on interim results, further analysis, or negotiations between the government and private firms.

In the discussion that follows, the seven high-priority technologies becoming available in the near- and mid-term are addressed before the three longer term technologies. The order of presentation is:

1. Conservation
2. Light water reactors
3. Enhanced oil and gas recovery
4. Direct coal utilization
5. Synthetic fuels
6. Geothermal
7. Solar heating and cooling
8. Breeder reactors
9. Fusion
10. Solar electric

Additional detail on these and other Federal Technology efforts is presented in Volume II of this Plan being published separately.

Conservation Technologies

In the aggregate, conservation technologies—i.e., those permitting a more efficient use of energy—will contribute substantially to balancing the domestic energy supply and demand. ERDA–48 estimated that full implementation of more efficient technologies would permit continued economic growth without increased levels of imports through 1985; by the year 2000, such technologies would permit total energy consumption to be 25 percent less than it would be without their adoption (Scenario 1 of ERDA-48). Moreover, many of these technologies can have a more immediate—i.e., within 5 years—impact than those discussed later.

It must also be recognized that conservation technologies provide a potential cost-effective alternative to development of more supply technologies—i.e., in many instances, it will cost less to **save** a barrel of oil (e.g., through more energy efficient home heating) than it will to **develop** a new barrel of supply. This conclusion was suggested by the conservation scenarios of ERDA–48 (see Appendix B), which indicated that national energy needs could be met at lowest cost by employing improved efficiencies in end-use. Although these scenarios were not able to reflect the costs of modifying end-use installations, the large difference in total costs among scenarios indicated that ample financial margin exists to cover these additional costs and still provide a low-cost solution. Moreover, the barrel saved will make more of the finite resource available for future needs.

Finally, these technologies generally will help meet energy needs with the least adverse impact on the environment. Specifically, as conservation actions reduce energy consumption levels, pollutant emissions and disruptions will be decreased because of reduced energy extraction and transportation activity, reduced fossil-fuel combustion, and the lessened need for disposal of waste heat and other materials. In addition, reduced energy consumption will extend the availability of fossil energy resources and allow time to develop technologies that use inexhaustible energy sources (e.g., solar, fusion, breeder reactors).

The advantages of conservation technologies are expressed generally above. The rate of application and introduction of conservation technologies in specific instances will be determined by the comparative economics and social acceptability of the available alternatives.

Many of these advantages were recognized in the recent enactment of the Energy Policy and Conservation Act. The stated purpose of the Act is to "reduce domestic energy consumption through the operation of specific voluntary and mandatory conservation programs."

The key conservation technologies under consideration differ significantly from supply technologies discussed later in this chapter. Specifically, their number, their diversity, and the relatively small energy contribution of any one preclude a single approach; rather, a broadly conceived strategy is needed. The nature of the conservation technologies ready for market penetration, the problems to be surmounted to gain adoption, and the broad-based strategy for facilitating their penetration of the market follow.

The Opportunities

The Nation has manifold opportunities for greater efficiency in the use of energy. Many are sufficiently developed to permit their rapid market penetration. They fall into four groups:

1. **Industry conservation.** The industrial sector currently consumes 40 percent of the Nation's energy. Reduction of this level of energy consumption will require a systematic evaluation of the industrial processes involved and a determination of those processes in which increases in thermodynamic efficiency can be achieved. Industry has made substantial progress in this regard, but more remains to be done. A host of more efficient technologies—some specific to individual industries and others applicable to many industries—is known. Many of these promise efficiency improvements of more than 30 percent. By implementing the successful results of RD&D, projected industrial energy consumption can be decreased by up to 17 percent per unit of output (equivalent to 1.8 to 2.7 million aggregate barrels of petroleum equivalents per day (BPDE) by 1985).

   Some of these more efficient technologies:
   —Intermediate temperature heat pumps to minimize primary fuel consumption
   —Brayton cycle turbine generators to produce electricity from the thermal discharge of furnaces (e.g., aluminum smelter or glass kiln)
   —Heat transfer/thermal storage techniques to cascade energy flow within process industries
   —High temperature insulation/refractories
   —Waste heat recuperators and regenerators.
2. **Buildings conservation.** Commercial establishments and residential housing, which consume 29 percent of all energy in the U.S., present a number of opportunities to improve energy efficiency. Full understanding of these opportunities requires a systematic evaluation of essential factors associated with meeting a community energy needs. Three areas seem to hold large promise. First, a number of specific technologies exist—notably in insulation, shell design and heating, ventilating, and air conditioning—that need to be integrated and may require innovative marketing by industry to motivate consumers to accept and install them. Second, waste energy can be used more effectively in community systems. Third, some new technologies, such as the Annual Cycle Energy System,* appear promising but require further testing and/or development.

   Implementation of the results of these RD&D efforts could save 2.0 to 2.8 million BPDE by the year 1985.
3. **Transportation energy conservation.** The transportation sector, which consumes 31 percent of total U.S. energy, can reduce its petroleum consumption by using proven technologies and by implementing well-studied operational changes, including:
   —Retrofitted aerodrag reduction devices on long-haul trucks

* **Annual Cycle Energy Systems (ACES) for Buildings.** A system potentially applicable to the residential and small commercial buildings market for space heating in winter and cooling in summer. Properly sized water storage tanks are incorporated in new building designs, including use of heat pumps. Heat is extracted from storage water in the winter; ice or chilled water in storage is used to cool in the summer.

—Reduced horsepower losses on accessory drive for autos and trucks
—Use of drag reduction devices between freight cars on trains
—New, energy-efficient engines for autos.

These improvements are expected to achieve savings of about 0.5–0.7 million BPDE by 1985.**

4. **Electric energy systems.** The electric utility sector presently uses about 27 percent*** of all U.S. energy consumed. This percentage is expected to increase substantially in the years ahead. Significant energy savings—expected to be 1.0–1.5 million BPDE by 1985—can be achieved by using improved equipment, and by altering consumption patterns, system structures and operations. Substantial capital and land savings and savings of oil can also be achieved. There are a number of opportunities for near-term savings, such as electric load management, application of energy storage, and removal of constraints to more efficient higher voltage transmission lines. A reliable electric energy system is also the critical link between advanced source technologies and end-use.

In addition to these opportunities, a continuing stream of new ideas and projects flows from the scientific community, individual inventors, and entrepreneurs. For example, recent private efforts have produced more efficient light sources and thermally activated heat pumps. Moreover, technological opportunities need to be considered in the light of alternative socio-economic-regulatory actions such as standards and innovative financing.

Market Barriers

By and large, most of these conservation technologies will have to overcome problems of economic, uncertainties, and normal resistance to the acceptance of new "products." Economic barriers will diminish as fuel prices rise and as more economical conservation technologies become available. For example, as fuel becomes relatively more expensive, end-users will be increasingly likely to invest in initially more expensive new technologies in the knowledge that **overall** (i.e., life-cycle) costs will be competitive for a given level of output. This "conversion" process will occur naturally but slowly within the market. In some instances the large, potential benefits may justify government action in the form of economic incentives or RD&D assistance.

In addition to the economic barriers there are several other kinds that must be considered in mapping implementation strategies. Specifically, end-users may be reluctant to invest in new technologies because they do not know whether the technologies will perform as designed, or whether they will be reliable; developers and manufacturers are sometimes reluctant to create new technologies because they do not know whether they can, in an acceptable time frame, meet the institutional tests posed by state and local governments, lending institutions, unions, and other key groups whose support is required to implement new approaches in literally every segment of society. For example:

1. Most individuals and some industries are unaccustomed to using life-cycle costing as a basis for purchase decisions, and tend to make decisions on the basis of lowest initial cost. If companies continue to make investment decisions solely on the basis of initial cost, some new technologies (e.g., long-life light sources, and integrated appliances for mobile homes) will fail to realize full potential.
2. Personal taste and value are often wedded to existing technologies. For example, the changes in home appearance caused by the installation of solar heating may be an important deterrent to some prospective buyers, and the "look" of low drag automobiles and trucks may impede their acceptance by potential operators.
3. Vendors may be deterred from marketing a device because new and unexpected environmental standards might inhibit the use of a technology before the investment for development and marketing can be recovered.
4. Even though a basic technology is available, manufacturers may have to overcome numerous other technological hurdles and some institutional hurdles to adapt the technology to particular markets. This effort may greatly compound the economic uncertainties.
5. Potential users may be unsure whether the first generation of a technology will perform as advertised. The problem is accentuated where the available technologies have not been sufficiently demonstrated. Potential consumers cannot afford operating fuel-saving products at a loss, especially when no significant gain results from being the first operator of a new technology.

Finally, market penetration of conservation technologies may be impeded by a range of valid environmental, human health, and safety considerations. All new or modified energy related technologies must, of course, meet any existing pollution control requirements and many are required to meet new source performance standards. In improving energy efficiency in commercial establishments and

** The savings envisioned are in addition to those currently being pursued by Detroit (e.g., lighter weight cars), but may be included by manufacturers in the efficiency improvements recently mandated by legislation.

*** This 27 percent is includ[illegible] preceding three end-use sectors and is th[illegible] nonadditive.

residential housing through improved insulation or reduced ventilation, for example, the potential hazards of increased exposure to fine particulates from insulation or the effects on human health of reduced ventilation must be evaluated.

In addition, exotic technologies and/or fuels producing electricity may produce some negative environmental impacts. For example, higher temperature combustion will substantially increase certain types of emission (expecially NO_x), higher temperature wastewater, and increase material deterioration. The use of certain fuels (e.g., nitrogen- and sulphur-bearing oils) in conjunction with high-temperature cycles will likely adversely affect air emissions.

On the positive side, quantification of the environmental benefits resulting from reduced energy consumption may help overcome institutional and social barriers impeding large-scale conservation.

Strategic Approach

In recognition of the need to address these general commercial and socioeconomic factors, the strategic approach to bringing a large number of conservation technologies into use in the near term incorporates five main elements:

1. **A national policy conducive to the adoption of energy-efficient technologies.** An element of this policy is the enactment of the Energy Policy and Conservation Act* which, in part, provides for:
   —**A gradual removal of oil price controls,** to encourage normal workings of the marketplace —i.e., to increase supply and to reduce demand
   —**Insuring the continuing progress in the improvement of automotive energy efficiencies,** to ensure consumer adoption of more energy efficient automotive technologies
   —**The identification of areas for improving the energy efficiency of major household appliances,** to encourage consumers to make the most energy-efficient choices
   —**Working with energy-intensive industries,** to encourage the adoption of existing conservation technologies
   —**Federal conservation efforts,** to be carried out through procurement policies and through a 10-year plan relative to federally owned or leased buildings.
2. **A 0- to 5-year planning horizon.** In addition to the near- (1985), mid- (1985–2000), and long-term (post 2000) planning horizons established by ERDA's enabling legislation, a new planning horizon—0 to 5 years—will be included in the annual energy RD&D Plan. Opportunities in nuclear, fossil, solar, and other technical areas will be included, although the predominant opportunities will probably be in the conservation program. Fuel substitution opportunities also will be sought because of the beneficial impact on oil imports and relief of gas shortages. This 5-year focus is intended to roll forward each year. The process will be institutionalized and monitored for successes and failures. The results of the initial ERDA review will be coordinated with other interested agencies, particularly FEA, to ensure a proper overall governmental approach is being designed and the best opportunities are being identified. Industry views will also be sought in this design phase to ensure that any government action assists and provides incentives to industry rather than result in preemptive, unneeded, or irrelevant government action.
   Although some of these technological improvements will begin to appear in the marketplace between now and 1980, it may be cost effective for government to assist industry in accelerating their introduction and acceptance by the American public.
3. **Accelerated identification of promising technologies (particularly within the 5-year horizon) and dissemination of information about their application in potential end-users.** For some time, FEA has had a program to identify conservation opportunities in industry, buildings, and transportation. Other involved agencies include the Cooperative Extension Service, Department of Commerce and Housing and Urban Development.
4. **Integration of market and institutional barriers into the plans for developing the most attractive conservation technologies and for facilitating their implementation.** A general approach is being developed to consider implementation barriers at the inception and throughout the RD&D planning process. (See Chapter V.)
5. **Demonstration programs to work out the implementation details of more complex technological approaches.** Such efforts will most likely be needed in the highly fragmented building industry. Leading candidates for such programs include the Annual Cycle Energy System, integrated housing, and community energy systems. Similarly, demonstrations of conservation technologies with broad industrial applicability may be justified. The appropriate government role in this area will be determined by further analysis of promising technologies and by socioeconomic research that diagnose barriers and the cost effectiveness of alternative approaches to overcoming them.

Action Program

The principal elements of a Federal program to carry out the strategy outlined above include:

- Carrying out the provisions of the Energy Policy

* Public Law 94–163.

Conservation Act within Federal Energy Administration, and the Department of Commerce

- Encouraging the private sector to implement conservation and fuel-substitution technologies within the 5-year planning horizon
- Establishing a joint FEA and ERDA planning and implementation capability
- Developing a capability for:
  —Identifying the energy-savings technologies that are attractive from the point of view of cost and implementation
  —Developing energy-consumption standards
  —Identifying environmental costs and benefits
  —Verifying technology capabilities
  —Informing end-users about new technologies
  —Identifying and assisting in removing institutional obstacles
- Carrying out demonstration programs as appropriate.

Light Water Reactors

Although forecasts vary, most show nuclear power as a major factor in meeting U.S. energy needs by the end of this century. A typical forecast is for an installed nuclear capacity building from the present level of 39.6 millions of kilowatts of capacity (gigawatts—GWe) to 70–76 GWe by 1980, increasing to 160–185 GWe by 1985, 265–340 GWe by 1990, and 450–800 GWe by 2000.*

Industry and Government, in cooperation, have brought light water power reactors to their current status of safety and economic viability. As a result, this energy source presently supplies some 8 percent of U.S. electricity demand. Although several problems impede rapid market penetration (e.g., long lead times; evolving regulatory requirements; less than desired plant reliability and availability, a feature also shared with large coal plants, and high capital cost **), over 200 nuclear power plants have now been committed or ordered.

To bring the technology of light water reactors to full economic fruition several parts of the fuel cycle must be validated—technically, commercially and environmentally. In brief, the areas requiring increased emphasis are:

- Better definition (i.e., in terms of location, grade, extent, economics and availability) of recoverable domestic uranium resources

* Includes up to 60-80 GWe of breeders, assuming successful completion of the breeder development program.

** Despite higher capital costs, nuclear energy's lower fuel costs (compared with fossil fuels) allow power to be produced at a lower **total** cost in **most** of the Nation. Only in those areas of the West where abundant, low sulphur coal reserves can be mined cheaply is nuclear power not currently competitive. Of course such estimates depend on the accuracy of future estimates of both nuclear and coal costs.

Table III–7

Cut Off Cost*	Reserves**	Potential	Total
10	315,000	1,000,000	1,315,000
15	420,000	1,620,000	2,040,000
30	600,000	2,900,000	3,500,000

* Recovery cost per pound.
** In addition, 90,000 tons of by-product is expected through 2000.

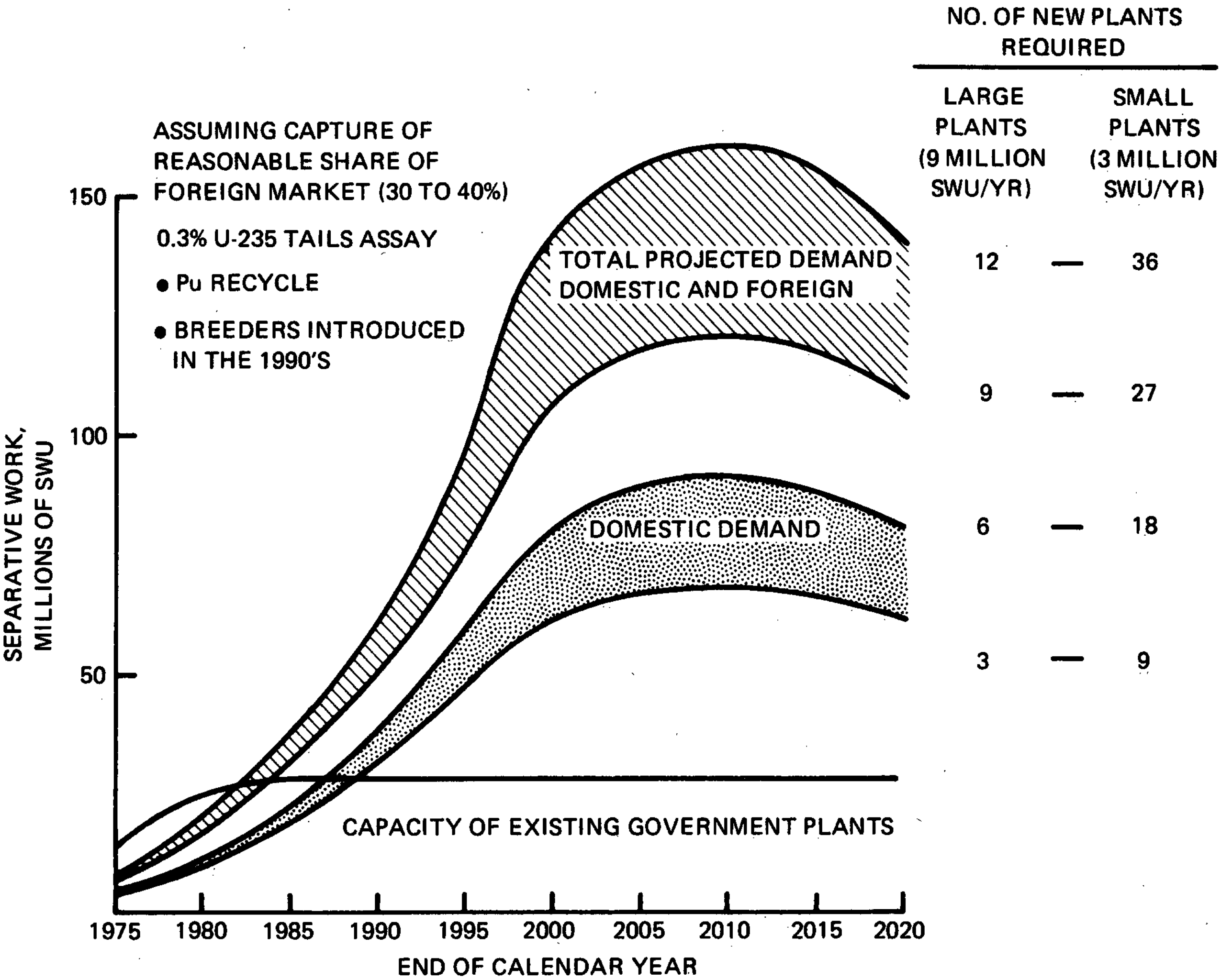
- Success in the transfer of responsibility for uranium enrichment to private industry and progress in initiating new U.S. capacity to meet future U.S. and overseas demand for enrichment services
- A commercial fuel reprocessing and recycling capacity
- Demonstrated safe and environmentally acceptable waste treatment and storage and disposal processes and facilities
- Improved LWR technology
- Strengthened safeguards.

Uranium Resources

If the use of light water reactors using domestic uranium resources is to expand as projected, an increase in the domestic uranium resources must also take place. Although uncertainties about the extent of uranium and the economics of its recovery exist, ERDA's present assessment (see Table III-7, above) is that the reserve base is adequate to provide for all operating and planned power reactors (235,000 MWe) and to permit further growth even without the recycling of plutonium and uranium. However, currently identified economic-grade ($30 or less per pound production cost) uranium resources may be inadequate to support the postulated long-term expansion of light water reactors beyond 1990 for their lifetime. Thus, additional major quantities of uranium resources of all grades must be identified and developed into reserves.

Uranium Resources—Tons of Uranium Oxide (U_3O_8)

The necessary industrial commitment to exploration and expansion of production capacity to ensure adequate development of resources has been retarded. To identify areas favorable for uranium exploration, to assess more completely the resource base, and to improve exploration and extraction technology, a comprehensive government program, National Uranium Resource Evaluation (NURE) has been in progress for about 2 years. Under ERDA's direction, it is designed to provide a systematic and extensive survey of the conterminous U.S. and Alaska by FY 1981. NURE is expected to identify localities that appear favorable for detailed exploration



SOURCE: URANIUM ENRICHMENT: A VITAL NEW INDUSTRY, ERDA-85.

Figure III–2 Annual Demand for U.S. Separative Work

and to provide an initial estimate of the resources in such localities. Such information will support private industry exploration and will provide a more comprehensive basis for estimating the potential uranium resources that may be available in future years. It is expected that the uranium production industry will continue to take responsibility for assuring the transferral of identified uranium resources to production capacity and for the establishment of relationships between buyers and sellers that will guarantee that uranium demands will be met. ERDA will also continue to analyze the industrial capability to produce uranium at needed rates.

Uranium Enrichment

Light water reactor technology depends on separating the small fraction (0.7 percent) of natural uranium that is fissile (i.e., will fission when struck by a neutron) from the much larger mass of nonfissile natural uranium. Uranium used as a fuel must be enriched by increasing the concentration of uranium-235, the fissile isotope.

During and subsequent to World War II, the government built three large enrichment plants that use the gaseous diffusion process to enrich uranium. These plants will produce about 15 million separative work units (SWUs)* this year for both foreign and domestic use, which would be sufficient for about 150 nuclear power plants of 1000 MWe each. The capacity of the existing ERDA gaseous diffusion plants will be improved and electrically uprated to a capacity of approximately 28 million SWUs by 1981, which should meet the long-term enrichment

* Separative work units are a measure of the effort required to enrich the uranium fed to the enrichment plant.

services requirements for reactors planned through about 1984. However, by 2000, projected domestic and foreign nuclear power expansion could require as many as 15 additional 9 million SWU enriching plants depending on the tails assay, the introduction date of Pu recycle, and the level of enriching services sales to foreign markets. (See Figure III-2.)

ERDA believes that expansion of uranium enrichment is a business operation best carried out in the private sector. To this end, over the past few years, ERDA has been transferring uranium enrichment technology to a number of qualified domestic industrial firms. But several factors have inhibited the private sector's moving ahead quickly in this area. First, enrichment plants require enormous investments—about $3 billion for each full-scale plant—and long return-on-investment lead times. Second, the technological competition between the diffusion process and the centrifuge method creates an element of technical and financial uncertainty. Although gaseous diffusion is an established technology with a demonstrated reliability greater than 99 percent, gas centrifugation might prove to be more economical. In addition, there is another process, laser isotope separation, whose technology has yet to be demonstrated.

To enable and encourage the private sector to begin the necessary investment to expand enrichment capacity, the Nuclear Fuel Assurance Act, was proposed to Congress in June 1975. This Act will provide ERDA necessary authority to negotiate cooperative agreements with private firms, which, after Congressional approval, would provide temporary financial assurances to these private firms. Specifically, ERDA is seeking authority to enter into contracts for cooperative agreements up to the amount of $8 billion to assure that in the unlikely event the proposed private ventures do not succeed, the government could still take actions to ensure that the plants would be brought on-line in time to supply domestic and foreign customers with uranium enrichment services when needed. It is expected that none of these funds would have to be expended for the assumption of private ventures. In addition, the legislation provides for a backup plan for a new government-owned facility at its Portsmouth, Ohio, site as a contingency measure in the event that private ventures are unable to proceed. When private industry efforts have made sufficient progress, the backup plan will be dropped.

Reprocessing and Recycling Capacity

Fuel elements discharged from light water reactors contain about half the fissile material present in new fuel elements. From economic and conservation points of view, recovery and reuse of the materials appear desirable, but no domestic or foreign commercial facilities currently process spent fuel from commercial reactors. The first domestic commercial plant experienced some operational and maintenance difficulties and was shut down for modification and expansion; restart before 1982–1983 is not foreseen. A second plant has not reached—and may never reach—the operational stage. A third commercial reprocessing plant was expected to commence operation in 1976, but will be delayed pending construction of facilities to satisfy new criteria for waste treatment and plutonium shipment. It would appear that, before any new commercial fuel refabrication plant that depends on large-scale utilization of plutonium can be fully licensed, a decision on the General Environmental Statement on Mixed Oxide Fuel (GESMO) must be forthcoming. A final statement by the Nuclear Regulatory Commission (NRC) is expected in 1977.

From a resource standpoint the development of a commercial reprocessing and recycling capacity is highly desirable for the continued growth of nuclear power. The continued absence of a reprocessing and recycling capability will materially increase the demands for uranium, increase enrichment capacity requirements, and necessitate interim storage of large volumes of spent fuel elements.

ERDA is proceeding with a program to assist industry to resolve outstanding problems associated with LWR fuel reprocessing and recycling. Initial program efforts (i.e., those to be completed during 1976–1977) include:

- Solicitation of expressions of interest and information from the nuclear industry on impediments to commercialization faced by industry and suggestions on what steps by industry or actions by ERDA could overcome these impediments.
- Based on industry response, other studies and evaluations, and discussions with industry and other government agencies, a specific plan of action will be formulated. If necessary, legislation for any required assistance would be drafted and submitted for Congressional approval.
- A broadly based program of research and development of the chemical processes, systems, and components applicable to the final phases of the LWR fuel cycle will be pursued concurrently. Areas requiring additional development include the process technology, systems operations and maintenance, design concepts and understanding of environmental impacts.

Radioactive Waste Management

A safe and environmentally acceptable program for the management and control of radioactive wastes is essential. Central to this waste management program is ERDA's acceptance of the responsibility for the custody of those radioactive wastes that have been identified by the NRC as requiring long-term federal control for reasons of human health and safety. The realization of nuclear power's full potential can only occur if environmentally safe waste disposal methods are developed.

Of the various radioactive wastes produced, most of the radioactivity is concentrated in one of the waste streams from the chemical processing of spent nuclear reactor fuel to recover its residual potential energy sources. This high-level liquid radioactive waste, as defined in NRC regulations, may be stored no more than 5 years after the processing of the parent fuel, and the stable, solidified product, sealed in high-integrity containers, must be delivered to ERDA no more than 10 years after processing the fuel. The very long-term potential hazard of high-level waste is from its content of plutonium-239 and related materials (known collectively as transuranium nuclides). Transuranium waste will also be generated in plutonium recycle facilities and a proposed NRC regulation would require that transuranium-contaminated waste, converted to solid form if necessary, be transferred to ERDA no more than 5 years after its generation.

These wastes need to be isolated from man's environment for extremely long periods of time. The preferred solution appears to lie in emplacing the relatively small volumes of these potentially hazardous radioactive wastes within deep, stable geologic formations. (Some geological formations have been stable for hundreds of millions of years, and there is every reason to believe they will continue to be so for further geological periods. Studies to date of a prehistoric underground natural nuclear criticality in what is now Gabon, indicate the radioactive residues of the phenomenon—natural high-level waste—have remained essentially at the generation site for well over 1 billion years.)

Laboratory and theoretical studies of geologic isolation of waste have been in progress for 20 years, and site investigations are now being conducted in southeastern New Mexico. A potential application for this location, beyond its use as a pilot plant, would be storage of transuranium waste generated by ERDA in its military production operations. In addition, it would also provide a facility for limited experiments with commercial high-level waste, beginning in the mid-1980's. However, demonstration of geologic emplacement or storage of high-level waste on a much larger scale is essential. The timing is propitious to undertake a major program to develop sites in several sections of the Nation in several different types of geological formations. This expanded effort would facilitate waste management on a regional basis, including the involvement of knowledgeable state government and university scientists.

In geologic isolation of waste, the geological medium itself provides one of the primary safety factors. The form of the waste and its container provide additional safety factors. In earlier stages, when the waste is still in retrievable storage or in transit, the physical and chemical forms of the waste may affect the margin of safety available in case of container rupture, however unlikely that might be. A development program aimed at less soluble, more monolithic waste forms has been underway for some time. Primary emphasis has been given to the silicate glass form.

Another program, begun in 1972, concerns retrievable surface storage of commercial, solidified, high-level waste at a central federal site. The draft environmental impact statement published by the former AEC in September 1974, which was a key step in proceeding to the location, detailed design, and construction of such a repository, was criticized for lack of detail in its discussion of the follow-on ultimate disposal of waste, and for failure to discuss regulatory issues. Pending issue of one or more generic environmental impact statements to replace the previous draft, retrievable surface repository work is being deferred. In view of the delays in generating commercial high-level waste and the planned acceleration of the geologic site development program, ERDA now believes that the eventual need for a surface storage facility will be much less than was thought when development started. ERDA's present plans are to begin demonstration of the terminal (geologic) storage of commercial high-level waste by the early to mid-1980's. Since criteria for waste forms and packaging will affect processes, facilities, and economics of the commercial fuel cycle, ERDA has a goal of establishing (or recommending to NRC) such criteria by the end of 1978.

LWR Technology

In addition to the critical need to establish a complete fuel cycle, a number of lesser problems impede full development of nuclear power. These include less-than-desired plant availability and reliability, long construction and licensing lead time, and evolving regulatory requirements.

If the level of availability and use of nuclear plants improved, it would translate directly into savings of fossil fuel—e.g., the daily output of a 1000-MWe LWR is equivalent to approximately 30,000 barrels of oil. Cost savings from realistically attainable construction time and design standardization/modularization could be on the order of \$1–\$3 billion during 1980–1985.

Although the solutions to these problems lie in the industrial/utility sector, the amount of effort being devoted to them by industry is not yet commensurate with the potential economic benefit to the public or reduction in oil consumption. Governmental analysis and planning could identify approaches to stimulating private investment in this area.

Specifically, ERDA is undertaking a program to stimulate greater industrial involvement in improving existing LWR technology and techniques. This program will include component testing and support in the basic technologies required by industry to increase the availability and productivity of existing plants. Determination of the underlying causes of plant deratings will be sought. These efforts should result in improved component reliability and in a reduction of scheduled and unscheduled downtime. The program will also seek to reduce the time and cost of new plant construction through such efforts as engineering standard support, standardization/modularization design studies, improved construction technology development, and special siting studies. The efforts will be conducted with industry and utility groups, and will be closely coordinated with other interested government agencies, including NRC and FEA.

Safeguards

The potential for sabotaging facilities or stealing and diverting fissile materials raises a fundamental safety issue. Unless the public fears concerning these issues can be allayed, future expansion of the nuclear power industry is likely to be curtailed.

The question of the degree of protection to be afforded nuclear facilities to prevent criminal diversion of materials or other criminal acts that could constitute a public safety threat continues to receive substantial government attention. In addition to NRC's establishing appropriate safeguards criteria for commercial nuclear facilities, ERDA is supporting a program of research and development on more effective safeguards systems and physical protection measures.

All facilities to be constructed and operated under cooperative demonstration programs will include the demonstration of appropriate safeguards systems and measures. To implement this policy, ERDA, for example, is currently supporting the development of a conceptual design that will identify performance requirements for the various parts of the physical protection system, the accountability system, and the materials control systems. Such information can then be integrated into the detailed design of future fuel cycle facilities.

Enhanced Oil and Gas Recovery Techniques

From past exploration, approximately 290 billion barrels of conventional oil, 130 billion barrels of heavy oil and bitumen, and 600 trillion cubic feet of natural gas are known to exist but cannot be recovered with present commercial recovery techniques. Enhanced oil and gas recovery techniques might eventually recover 40 billion barrels of this oil and 250 trillion cubic feet of the natural gas, or the equivalent of 10 to 12 times current annual production levels.* If costs of the recovered oil and gas were competitive with alternative fuel sources, enhanced-recovery techniques could postpone the expected domestic oil and gas production decline by a decade or more.

Enhanced recovery is a generic term for a variety of techniques for increasing the flow of oil and gas from their natural locations in permeable rock to producing wells and for increasing recoverability of the resources. The individual techniques, which have different applications in different reservoir formations, are at various stages of development; if proven successful and marketed, they would permit greater recovery not only from existing declining fields but also from new fields under development. Present high priority areas are inland.

Implementation Barriers

A number of techniques for enhancing the recovery of oil and gas are being researched and tested by private oil and gas companies, and, eventually, industry would undoubtedly develop and implement these technologies on its own. However, because of current economic circumstances, private industry might pursue alternative investment opportunities, thus postponing development and marketing of enhancement techniques.

Indeed, enhanced recovery techniques require significantly larger capital investments than conventional secondary recovery. Specifically, the estimated cost of oil using several of the enhanced oil recovery methods now being tested exceeds current domestic oil prices; however, this situation may become more favorable as oil prices are decontrolled over the coming years.

Not only is industry hampered by uncertainty over such institutional barriers as price regulations and tax requirements, but the possibility of antitrust action has tended to limit cooperaive ventures that could spread the risk and increase the support base.

Environmental problems are principally the same as those associated with primary production. However, tertiary oil recovery techniques may affect geological substructures differently. Secondary and tertiary methods, which will be used to stimulate existing wells, could cause contamination of ground water through pipe casing leaks—a problem similar to that which now exists for primary drilling—

* The estimate of potential oil recovery is ERDA's, based on a range of industry estimates. The gas recovery estimate is based on the **Natural Gas Survey, Volume II,** U.S. Federal Power Commission, 1973.

as well as through geologic faults. Biological concerns include what impacts waste heat and dissolved and suspended solids may have on aquifers. In addition, enhancement techniques for oil recovery may result in gaseous emissions of H_2S.

Strategic Approach

The Plan anticipates that the enhanced recovery techniques will be developed primarily and applied commercially by industry as its ability to predict returns on a project improves and in response to rising domestic and international oil prices. This process may be accelerated by complementary Federal efforts to address production, market, and environmental uncertainties. The Federal program is intended to provide more quickly an understanding of the magnitude of the recoverable resources; evaluation of the real potential of alternative technologies; understanding of the environmental impacts; and, ultimately, more complete recovery of the reserves.

The earlier various enhanced recovery techniques are researched and developed, the faster reasonable estimates of actual additional recoverable resources can be developed as input to substantive planning, development of national energy strategy, and the setting of priorities.

Development and commercial application of enhanced recovery techniques requires several years for evaluating the necessary technology, the potential environmental impacts, and the attendant economics. For example, 5–6 years may elapse between project initiation and resultant production; several more years may pass before profitability and extent of environmental impact can be demonstrated. Thus, research on resolving the uncertainties associated with advanced technologies needs to be intensified.

The availability of economical enhanced recovery techniques might result in more complete, ultimate recovery of reserves. More complete recovery might result from changes in the current production cycle from primary recovery to the various phases of enhanced recovery. For example, further research might obviate the need for the traditional primary—secondary—tertiary cycle indicating that in certain instances water flooding (secondary recovery) should be omitted and replaced by micellar-polymer flooding (tertiary recovery), and that water flooding should be done concurrently with primary production. Such advanced technology application might replace the "last ditch" applications that often have marginal economic returns.

The costs and benefits of various enhanced recovery techniques are being analyzed by ERDA to determine the appropriate mix and level of Federal R&D expenditures.

Action Program

The Government is developing an approach to accelerate the development and application of enhanced-recovery techniques:

- ERDA is co-funding research, development, and demonstration projects with industrial firms.
- ERDA is analyzing and interpreting field test results to understand the potential for the profitable use of certain enhanced-recovery techniques.
- FEA is reviewing price regulations, tax requirements, and other institutional barriers relative to enhanced-recovery.

Under jointly funded Federal RD&D projects, private firms provide an average of 60 percent of the funds. However, as the risks become lower the Federal role should be reduced. Each of the projects involves a field demonstration, which is expected to produce technical, economic, and environmental results that will be transferred to other firms in the industry to obtain maximum benefit. Presently, 15 major enhanced-recovery demonstrations are under way. These demonstrations are split between enhanced oil recovery (approximately 55 percent) and enhanced gas recovery (45 percent). Additional demonstrations are anticipated for FY 1976, with about the same split between oil and gas recovery efforts. Environmental factors are considered in developing and executing this demonstration program.

The legal and institutional questions are being investigated by the FEA, which implements the price regulations. FEA is also evaluating applicable tax laws to determine if reasonable changes can be made to encourage enhancement projects. Reduction of uncertainty over oil price legislation might speed industrial activity since the economics of the various advanced technologies for enhanced recovery are very sensitive to price. A clear-cut explanation of how output from enhanced recovery techniques will be priced and how the large accompanying research and development expenses will be treated for tax purposes could serve as an incentive for initiating major projects.

Direct Utilization of Coal

Although the Nation's coal resources are not inexhaustible, they do represent one of the Nation's most abundant fuel resources. At present, coal is supplying only 17 percent of domestic energy. At that rate of consumption, known reserves economically recoverable in a 1970s competitive environment would last more than 300 years. As prices of alternate fuels escalates in the future, less accessible coal reserves will become increasingly attractive. Thus, coal's economic usefulness should continue well into the 21st Century and perhaps beyond.

Production of coal is now beginning to grow again and reached 640 million tons in 1975, exceeding the 400- to 600-million tons-per-year range that had persisted since World War II. Indeed, several forecasts project a tripling of domestic demand by the year 2000, provide barriers to such high levels of use can be overcome. Currently, about 65 percent of the coal is used in central station electricity generation; about 15 per cent, as coke; and most of the remaining 20 percent, in industrial plants for power or process heat. Consequently, in considering how to increase the use of coal, interest centers first on application in central station power plants and second, in industry.

Implementation Barriers

Immediate expansion in the use of coal is limited by the high costs and uncertainties associated with the environmental acceptability of this energy source. The critical environmental concerns are twofold.

First, much of the coal can best be extracted through strip mining. This will require restoring the land to original productivity and recontouring. The necessary revegetation would consume substantial amounts of water, a commodity in short supply in western regions where much of the strip mining would occur. Moreover, if stripping were indiscriminate, disrupted habitats could endanger wildlife species and upset ecological balances. In some areas, coal extraction threatens aquifers which lie above or in a coal seam.

Given these problems, research must be continued on restoration of productivity. The reclamation effort itself will have some impact on water quality and quantity. Acid and alkaline leaching into ground and surface waters will occur before strip-mined land can be fully reclaimed. Wind/water erosion can also deteriorate water quality by increasing sediment loads. Thus, prompt reclamation efforts, even as mining continues elsewhere at the extraction site, needs to be instituted to reduce this potential for erosion, soil loss, and water contamination.

The second environmental concern is the problem associated with stack effluents. Central station operations generate such atmospheric pollutants as noncombustible residuals (ash), and noxious gases, Existing technology can remove the ash satisfactorily, and the cost of the necessary equipment to do so has been incorporated fully in utility rate bases. Fly ash systems developed for the utilities by industry during the last several decades are now standard equipment on new power plants.

The discharge of noxious gases (oxides of nitrogen and sulfur) has become a concern only in the relatively recent past and, as a consequence, control of this pollutant is not as well in hand. Nitrogen oxide emissions can be controlled by controlling combustion temperatures through techniques such as staged combustion, or flue gas recirculation. Moreover, this technique can achieve EPA discharge levels of 0.7 pounds of NO_x per 10^6 Btu at a cost close to that of conventional combustion systems. It is expected that industries will adopt this technique.

Nitrogen and sulfur oxide emissions may degrade air quality in the vicinity of the emission source beyond allowable levels. In addition, sulfate transport over long distances is a concern. An EPA regulation forbids more than 1.2 pounds of sulfur dioxide per 10^6 Btus, which is achievable by burning low-sulfur fuels. However, because supplies of low-sulfur fuels are limited, it will be necessary to employ sulfur-removal systems to permit use of fuels with a higher sulfur content.

In addition to the environmental problems, rapid development of extraction sites in the Northern Great Plains and the Rocky Mountains will bring large outside populations to remote and sparsely populated regions. This influx may create a sudden, heavy demand for such necessities as housing, schools and health care facilities, needs which small communities may have neither the capability nor the money to respond to. On the other hand, many regions might profit from the increased activity.

Strategic Approach

Private corporations, government and industry organizations, such as Electric Power Research Institute (EPRI) have been involved in developing approaches to improve technologies for the direct utilization of coal. Major private sector R&D efforts are ongoing with regard to coal utilization technologies. It is expected that industry will have a continued high interest in developing and implementing these technologies. The government role is to identify those aspects of coal utilization that have high potential payoffs to society, but are not receiving adequate attention or funding. Furthermore, the government has a role in disseminating information and providing financial incentives (where necessary), in order to facilitate market penetration of near commercial technologies.

The strategic approach to be undertaken addresses mining and air pollution problems separately. In the extraction area, improvements in mining techniques and equipment are under investigation to increase both the recoverable fraction (leaving less unmined coal in the ground) and the efficiency of extraction so that fewer man-hours and less energy is expended per ton of coal mined.

Environmentally acceptable methods of land reclamation are also being developed to restore mined areas to an acceptable condition with equal or superior productivity. Simultaneously, improved miner health and safety are being sought, especially in underground coal mines.

To deal with the problem of complying with air pollution standards, coal can be cleaned in advance of combustion, sulfur can be removed during combustion, or sulfur can be removed from stack gases.

Removing sulfur from coal with various mechanical or chemical separation techniques in advance of combustion or conversion reduces problems of onsite waste disposal; allows use of existing coal combustion systems; and may improve the economics of use and transportation (compared to raw coal). Coal cleaned in this manner can be further enhanced by crushing and blending to uniform size and Btu value, in order to improve its operability and reliability. One disadvantage of this process is the loss of some of the coal due to imperfect separation. Government and industry groups such as EPRI have been developing such improved benefication methods. ERDA is monitoring and utilizing results of these efforts to perform economic trade-off studies and analyses in order to promote their use and adoption by private industry.

Substantial effort is being devoted to removing sulfur pollutants during combustion. One promising process is the fluid bed combustion system in which the coal is burned in a solid/air mixture, with the solid including a substantial quantity of limestone. Combustion temperatures are lower, which aids in controlling nitrogen oxide emissions. The sulfur is converted to a dry calcium sulphate. The cost has been estimated (but not yet demonstrated) as being comparable to that of scrubbers. In addition, fluid bed combustion systems do not have the plant-efficiency penalty of scrubbers.

Other advanced technologies with potentially attractive environmental features in terms of air pollution include coal gasification in combined cycle systems and MHD. Direct use of coal in industry (as opposed to use in an electric utility that generates electrical power used by industry) faces a more complex set of problems. Frequently, scrubbers, the most immediately available air pollution control solution for large central stations, are uneconomical for smaller scale industrial applications. It is principally the operating and maintenance costs of the add-on scrubber systems that discourage such application. Consequently, fluidized beds, which eliminate the need for add-on systems, appear to be the more attractive solution.

In addition, large, central power stations could use low-sulphur coal in conjunction with stack gas scrubbing systems, which have reached the stage of limited commercial application. However, even though these systems meet immediate requirements, their commercial reliability has not yet been fully demonstrated. Furthermore, the sludge-like gypsum formed in the process is difficult to dispose of and nearly doubles the bulk of the waste from a power station. Scrubbers may increase the cost of central stations by about 20 percent and reduce station efficiency. Consequently, the Plan provides for developing alternative air pollution control means that reduce the total disposal problem and increase the pollutant removal capacity of the central stations.

In addition to the above technologies for using coal directly, it may be possible to substitute to some extent coal for oil in **oil-burning** equipment used by utilities. Finely pulverized coal suspended in fuel oil can possibly be accommodated by minor modifications of existing burner and fuel-handling equipment. For a given heat rate, the fuel oil demand may be reduced as much as 30 percent. As might be expected, the air pollution problems for both fuels are NO_x and SO_x, and particulates. Because of the utility industry's large investment in existing oil-burning equipment, retrofitting to permit an oil-coal slurry could simultaneously result in lowering petroleum demand and increasing coal consumption. The economics and practicality of this approach are being investigated.

Action Program

By 1985, the Department of the Interior's Bureau of Mines (BOM) will have completed major demonstrations in the eastern, central, and southwestern sections of the country to establish the economic efficacy of integrated extraction-reclamation systems. The Department also has a health and safety program to address related issues. In addition the BOM and the EPA are developing improved coal treatment technology to upgrade the quality of coal by reducing the amount of ash, sulfur, and other constituents.

The cleaning of flue gases from coal-fired utility and industrial boilers—i.e., scrubbing—has been assigned highest priority within the EPA-coordinated Federal Interagency Environmental Control Technology R&D Program. To this end, EPA is developing second-generation Flue Gas Desulphurization (FGD) systems that offer improved economics and reliability and reduce the amount of by-products that must be disposed of. A comprehensive sludge disposal technology program supplements the second generation work. In a parallel program, EPA is pursuing flue gas treatment to develop a cost-effective process for full-scale control of nitrogen oxide. Fuel additives, which will serve the same purpose as sulfur in enhancing electrostatic precipitator performance, are under study and development. And advanced particulate control technology is undergoing development to broaden applicability and effectiveness.

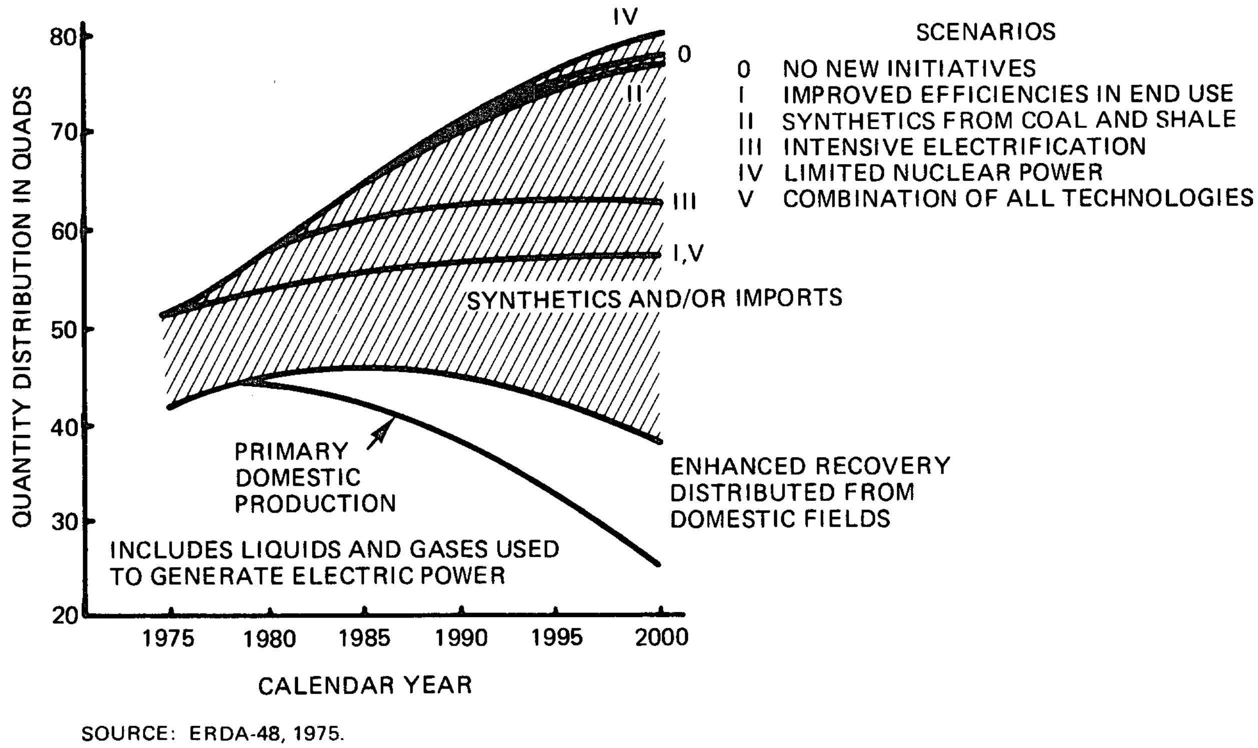


Figure III–3 Projected Demand for Liquids and Gases to be Met by Synthetic Fuels

ERDA is developing advanced power systems which will permit power generation from direct firing of coal and coal derived fuels in an efficient and environmentally acceptable manner. ERDA's research includes the use of open and closed cycle gas turbines in combustion with advanced combustion and gasification technologies, such as atmospheric and pressurized fluidized bed combustors. The fluidized bed combustors offer the major advantage of internal removal of sulfur oxides from combustion products. This approach offers the potential for eliminating the need for stack gas scrubbers; required in conventional coal-fired boilers to meet emission standards. In addition to research units which have been operated by ERDA and EPA for several years, there is currently under consideration an atmospheric fluidized bed pilot plant.

Synthetic Liquid and Gaseous Fuels

The absolute demand for oil and gas, even under optimistic energy-conservation assumptions, will outstrip the supply provided by conventional domestic oil and gas sources, thus increasing the level of oil and gas imports. Moreover, the gap between the demand and domestic production is widening. Therefore, in the years ahead, the U.S. must seek to exploit untapped domestic oil and gas sources and must develop alternative energy sources to minimize its dependence on energy imports.

Over the next 25 years, synthetic fuels* offer a domestic energy alternative to imported oil and natural gas. For this option to be credible, however, under the most favorable energy-conservation assumptions and enhanced domestic oil and gas recovery techniques, approximately 5 million barrels per day equivalent synthetic production capacity must be operational by 1995 to hold imports at current levels (or about 6 million barrels per day). (See Figure III–3.) Under less favorable assumptions, the need for synthetic fuels could be twice this amount or more.

Implementation Barriers

Although not in commercial use in the U.S., technological processes for converting coal to clean liquid and gaseous fuels—e.g., Lurgi gasification, Fischer-Tropsch synthesis, and Koppers-Totzec—have been available for many years. However, given the present cost and the uncertain relative economics of synthetic fuel production cost, it is not surprising that a synthetic fuels industry has not recently been developed in the U.S. by the private sector. Commer-

* That is, the clean liquid and gaseous fuels produced from converting coal and shale.

cial size plants—i.e., those with a daily capacity of 20,000 to 50,000 barrels of oil or up to 250 million cubic feet of gas—are complex and expensive, costing up to $1 billion or more each. Such investments are beyond the capability of all but the largest industrial firms. The products of these plants must compete in the marketplace with all other similar products, the prices of which are often controlled by nonmarket forces. For example, the world price of oil is controlled by an international cartel, and the domestic price has been strictly regulated. These impacts on the natural market forces affecting competing fuels, coupled with uncertainties in the costs of synthetic fuel production, create a pricing risk that is, at present, unacceptable to virtually all private investors.

Possible escalation in project cost and other risks arising from environmental and regulatory delays in construction or start-up add to the uncertainties surrounding synthetic fuel product costs and prices of competing fuels, thereby further reducing the attractiveness of investment in synthetic fuel plants. Project delays resulting from environmental, regulatory, technical, or other causes could severely strain the financial resources of any firm. Indeed, an industry survey conducted in 1975 indicated that there is unlikely to be significant private investment in production of synthetic fuels from coal and shale before 1985 without some form of government incentives or substantial changes in federal regulation.

In addition to technical and economic barriers, implementation barriers also include a range of unsolved social and environmental problems. The principal social problems are community impacts of rapid growth, while the most important environmental problems relate to: (a) coal and shale extraction; (b) use of water in the conversion process; and (c) contaminating effluents from the synthetic fuel plants.

With regard to extraction, in addition to the problems cited for the extraction of coal, the major unique problems of oil shale processing include fugitive dust and the disposal of spent shale. The large quantities of spent shale resulting from commercial operations will require significant land areas for disposal, which may be affected by erosion, fugitive dust, leaching, and productivity reduction. Disposal of spent shale can cause high salinity and sediment problems. Other environmental problems may occur as a result of heavy metals and carcinogens in shale as well as land-use changes. And the mining itself could affect subsurface water flows.

In addition, synthetic fuel processes require large quantities of water and thousands of acre feet per commercial facility. In some areas the acquisition of the necessary process water will be difficult. Further, process water not used consumptively may be degraded in quality to the point it is unsuitable for other uses.

Finally, there is the potential for gaseous and liquid releases from synthetic fuel conversion facilities, which may contain polycyclic aromatic hydrocarbons. These hydrocrabon releases could include known and suspected carcinogens.

Strategic Approach

These implementation barriers, especially the economic ones, are serious impediments to private-sector development of a synthetic fuel industry in the near term.

Therefore, the strategic approach of the government would be to provide Federal financial assistance in carrying out critical technology RD&D while taking action that would mitigate against the uncertainties associated with developing an industry.

The strategy for implementing the first initiative is embodied in ERDA's coal RD&D program. This program is based on the assumption that for the private sector to eventually make widespread use of newer, lower cost synthetic fuel technologies, they must participate with ERDA in their development. Therefore, the strategy is keyed to producing concepts, processes and equipment that will meet the needs of the private sector. Specifically, the strategy aims at producing a commercially viable technology for each key stage of extracting, refining, and use, while closely involving the private sector. This strategy has led to a cost-sharing philosophy used in the demonstration projects.

But industry is involved throughout the typical development sequence which is shown in Figure III–4. The cost-sharing, for example, is concentrated in the pilot plant and demonstration plant phases but also occurs to some extent in earlier phases.

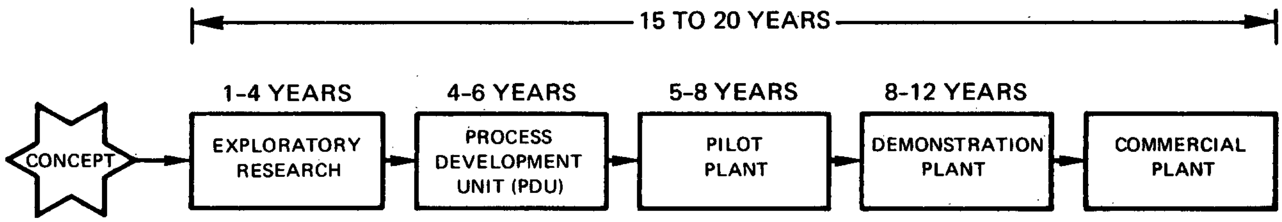


Figure III–4 Typical Process Development Sequence

The development phases take varying lengths of time depending on the complexity of the process and project, the scope of the effort, and the resources applied. (See Figure III–4.) Total development time from laboratory to completion of demonstration plant operation is typically 15 to 20 years.

The technical feasibility of the concept being developed is evaluated in each phase to determine the advisability of carrying the project to the next phase. Tentative economic and environmental evaluations start in the early stages of process development and continue through pilot plant and demonstration plant phases; more extensive evaluations are made with demonstration plants. In addition, before projects reach the stage of major construction, environmental analyses and water resource availability assessments are made; environmental impact statements are developed as required.

To have an industrial infrastructure in place to draw rapidly on these new technologies when they will be needed in the 1990s appears to require extensive commercial effort in the near term.

By and large, even if normal economic incentives were developed after 1985, it would be too late to establish the scale of industry (5 to 10 million barrels of oil equivalent per day) needed by the end of the century to hold oil imports at current levels since each plant needed would take 5 to 10 years to plan, design, site, and build. For the necessary number of plants to be operating in the mid-1990s, an industrial base on the order of 1 million barrels per day may have to exist by 1985. But uncertainties about regulations, environmental impacts, financing, labor, product pricing, and transportation must be resolved before these decisions can be made, and resolving these questions requires the construction and operation of a limited number and range of synthetic fuels plants in the next 5 to 10 years.

To determine the viability of initiating a limited number of synthetic fuels plants the Synthetic Fuels Interagency Task Force* carried out preliminary economic analysis. In that analysis, it was found that the net economic benefit of such plants depends on the ongoing strength of the OPEC cartel, the eventual price competitiveness of synthetic fuels, the influence of technology and economics of scale in reducing the cost of synthetic fuels, and the U.S. energy position in 1995. The results of that analysis showed that, on average, a slight ($1.65 billion) net **negative** benefit would accrue from the first phase of an action program to develop a synthetic fuel capacity of 350, 000 barrels per day equivalent, compared with no program. Moreover, this benefit became more negative as the program grew to 1.0 and 1.7 million barrels per day equivalent, assuming a 50-50 probability that the OPEC cartel would not retain its present strength over the next 10 years. However, the analysis did not include other, nonquantifiable benefits that might accrue to the U.S. as a result of undertaking a program such as: (a) the international leverage improved bargaining position associated with positive U.S. leadership in developing alternative fuel sources; (b) the impact on industry of government support for synthetic fuels development; (c) the political as well as economic value of a decrease in world oil prices paid by importing nations; and (d) possible weakening of the cartel strength (this was assessed as negligible).

The Interagency Task Force concluded that the value of these four nonquantifiable benefits makes a limited synthetic fuels program worthwhile. Furthermore, the program to be discussed later has positive benefits greater than those calculated by the Task Force because of the elimination of synthetic crude from coal from the plant mix analyzed. This technology is the least cost efficient of all the processes examined in the analysis. Currently, the recommended first phase of the program does not include this technology until the results of current R&D efforts on coal technologies are known.

* Published in November 1975.

Action Program

With the clear need to move ahead in laying the foundation of a synthetic fuels industry, the Administration supported a formal market penetration program in 1975. The major objectives of this Synthetic Fuels Commercialization Program are to:

- Lay the groundwork for developing an industry infrastructure by:
  - —Investigating and acquiring information on environmental, economic, institutional, technical, and other potential problems
  - —Gathering and reviewing information on the private sector's experience in the synthetic fuels field
- Develop an energy supplement to existing and planned domestic energy production
- Improve the Nation's international leadership position in energy development by demonstrating our ability to tap our vast resources.

The program would entail two phases. In the first, or Information Program phase (350,000 barrels per day), approximately 14–19 commercial-sized demonstration plants would be constructed, including facilities for high-Btu coal gasification, oil shale conversion, substitute utility of industrial fuels, and conversion of waste material to liquids and gas. This first phase of the program would demonstrate and obtain information on the technical, economic, and environmental feasibility of synthetic fuel plants, using different available energy resources and technologies.

Table III–8 Illustrative Plant Mix

Type Plant	Probable Number	Est. Production Capacity—Each Plant	Affecting Industry
High-Btu Coal Gasification	3	40,000 BPDE	Pipeline Gas
Oil Shale Conversion	2–4	10,000 to 50,000 BPDE	Petroleum
Substitute Fuels Utility/Industrial	6–7	5,000 to 25,000 BPDE	Utilities/Industrial Users
Biomass Conversion (Gas/Liquid)	3–5	1,200 to 6,000 BPDE	Various
Totals	14–19	350,000	

To illustrate, one **possible** plant technology/resources is shown in Table III–8.*

In carrying out the first phase of the synthetic fuels program, the Federal Government would reduce financial uncertainties by providing limited economic incentives to the private sector to construct and operate the commercial demonstration plants. The Government would also provide limited guarantees or, if necessary, assistance to localities for needed socioeconomic infrastructure planning and development. Finally, the Government would help expedite the construction of the plants by facilitating the necessary federal regulatory permits and clearances.

The program might be expanded to 1 million barrels of oil equivalent per day during the second phase, if the energy situation warranted and if the environmental, social, technological, and production cost problems were sufficiently tractable. However, this decision is not anticipated until 1978–1979 and would depend on overall energy RD&D results, industry response to the program's first phase, and the results of information on environmental and other impacts.

In addition to laying the groundwork for a viable synthetic fuels industry, important RD&D will be carried out on advanced synthetic fuel technologies. These efforts would support development of a number of synthetic fuel processes in parallel, moving from basic R&D in the laboratory, through process development units (PDUs) and pilot and demonstration plants, to market penetration. A significant number of liquefaction and gasification PDUs and pilot plants are currently operating; additional PDUs and pilot plants are being designed or are under construction. Finally, a contract for a clean boiler fuel demonstration plants (COALCON) has been let, and the plant is being designed. Additional contracts—for high-Btu and low-Btu demonstration plants—will be initiated shortly.

In parallel with these legislative, budgetary, and administrative actions, ERDA is carrying out a program, still being formulated, will include a number of efforts, such as measurement of water quality at test sites and the prediction of degradation resulting from commercial operations; investigation of options that minimize the need for water; development of improved recycling and effluent treatment techniques; and evaluation of process and by-product pollutants and associated health effects. In addition, assessments of the potential health impacts would require environmental and health information which involve both short-term and long-term studies. Data from these studies are necessary for setting appropriate regula- gram to address environmental concerns. This pro- tory standards and for the design of effective control technologies, including incineration, collection-disposal, and chemical absorption techniques.

Investigations into revegetation dynamics and plant species selection are continuing. *In situ* processing of both coal and oil shale is being given considerable attention. However, the *in situ* approach would leave most of the solid waste products in place. In addition, there could still be problems of land subsidence, hydrocarbon and particulate emissions through the fractures, and contamination of aquifers. Studies of oil shale formation and kerogen content and the characteristics of pollutants, seam size, and associated underground aquifers are being conducted.

Efforts also are under way to establish air pollution control requirements to prevent or minimize environmental pollution from production and use of synthetic fuels. Initial efforts in the program are concentrated on assessing the potential environmental effects of the coal-conversion processes. Control technology aimed at controlling sulfur and particulate emissions from hot, acidic gas streams is also under development.

Specific Steps in Action Program

Moving ahead with the first phase of the market penetration program requires a series of legislative, budgetary, and administrative actions, including:

- Legislative authorization of the limited financial incentives to be awarded to the private sector for

* The actual plant number and sizes may vary from this estimate, depending on the proposals received from interested firms and final environmental impact statements.

Table III–9 Geothermal Resources—Estimated Recoverable Heat with Present or Near-Term Technology without Regard to Cost†; (In Quads)*

RESOURCE TYPE	KNOWN	INFERRED	STATE OF TECHNOLOGY
HYDROTHERMAL CONVECTIVE**			
VAPOR DOMINATED (>150° C)	2	2	COMMERCIAL
LIQUID DOMINATED			
HIGH TEMPERATURE (>150° C)	20	110	TEST PHASE
LOW TEMPERATURE (90°-150° C)	80	250	TEST PHASE
GEOPRESSURED			
ELECTRICAL UTILIZATION	100	230	EXPERIMENTAL
METHANE PRODUCTION	500	1500	
HOT DRY ROCK	80	240	EXPERIMENTAL
MAGMA ++	80	240	UNEXPLORED
TOTAL	~900	~2500	
GRAND TOTAL (KNOWN PLUS INFERRED)	3400 QUADS		

* NORMAL GRADIENTS ARE NOT INCLUDED AT THIS TIME AS THEY ARE NOT PRESENTLY CONSIDERED RECOVERABLE. 1 QUAD=10^{15} Btu's.
** DOES NOT INCLUDE LESS THAN 90°C SYSTEMS, ALTHOUGH SUCH SYSTEMS MAY BE ECONOMICALLY EXPLOITABLE ESPECIALLY FOR NON-ELECTRIC APPLICATIONS.
+ASSUMING 2% EXTRACTION RECOVERY, 8% CONVERSION EFFICIENCY.
++MAGMA RESOURCES MAY BE RENEWED BY NATURAL RESUPPLY FROM THE INTERIOR OF THE EARTH; THEREFORE, THIS ESTIMATE MAY BE CONSERVATIVE.

SOURCE: DEFINITION REPORT: GEOTHERMAL ENERGY RESEARCH, DEVELOPMENT AND DEMONSTRATION PROGRAM (ERDA-86), OCTOBER 1975.

demonstration plants. Although loan guarantees are essential, price guarantees and grant authority may also be needed to ensure all major synthetic fuel technologies and the important types of resources are included in the program. If needed, price guarantees and grant authority would be sought under the authority of the Nonnuclear Act.

- Legislative authorization of the limited financial guarantees to localities for needed socioeconomic infrastructure as well as assistance for planning and development. This could be in the form of guarantees of local government debts incurred to provide the necessary infrastructure.
- Continue the necessary environmental studies that will ensure environmental acceptability of a commerical synthetic fuels industry.
- Evaluate mechanisms to expedite federal regulatory permits and clearances.
- Administrative action to ensure the technology demonstrated by the program will be available to all interested firms at a reasonable cost.

Geothermal

The Nation's geothermal resource base is one of the largest potential domestic energy sources. As estimated by the U.S.G.S., ERDA-86,* reported the total heat content of the accessible geothermal resource base (depth less than 10 km) to be about 600,000 quads, excluding the highly diffuse "Normal gradient" resource. However, only a small fraction of this base is recoverable in usable form with presently foreseeable technology. On the basis of conservative assumptions of extraction and conversion efficiencies the total recoverable energy from this base, with near-term technology but without regard to cost, was estimated to be only about 3400 quads, which is still about 45 times the total U.S. energy consumption in 1974,** as shown in Table III-9. However, as esti-

* **Definition Report Geothermal Energy Research, Development and Demonstration Program,** ERDA–86.
** However, a significant proportion of these resources exist away from population centers and thus may not be fully exploitable.

mated in ERDA-48, only a small fraction of this resource (reaching an annual level of approximately 5 quads by the end of the century) is estimated to be extractable over the next 25 years. Economic exploitation of this resource will require the reduction of technological and financial risks, the reduction or removal of a number of institutional barriers, and the development of technology to provide acceptable control of possible environmental problems. The latter, often site- or type-specific, include subsistence, brine disposal, and the emission of noxious or toxic substances, such as hydrogen sulfide, in varying amounts.

Only the vapor-dominated hydrothermal resource (The Geysers in California) has been economically exploited in the U.S. This type of resource is rare and amounts to only a few percent of the known or inferred total geothermal resources. The more extensive liquid-dominated hydrothermal resources have not been exploited to any degree for power production in the U.S. (although there has been some foreign experience, using techniques currently not environmentally acceptable in this country). A few hydrothermal development efforts in the U.S. are in the technology verification or pre-pilot stage, but the technology for tapping the larger geopressured resources along the Gulf Coast is in the stage of engineering feasibility studies. Commercialization of geopressured resources will probably follow that of hydrothermal. Thus, the liquid-dominated hydrothermal resources represent the principal near-term opportunity for exploitation. It awaits the development of improved versions of existing reservoir assessment, extraction, and utilization technologies, and the solution or abatement of a number of environmental and institutional problems, as discussed below.

Implementation Barriers

Because the costs of extracting energy and of controlling environmental impacts vary greatly among the different types of hydrothermal reservoirs, mature technology will be directed initially at the development of the **most favorable**, known hydrothermal reservoirs. For some sites, based on an extension of foreign technology, the cost of electric power generated by geothermal resources has been estimated at well below the cost of power produced in conventional coal or nuclear plants. However, uncertainties about the actual power production costs and reservoir lifetime associated with an untried geothermal site, as well as the basic uncertainties of a new technology, have discouraged most utilities from proceeding with geothermal energy development. And the few utilities that have taken an interest have had little success in attracting support from public utility commissions, lenders, or investors.

The reasons impeding the commercial development are principally threefold:

1. **Lack of reliable, detailed resource information**, e.g., on the changes in the characteristics of a reservoir resulting from energy extraction
2. **Lack of proven domestic technology** for use with all but one type of recoverable resource, the vapor-dominated hydrothermal
3. **Legal and regulatory complexities** involving leasing, resource ownership, water rights, taxes, and the like.

In addition, insufficient knowledge of possible environmental impacts and the lack of proven control techniques for all but the vapor-dominated hydrothermal resources inhibit rapid commercial development. The environmental issues fall into three areas.

First geothermal development may produce seismic disturbances and subsidence. Removal or injection of massive quantities of water may result in seismic activity, with effects varying from site to site. Withdrawal of water may also cause subsidence as reservoir pressure is decreased, unless appropriate control measures are taken, such as brine reinjection.

Data required to predict subsidence rate and seismic activity are currently unavailable. Potential seismic activity at each site must be assessed and the potential effects of withdrawal or injection of large quantities of water analyzed and monitored. Ground levels must be monitored and base lines established with predictive modeling prior to development. Reinjection technologies must be explored as important environmental control measures.

Secondly, quantities of air pollutants released from hydrothermal activities are not known. Hydrogen sulfide, emitted in large quantities is a significant pollutant because of its toxicity and disagreeable odor. Methods of treating large gas volumes with low H_2S concentration must be developed.

Third, where a fresh water aquifer occurs above a geothermal reservoir the fresh water could be contaminated by tapping the geothermal strata. Saline waste waters cannot be discharged into surface waters without treatment. Subsurface reinjection of brine-liquid effluents may represent a significant control measure not only for brine disposal but also for subsidence, although it may be accompanied by other environmental problems such as seismic disturbances (see above).

When such reinjection is not feasible or desirable, surface treatment and disposal must be considered. Because it may also introduce trace contaminants, removal of toxicants must be effected and environmental impacts of effluents on fauna and flora must be determined. Unless adequate controls are devised and implemented, the associated water pollution problems may inhibit development of geothermal energy.

ERDA-86 has estimated that, without Federal involvement, only about 1,500 MW of geothermal power would be on line by 1985. Most of this would result from the planned expansion of vapor-dominated geyser fields with limited additions of liquid-dominated hydrothermal resources in southern California and scattered small-scale, nonelectric applications in the western U.S.

Strategic Approach

Although the necessary detailed analyses of the various types of geothermal resources have not been completed, it appears that the development of geothermal energy may have an attractive positive rate of return. However, as perceived by private investors, who make conservative estimates of technical and other risks, this rate of return seems marginal. Government-sponsored studies of the more economically attractive hydrothermal resources suggest that these could, where available, provide electricity at competitive prices. Equally important, capital costs of installed hydrothermal capacity are expected to be competitive. As in any unproven technological area, significant uncertainties exist in the economic analyses and sufficient analysis has not been done to derive predictions of expected rates of return that will be accepted by utility decision-makers and private investors.

Nonetheless, it is ERDA's current judgment that the geothermal resource will prove to be a commercially attractive source of energy. However, the private sector has not utilized the geothermal resource beyond the limited dry steam type because of existing barriers. Both utilities and resource companies will have to cooperate in individual projects.

To address this impasse, a limited and targeted governmental program could help a fledgling industry over the initial barriers and permit the Nation, as a whole, to realize geothermal's full potential. The strategic approach governing commercialization efforts would encompass four principal elements.

First, the Government would assist the private sector in identifying and verifying the extent and lifetime of usable geothermal resources. This assistance, consisting of the U.S. Geological Survey's regional and national assessment of geothermal resources, the development and testing of improved exploration techniques, and an accelerated leasing program to improve the availability of Federal land, would lessen the uncertainties and risks now confronting investors.

Second, Government would assist industry in utilizing the sizable hydrothermal resources. Greater utilization of hydrothermal resources will enable industry to gain the momentum necessary to undertake the development of the other forms of geothermal resources, such as the still larger geopressured and hot dry rock types. (The "momentum" approach is based on the current judgment that breakthroughs in an already generally understood technology are not probable; rather, as additional experience is acquired, sustained and systematic performance and cost improvements in extraction and utilization will accrue.) However, to tap these resources, the necessary technology, which is improving and is closely related to that already in operation with vapor-dominated resources, must be brought to fruition. Parallel to efforts to accelerate market penetration, Government RD&D would assist in bringing the technology for the advanced geopressured and hot dry rock sources to comparable maturity.

Third, the Federal Government can act as a catalyst, or "broker" in forming a consortia of institutions needed to commercial geothermal resources—i.e., electric utilities, resource development companies, specialized equipment manufacturers, and local government.

Although electric utilities are not suited to conducting the exploration, drilling, and production operations because of regulatory constraints, they are necessary consortia participants because they form the largest single market that can be immediately identified. Other possible user industries, such as those requiring process heat or those that could use geothermal heat for space heating and cooling, are more diffused and less readily identifiable, but form an important future market for geothermal energy and should be included.

The oil and gas industry is the most prominent candidate among the resource developers because it has basic commitment to energy supply, expertise in the technologies of resource discovery and extraction, the equipment (or ready access to the equipment) necessary for discovery and extraction, and access to the capital required to support the effort. Other possible resource developers, whose problems also will be considered, include the minerals industry and the specialized exploration industry beginning to form around geothermal energy.

Unlike most other energy resources, geothermal energy is nontransportable. This aspect alters this traditional perspective of the market. The developer no longer has a large commodity-like market for his resource; rather, he must sell it to those specific users able to exploit the **specific** characteristics of the resources and willing to locate at the **specific** site of the resource. The user no longer has a large market from which to draw his energy; rather, he must accept the specific resource and its finite limitations and deal with a single developer. He also must accept the specific site, thereby losing all flexibility in location; availability of services such as transportation, transmission line location, and the public services; and proximity to markets. (This situation is comparable to that for hydroelectric power.) The community, in permitting the development of the resource, must accept the impacts not only of the extraction of the resource, which can be relatively easily foreseen, but also of its use, which are not so easily foreseen and can be major. Thus, three parties—the developer, the user, and the community—must have individual perceptions of profitability before development can proceed.

The Federal Government would play this broker role in two ways. A planning and program updating effort would acquire information and develop potential geothermal utilization growth scenarios for high-payoff regions. The regional cost/benefit and socioeconomic analyses performed as input to this planning would spur action in the specific cases and help determine whether Federal assistance would be beneficial. In addition, and growing out of the planning, Federal assistance may be provided for high-leverage cases in one or more of four forms: (a) direct contracts with industry; (b) cost-sharing of RD&D or demonstration projects with industry; (c) loan guarantees to obtain necessary capital; and (d) accelerated leasing of public lands.

The fourth element of the Government's strategic approach is "seeding." Specifically, the Government may provide the above forms of assistance to develop the prototype plant (i.e., the first of many) in resource-rich fields. Given the nature of geothermal technology that makes numerous moderate-sized plants (e.g., 50 MWe) more appropriate than a few large plants, the experience gained from developing a prototype may be transferred quickly and economically to construction of the remaining plants in the field. In this way, limited Government assistance could help industry acquire first-hand experience and facilitate the development of the industrial-banking-user infrastructure.

Action Program

The action program necessary to effect this strategic approach will consist of five steps:

- DOI will evaluate Federal lands for geothermal leasing, issue leases, and administer and supervise leases. The role of the Bureau of Land Management is to encourage the utilization of geothermal reservoirs by designing and implementing an economically attractive leasing program.
- ERDA will carry out programs to establish the technical, economic, and environmental acceptability of geothermal technologies.
- Regional analysis will be undertaken to determine the match between geothermal resources and needs within the region.
- The geothermal loan guaranty program is being developed to facilitate the availability of risk capital to the geothermal industry; alternative economic incentives will be analyzed and recommended when in the national interest.
- Studies to determine the environmental and socioeconomic implications of the application of geothermal technologies will be carried out, and appropriate control technologies, standards, regulatory policies and planning methodologies will be developed.

Solar Heating and Cooling in Buildings

Solar energy is a very large, nondepletable, domestically available resources for the United States and is now virtually untapped. Among the numerous possible technologies for applying solar energy for U.S. energy requirements, direct heating and cooling of buildings offers the best opportunity for early large-scale application and commercialization. A substantial market potential is present because about one-fourth of the total national need is for building operational requirements and 80 percent of that usage is for space temperature control and heating water. Since most of these requirements are now dependent on the use of depletable fossil fuels, either directly or through generation of electricity, widespread use of solar energy to heat and cool buildings can substantially reduce such dependence. Specifically, the installation of solar heating and cooling systems in about 1 percent of the present buildings in the United States would save the equivalent of about 80,000 barrels of oil per day. If 10 percent of the then-existing buildings were solar equipped by the year 2000, oil-equivalent savings of about 1 million barrels of oil per day—or about 2 quads—may be realized.

The basic technology for using solar energy at low temperatures is reasonably well understood. Significant numbers of different types of systems for space heating and water heating are being rapidly developed, tested, and installed. For example, more than 300 solar-heated buildings are completed or under construction in the U.S. The total production of solar collectors in 1975 was in excess of 700,000 square feet. The cost of the installed systems in 1975 is estimated at about $10 million.

Results of economic analysis indicate that, for fuel costs in the $10-per-million-Btu range (equivalent to about 3 cents per KWh—which is near the average electricity cost in the U.S.), solar heating system costs must be below about $15 per square foot of installed collector.

Although little long-term performance data exist and only general interim standards have been implemented, recent studies indicate that some systems are beginning to be marketed at costs well under

$15 per square foot of installed collector area (based upon prices being quoted by at least one manufacturer). However, other recently completed buildings show system costs ranging from $10 to $20 or more per square foot of installed collector and costs of some experimental, high performance heating and cooling systems appear to be on the order of $20 to $50 per square foot of installed collector area. Significant questions, of course, remain concerning the reliability, operating effectiveness and maintenance of these systems over their projected lifetimes.

Present systems, then, are commercially competitive in only a limited range of applications and geographic regions. If the use of such systems is to grow, it will be necessary for the private sector and, in some instances, the Federal government, to continue new-technology research, but also to refine the present technology and to demonstrate its practicality.

While solar heating and cooling is considered an environmentally beneficial technology, a systematic assessment has not yet been completed of direct and indirect environmental issues of the solar product life cycle. The production of economic components for solar heating and cooling systems may be preceded by the development of new materials and equipment. Emissions and materials use related to fossil fuel consumption must be balanced against increased (and new) environmental impacts and materials requirements from the solar industry.

Implementation Barriers

The principal barrier to successful commercialization of solar systems is their lack of economic competitiveness with available conventional systems and fuels. Except in special cases, present solar heating and cooling systems must be used in conjunction with normal-sized conventional systems to ensure that continuous hot water and space conditioning are provided during extended periods of reduced sunshine. Thus, over the near term, solar systems will generally require substantially larger investments than conventional systems. The extent of such additional investment and the speed and method of payback (by operational fuel savings and in potential property value enhancement) are crucial to successful market development. Competitive use of solar systems is contingent upon many factors, including the unit cost for purchase and installation of available solar equipment, the climate and average available sun flux, the initial and operational cost of conventional heating and cooling systems, the cost of the additional conventional energy, and the availability of capital funds.

If solar heating and cooling technology should become economically advantageous (through either cost-effective improvements in solar technology or cost increases in alternative energies), it will be constrained by other barriers including two that are inherent in any technology innovation in the construction industry. First, home or building buyers show a marked preference for lower initial costs. Therefore, because solar heating and cooling systems typically require higher initial expenditures, the average homeowner must be convinced the system provides sufficiently rapid operational returns or enhancement of property values to justify the additional investment. Second, there generally is a strong reluctance by speculative builders, developers, lending institutions, and other major components of the construction industry to accept the risk of introducing a new technology to an already high risk industry. The problem is intensified by the current absence of consensus standards on construction and performance, modifications in current construction practices, and lack of information on systems reliability and maintenance requirements.

Other institutional, social and legal barriers that must be overcome include the definition of appropriate land use regulations, air and sun rights, and building codes, as well as acceptance of the unfamiliar solar technology by mortgage lenders and insurance groups.

Strategic Approach

The overall goal of the Federal program for solar heating and cooling is to stimulate the advancement of an industry to produce, distribute and service solar hardware for hot water heating and space heating and cooling for residential and commercial buildings. The Government will conduct its programs to encourage the participation of industry organizations, consumer groups, and state and local government. The program is structured to demonstrate the practical use of solar heating technology by the end of 1977, and to demonstrate the practical use of combined heating and cooling technology by the end of 1979. This will be accomplished by a series of cyclical demonstration projects applicable to new and existing buildings, and by research and development to advance solar technology. The first two cycles of demonstration projects will concentrate on space heating and hot water supply for both residential and nonresidential buildings, and subsequent cycles will emphasize combined space heating and cooling and hot water supply. The RD&D program is designed to yield components having lower cost, greater durability and improved performance, as well as a significant advance in the ability to predict the performance of solar systems. Improved systems should be able to reduce, and perhaps eliminate the need for conventional backup systems. If program objectives are met, the market could be increased to 10 percent of the new building starts in 1985.

Action Program

The major elements of the Federal program include:

- Residential Demonstrations
- Commercial Demonstrations
- Development in Support of the Demonstrations
- Research and Advanced Systems Development
- Collection and Dissemination of Information
- Additional Policy Measures Required to Achieve Rapid and Widespread Utilization.

Chief among the program elements is the demonstration of working systems to be carried out in close conjunction with private industry. Solar heating and cooling systems are planned to be installed and operated in several cycles through 1979 in a number of commercial buildings and residential family units to test specific systems in specific building types and under various climatic conditions in the U.S. Both new construction and retrofit systems are planned to be demonstrated, including many types of passive systems.

A heavy emphasis will be placed upon the involvement of small business in the demonstration of solar heating and cooling and in research and development to produce improved systems. Involvement of small business is well above 50 percent in most areas of the Federal program. The unique capabilities of small business organizations are recognized in their high innovation rate, lower organizational inertia, and flexibility in meeting local and regional needs.

This multicycle demonstration program, in which HUD will manage the residential applications while ERDA manages the demonstrations on commercial buildings and provide the necessary experience with viable applications. This, in turn, will provide information necessary to improve solar heating and cooling systems for use under a variety of conditions. The later phases will demonstrate cooling as well as heating systems. Efforts are intended to produce a substantial reduction in the installed heating cost. The demonstration program will also provide information on system reability and maintenance, and help to establish needed construction and operating standards. An additional requirement for early commercialization is the need for consensus standards. ERDA is working with professional and trade organizations, such as ASHRAE* and ANSI** to develop such standards. The demonstrations will also provide substantive experience for identifying and resolving legal and regulatory problems, and will exhibit the nature of applied solar technology to potential users and lenders. Also, they will provide an opportunity to identify and resolve operational and jurisdictional problems within the construction industry.

A comprehensive socioenvironmental assessment for the national solar energy program, including heating and cooling, is under preparation and is due in September 1976. This study will help verify benefits and identify any possible deleterious impacts of solar space heating.

In parallel with the commercial and residential demonstration programs, a Federal Buildings Program is being developed by FEA and ERDA. The basic aim is to encourage all Federal agencies to use solar heating (and potentially solar cooling) in their buildings if a life-cycle cost analysis indicates economic viability. ERDA is working with FEA to implement the project, wherein ERDA can provide additional experience by solar heating and cooling demonstrations on Federal buildings and increase the early market for solar equipment. This, in turn, should accelerate industrial interest in producing solar equipment and stimulate solar applications in the commercial and consumer sectors of the economy.

* ASHRAE—American Society of Heating, Refrigeration and Air Conditioning Engineers.
** ANSI—American National Standards Institute.

Breeder Reactor

The capability of the Nation to draw on nuclear energy to meet the electric and other energy requirements of this country beyond this century will depend on having available a proven, environmentally safe commercial breeder system by the 1990's that can effectively use total uranium resources—i.e. U-238 as well as U-235.

The Liquid Metal Fast Breeder Reactor (LMFBR) concept, a technology that has been demonstrated to be technically feasible, is the chief candidate for meeting this need. Eight breeder reactors are in operation around the world. However, the LMFBR is not now a commercially viable option that utilities can purchase to satisfy their electrical energy generation requirements. Specifically, several technological areas must be investigated and the total system concept must be demonstrated to be economically competitive and socially acceptable to the Nation.

Market Barriers

The specific technical, economic, and psychological barriers to currently marketing a breeder reactor are:

- An insufficient engineering base, which prohibits the nuclear manufacturing industry from designing and constructing safe, reliable LMFBR power plants and fuel cycle facilities in commercial sizes at competitive costs.

- The lack of advanced fuel and core materials and the technical basis for producing reliable and economic fuel systems, which prohibits LMFBR power plants from generating new fissionable material at a rate commensurate with the national growth in electric power demand.
- Lack of utility operating experience to demonstrate that LMFBR systems will perform safely, economically, and reliably in a power generation network.
- Lack of public acceptance in LMFBR power plants and fuel cycle facilities for safety, economic, and environmental reasons.
- Unknown capital costs which make the breeder system economically noncompetitive with other commercial power generation systems.

The development of a responsive overall program was addressed in the **Final Environmental Statement—Liquid Metal Fast Breeder Reactor Program.*** In his review of this document, the Administrator of ERDA stated:

"The FES shows that the major areas of uncertainty lie in plant operation, fuel cycle performance, reactor safety, safeguards, health effects, waste management, and uranium resource availability. I find that the availability of sufficient information to resolve these areas of uncertainty is crucial before ERDA can render a meaningful decision on the commercialization of that technology, i.e., the environmental acceptability, technical feasibility and economic competitiveness of LMFBR technology for widespread commercial deployment. ERDA has programs in place in each of these areas. The LMFBR Program has focused on plant operation through the development of experience in LMFBR demonstration plants, on fuel cycle performance through its base programs of fuel cycle development, and on reactor safety which is an integral part of both the plant demonstration program and the base program. The other areas of uncertainty—safeguards, health effects, waste management and uranium resource availability—are not unique to the LMFBR, and are being addressed generically by other programs."

To achieve this, eight specific areas of investigation are now under way:

1. **Components.** Developing engineering component options with demonstrated capability for meeting the safety, reliability and performance requirements of large LMFBRs operating on utility systems, with demonstrated capability of being reproducible, economical, and manufactured within cost and schedule.
2. **Materials.** Developing structural materials and design methods permitting economic design and operation of components at acceptable levels of plant availability and at up to 40-year lifetime for inaccessible components.
3. **Physics.** Developing design data and confirm computational methods with an accuracy sufficient to enable specification of core loadings, shielding requirements and control requirement for large LMFBRs factors of conservatism consistent with low design cost, low plant costs, improved plant performance and competitive power costs.
4. **Chemistry.** Developing instrumentation and methods for monitoring and controlling corrosion processes and system impurities to levels that preclude degradation of component and system performance over the plant life, and develop processes for removing sodium and radioactive contamination from components being repaired without affecting service life.
5. **Safety.** Developing and confirming analytical methods that will permit design flexibility relative to current practice, allow greater design confidence, improve efficiency and reduce costs and schedules, and to demonstrate the inherent safety of LMFBRs prior to a large-scale utility commitment to LMFBRs in the 1990's.
6. **Plant Experience-FFTF, CRBRP and PLBR.** Designing, constructing, licensing, operating, and maintaining LMFBR power plants on an electric utility power generation network, thereby demonstrating the economic, safety and environmental advantages of the LMFBR concept and establishing the industry capability to offer a salable plant in a competitive market.
7. **Fuels.** Developing fuels system options with performance characteristics that will ensure the commercial viability of early LMFBR power plants and that will enable achievement of doubling times of 10 to 15 years as determined by energy growth after 1990.
8. **Fuel Recycle.** Developing and demonstrating fuel reprocessing systems that accommodate all fuel system options and allow for the rapid fuel recovery and turnaround times necessary to ensure doubling times of 10 to 15 years.

However, to ensure the plants are accident-proof and environmentally acceptable, expensive design add-ons may be necessary. Therefore, several important issues are under investigation which, when satisfactorily resolved, will permit freedom to produce more economical plant designs.

In his findings on the **Final Environmental Statement,** the Administrator stated further:

"On the basis of the material set forth in the FES, I find that if the reference plan and its supporting programmatic efforts are vigorously pursued, sufficient information would be available as early as

* ERDA–1535 of December 1975.

1986 to resolve the major uncertainties affecting widespread LMFBR technology deployment and therefore to permit an ERDA decision on commercialization of that technology."

Action Program

As positive results are obtained from these investigations, a series of reactor plants will be designed, built, and operated to confirm the results and provide experience on a total reactor plant system. The Experimental Breeder Reactor-II has been operating since 1963 and the Fast Flux Test Facility is under construction, with operation due to begin in 1979.

In design is the Clinch River Breeder Reactor Plant, (with a start-up date of 1983), a cooperative venture with industry and the utilities. Target plant designs that will serve as a basis for further cooperative projects are being developed. This will lead to a Prototype Large Breeder Reactor that will provide experience with a commercial-size LMFBR.

These programs and supporting efforts are aimed at permitting a decision by 1986 as to whether commercial deployment of the technology is acceptable.

Fusion

Drawing on plentiful deuterium and tritium found in the oceans as fuels resources, fusion technology, if practically developed, could provide essentially limitless amounts of energy. Accordingly, the technology was designated as one of the three high-priority longer term energy supply technologies.

With this technology, energy is produced when nuclei of light atoms are joined or fused into larger nuclei, with an attendant release of energy. For such to occur, light elemental nuclei in the form of a plasma must be confined at high densities and temperatures for adequate periods of time.

The development and demonstration of this is being pursued along two different lines. The first is an investigation of several magnetic confinement systems; the second is research into inertial confinement by means of energy lasers or electron beams.

Magnetic Confinement Fusion

The primary emphasis in the magnetic confinement program at this time is the development of a sufficient understanding of plasma behavior and magnetic confinement systems to attain simultaneously the required plasma densities, temperatures, and confinement times. Engineering activities parallel to and coordinated with the scientific studies of plasma production, containment, and heating provide the technological base for near-term experimentation and, ultimately, for development of fusion power reactors.

The Magnetic Confinement Program is organized into four subprograms that emphasize the different aspects of the program's major goals. The Confinement Systems Subprogram conducts the major experiments to achieve the necessary conditions for practical fusion power. The Development and Technology Subprogram provides the engineering support and technology base for the major magnetic confinement experiments, and conducts fusion test facility and engineering experiments and studies related to reactor design. All theoretical and computational activities in support of the Magnetic Confinement Program as well as small-scale experimental studies are carried out in the Applied Plasma Physics Subprogram. The Reactor Projects Subprogram is responsible for the construction phase of the Tokomac Fusion Test Reactor and other large projects.

The most promising magnetic confinement concept at this time is the Tokamak. The Tokamak Fusion Test Reactor, on which construction began in FY 1976, is expected to be the first experiment to produce sizable quantities of fusion energy. In addition, backup approaches to the Tokamak are being pursued. The principal alternatives are the theta pinch and magnetic mirror concepts, which involve alternative magnetic configurations.

The magnetic confinement approach has recently achieved ignition-level temperatures and a ten fold increase in plasma confinement conditions in a magnetic mirror device. A similar advance has been achieved in a Tokamak device with confinement conditions five times better than any previously reported and only a factor of ten below the value needed for fusion break even. During FY 1977, the program will use the knowledge gained by these accomplishments to accelerate attainment of net fusion power and improve the performance requirements of the next generation of machines.

The major, planned milestones of this program are: (1) the production and understanding of ignition-level hydrogen plasmas in 1978-1980; (2) the production of substantial quantities of thermal energy in the Tokamak Fusion Test Reactor by 1982; (3) the production of substantial quantities of electrical energy in Experimental Power Reactors in the late 1980's; and (4) the operation of a commercial-scale Demonstration Power Reactor by the late 1990's.

Inertial Confinement Fusion

The Inertial Confinement Program seeks to determine the scientific feasibility of laser- and electron-beam-initiated thermonuclear burn, using principles of inertial confinement and applying it to such areas as nuclear weapons effects simulation, nuclear weapons physics modeling, military power systems, and commercial power production.

Program strategy involves the maintenance of a research, development, and application core research program within the ERDA laboratories. At the same time, full use will be made of unique university and industrial capabilities in support of the core program. Broadly based efforts in universities and industry will complement and extend the national laser fusion program base.

Studies of laser-matter interaction phenomena and advances in laser technology permitted the achievement of the first major program milestone of pellet compression in FY 1974. As more powerful laser systems become available, the next major milestone of significant fusion yield is expected to be achieved in FY 1978-1979, followed by scientific break even in FY 1981-1982 and net energy gain by the mid-1980's. Based on the success in achieving these milestones, an operational test system could be operational by the late 1980's and a demonstration commercial power plant, by the mid-1990's.

Solar Electric

As indicated earlier, solar energy is a very large, nondepletable, domestically available resource. If a small percent of the incident energy could be economically harnessed, a significant fraction of projected U.S. energy needs could begin to be met by the year 2000.

To tap this energy, four technologies appear most promising:

—**Solar thermal electric** generation involves the concentration of solar energy to create the high temperatures needed to heat water or other fluids to power turbines which, in turn, drive electrical generators. Total energy systems, based on solar thermal electric system concepts, can also supply industrial process heat or space heating and cooling needs.

—**Solar photovoltaic** conversion involves the direct conversion of sunlight to electricity through use of arrays of photovoltaic cells.

—**Wind energy** conversion systems commonly convert wind to mechanical energy, which may be used directly to drive energy storage devices (e.g., pumped hydrostorage, flywheels, or compressed gases) or electric generators.

—**Ocean thermal** energy conversion uses the temperature differential occurring between the solar-heated ocean surface and the deeper, colder water as a heat source to drive a working fluid in a thermodynamic cycle that powers turbines to produce electricity. Other renewable ocean resource options such as tides, waves, salinity gradients, and currents are also being explored.

Market Barriers

Although solar energy can be tapped with these technologies, by and large, it cannot now be tapped economically. For example, for photovoltaic electricity to be competitive with alternative sources (e.g., coal), the cost per watt of solar collector arrays must be reduced by a factor of 50 to 100. Similarly, wind energy can now only be used for some limited applications (e.g., in remote areas or in a fuel saver mode), but the regional and intermittent nature of the source and the absence of economic methods of energy storage make it uneconomical for meeting general energy needs.

Strategic Approach

Given these market barriers, the general thrust of the RD&D program is to develop the technology, and systems and gain the experience that will result in substantial reductions in the cost of using solar energy. However, since the specific problems with each of the four technologies are distinct, their respective RD&D program strategies are different.

In wind energy conversion, the program strategy is to stimulate industrial efforts to design more efficient rotor systems and to lower capital costs through prefabrication and more efficient production techniques, and through demonstrations of reliable, economically viable wind energy systems.

The program strategy for solar photovoltaic conversion is to lower the cost per watt of collector arrays by a factor of 50 to 100 from present levels by: (1) producing low-cost photovoltaic materials through large-area crystal growth, high-volume sheet production, modified array encapsulation, and improved cell and array designs; and (2) encouraging industry to achieve volume production so that they may gain manufacturing experience and develop economies of scale.

In solar thermal electric, the program strategy is to focus on small-scale models, large-scale experiments, and pilot plants to improve performance-to-cost ratios, reduce technical and economic risks, and verify operating characteristics. The critical areas of cost will be identified as a basis for subsequent programs that will concentrate on those alternatives with the greatest promise of lower costs.

Ocean thermal gradient conversion, while theoretically economical, has not yet been demonstrated as a practical energy source. Using current technologies to scale to large sizes requires major component development. For example, the improved, heat exchanger technology needed to use the small temperature differentials and to overcome the potential problems associated with biofouling has not yet been developed and is critical to the overall potential of the technology. Once such technologies have been demonstrated, it will be possible to develop large-scale components, subsystems, and full-scale ocean thermal systems.

Action Program

An action program has been designed for each technology area to carry out the approaches described above.

- **Solar thermal conversion.** Completion of a 5-megawatt solar thermal test facility in FY 1978 will permit testing and evaluation of the major subsystem concepts under development for central receiver approach to solar thermal electrical conversion. In addition, the conceptual design of a 10-megawatt electric solar thermal pilot plant is scheduled for completion in FY 1977, with construction of the pilot plant scheduled for initiation in FY 1978. Finally, initial operation of the total energy test bed is scheduled for completion in FY 1977.
- **Solar photovoltaic conversion.** Attractive applications that will advance the widespread use of solar photovoltaic conversion systems will be identified by the end of FY 1977. In addition, a major series of experiments on multikilowatt photovoltaic energy conversion systems will be initiated in FY 1976; these experiments will provide valuable operational experience and will stimulate the development of the industrial base. Thirdly, RD&D on materials and fabrication techniques will be carried out with a goal of achieving a price of less than $2,000 per peak kilowatt for concentrated photovoltaic systems by FY 1979 and for planar solar cell arrays by 1982.
- **Wind energy conversion.** It is anticipated that, in cooperation with utilities, the design, fabrication, and installation (at two climatically different sites) of two multi-hundred kilowatt wind energy systems will be completed in FY 1977, with the cooperation of utilities. In addition, completion of the design and fabrication of a megawatt-scale wind energy system is scheduled for FY 1977. This system will be of a cost-optimum design for high-wind-velocity sites. During FY 1977 the initiation of field testing of several innovative and advanced wind energy conversion concepts, and of a number of wind energy conversion systems suitable for small-scale applications will be undertaken.
- **Ocean thermal energy conversion.** During FY 1977, studies of programmatic planning alternatives and cost-benefit-risk tradeoffs will be completed and R&D on heat exchanger technology and biofouling will be conducted. Criteria will be developed for a possible future test facility. In parallel with the test program, critical components and subsystems will be developed and prescreened so that the most promising candidates can be developed for future large-scale testing.

* * * * *

To launch these multiple technology initiatives, discussed in this chapter, a number of important interrelationships have to be enhanced and/or developed. These efforts are laid out in the following chapter.

Chapter IV—Implementing the Plan: Interrelationships Among Energy RD&D Participants

Introduction of new energy technology and the development of new energy resources will directly affect the lives of all Americans and will thus require the concerted action of all private and public institutions. Cooperative efforts are required among the Congress, Federal Government agencies, state and local governments, regional organizations (e.g., regional governors' conferences), the private sector (e.g., industry, universities, and other nonprofit institutions), and the public. In addition, because of common energy interests and problems, because of the need to cooperate on the resolution of those problems, and because of the impact that new energy technology will have throughout the world, many nations will need to interact with the U.S. as the Plan is executed.

The role of the private sector is paramount. Indeed, one of the basic principles upon which the Plan is formulated is that the private sector and market forces represent the most efficient means of achieving the Nation's energy goals.

The Federal Government will provide leadership and assistance in several ways to help create the overall climate and develop the specific incentives needed to achieve national energy goals. First, it will encourage maximum private sector interaction and involvement in energy RD&D. Second, it will initiate energy RD&D efforts where the private sector is unable to achieve national energy goals; it will **not** manage or fund programs that the private sector can pursue profitably on its own. Moreover, the higher risk programs managed by the Federal Government will be brought to the point of commercial feasibility as rapidly as possible, but will not proceed unless the private sector becomes increasingly involved as the programs approach commercial feasibility. Third, the Federal Government will work to establish a consistent developmental and regulatory framework that balances the early development of alternative technologies with other legitimate public needs such as human health, safety, environmental protection, and economic regulation. Fourth, the Federal Government will seek to involve state and local governments, regional energy organizations, and the public at large in the planning efforts necessary to validate and implement the Plan.

State and local governments and regional organizations are involved in the energy problem because its solution is regional as well as national. Specifically, various localities and regions are affected differently by energy shortages, by large energy projects, and by environmental discharges or conditions. While individual states and regional groups of states are affected differently, in terms of cost and benefits, by some new energy programs, none can take precipitous action without affecting other regions. Moreover, to the extent that state and local governments perform energy planning, they have the primary responsibilities in the related areas of environmental control and human health; resource extraction; plant siting; promulgation of construction and building codes to accommodate innovative technologies; and industrial regulation.

Thus, one of the roles of state and local governments and regional organizations is to reflect these regional and local perspectives in the development of coordinated energy RD&D policy and planning.

The involvement and understanding of the public are necessary to achieve the objectives of the Plan. Since the public is the ultimate consumer of energy, its concerns for the environment, human health, and safety must be considered as carefully as technical and economic concerns. In addition, the public has a major role since it must reach literally millions of individual decisions to implement a truly effective conservation program as well as other elements of national energy RD&D policy.

Finally, international agreements are necessary to coordinate the energy efforts of countries conducting major efforts in RD&D. Benefits can be derived from coordinated international energy RD&D planning and the sharing of capabilities. This RD&D approach will complement broader efforts of international cooperation in energy policy and planning.

In view of the specific, important roles that government, the private sector, and the public at large must play in achieving the goals of the National Plan for Energy RD&D as well as the benefits provided by international efforts, it is clear that an important aspect of implementing the Plan must be the development of appropriate mechanisms to ensure the participation of and interaction among these entities. To this end, actions are being taken to:

- Develop international agreements
- Improve Federal agency interaction
- Strengthen the private interface
- Expand interaction with state and local governments
- Establish a regional interface.

Developing International Agreements

The United States is not alone in dealing with the continuing problem of a secure and economical energy supply. Many countries in the world have the same problem but, in most instances, are not blessed with natural resources as abundant and diverse as those of the United States. Thus, they, too, have recognized the need for and value of effective conservation programs and the necessity of developing new technologies.

Because of the obvious economic benefits that would accrue, it is clearly in the best interests of all the nations who share the problem to cooperate in finding its solution. The U.S. policy is to promote such cooperation and interaction wherever appropriate.

To this end, ERDA, the Department of State, and other Federal agencies are fostering international research, development, and demonstration initiatives in many energy areas. Several courses of action are being pursued, including: (1) entering into bilateral RD&D and nuclear supply agreements; (2) participating in the International Energy Agency (IEA); (3) providing assistance to developing countries; and (4) participating in the Safeguards Program.

Entering into Bilateral Agreements

More than 30 bilateral agreements are in effect that permit technical data exchanges as well as the supplying of nuclear reactors and uranium enrichment services.

Specific energy RD&D agreements exist between the U.S. and the U.S.S.R., and between the U.S. and Japan. Specifically, the U.S. currently exchanges information on breeder reactors with Japan, and in the fields of fusion and breeder reactors with the U.S.S.R. A number of agreements in the nonnuclear area are pending with Japan. The U.S. has entered into separate agreements with Iceland and Italy in the geothermal field, and has agreements with Poland on coal research. Energy RD&D cooperation also forms an important part of numerous other general Science and Technology Agreements with other countries. Finally, the U.S. has recently executed memoranda of understanding (MOUs) with eight countries calling for information exchange on solar heating and cooling of buildings.

Participating in the International Energy Agency

As a result of membership in the International Energy Agency (IEA), the U.S. is participating in a number of energy RD&D programs. For example, active efforts have been under way during the past year to identify areas of interest for cooperation, to prepare a framework of principles governing joint support of energy RD&D projects, and to draw up cooperative implementation agreements. In the coming year, work will proceed on producing an overall IEA strategy by the end of 1976.

In addition to these policy and administrative activities, the IEA has launched a number of specific, important energy technology RD&D projects. Originally, nine areas were identified for multilateral cooperation: coal technology, nuclear reactor safety, radioactive waste management, controlled thermonuclear fusion, conservation R&D, solar energy, hydrogen, municipal and industrial waste, and waste heat utilization. At special meetings on research and development on November 20-21, 1975, the IEA Governing Board recommended seven new areas: high temperature reactors for process heat, geothermal energy, solar power systems, wave power, wind energy, ocean thermal energy, and biomass conversion. The IEA also approved an energy systems analysis effort, which will be a major activity in 1976, to identify and evaluate energy technology options, their potential energy contributions to the various member countries, and their commercial implementation time frame; and to advise the member nations individually and collectively on RD&D priorities. This systems analysis work will be undertaken by national experts and by two international groups, one located at the Brookhaven National Laboratory in the U.S. and the other at the Julich Laboratory in Germany. In the course of these studies, data on energy and interfuel substitution possibilities will be collected and made available to all member nations.

Similarly, cooperative ventures among smaller groups of participating countries can be arranged under the auspices of the IEA. For example, in November 1975, the U.S. signed the five agreements as part of an overall IEA coal technology cooperative effort. One of these was an agreement among the United States, the Federal Republic of West Germany, and the United Kingdom to research more efficient and cleaner ways to burn coal. A fluidized bed combustion test facility, designed to burn coal more efficiently, will be built in Britain at a shared cost of $15-20 million.

Assisting Developing Countries

The U.S. participates in a number of international, energy-related activities that involve developing countries. For example, there are U.S. Joint Cooperative Commissions with Israel, Iran, and Egypt that allow for assistance in nonnuclear programs.

On September 1, 1975, during the special meeting of the U.N. General Assembly, the U.S. proposed an International Energy Institute (IEI) to assist developing countries in applying available energy technology to their energy needs. This concept was welcomed by other members of the U.N. and is now in the process of being developed in more detail. In the nuclear area, the International Atomic Energy Agency (IAEA) provides an excellent forum for cooperation and mutual reward among developed and developing nations. Two notable programs in this format are the IAEA's technical assistance program and its Safeguards Program.

Participating in the Safeguards Program

The International Atomic Energy Agency (IAEA) is responsible for the implementation of safeguards portions of the Nonproliferation Treaty relating to the peaceful uses of nuclear materials. In the Safeguards Program, the United States and other countries supplying nuclear material, equipment, and technologies require assurances that: (a) exported nuclear material is not diverted by the receiving country for explosive use; (b) receiving facilities have adequate safeguards and physical protection against domestic nuclear threats; and (c) any nuclear assistance will not be used by the receiving country to further any military purpose.

ERDA, the Arms Control and Disarmament Agency (ACDA), and the Nuclear Regulatory Commission (NRC) assist the IAEA in developing effective safeguards procedures and improving measurement techniques. ERDA is responsible for reviewing facilities that receive U.S. nuclear materials to ensure adequate physical protection before NRC grants the export license. These ongoing reviews have proved effective in encouraging adoption of these measures by other countries.

Improving Federal Agency Interaction

Effective Federal agency interaction in energy RD&D is essential to: (a) integrate the goals and objectives of RD&D into the broader context of national energy policy; (b) eliminate redundancies or gaps in energy RD&D planning and implementation; (c) accelerate the RD&D process and the market penetration of new energy technologies and systems by minimizing procedural delays and integrating tasks performed by different agencies; (d) optimize Federal resources (money and manpower) and thereby improve RD&D productivity in the Federal sector; and (e) fulfill legislative and administrative requirements expressed in Congressional mandates and joint agency agreements. Of these objectives, the two that must be vigorously pursued first are the: (1) integration of energy RD&D programs into the broader context of national energy policy, and (2) elimination of unintended redundancies or gaps in energy RD&D planning and implementation.

Integrating Energy RD&D Programs into National Energy Policy

Energy RD&D goals and objectives must be integrated into the broader context of a national energy policy. This necessitates interaction and coordinated program planning not only among the Federal agencies that are charged with RD&D, but also among **all** Federal, state, or local agencies as well as legislative bodies that will implement national energy policy. The Energy Resources Council (ERC) is the primary instrument for this coordination. The ERC ensures communication and coordination among the several agencies involved in developing and implementing energy policy or in managing energy resources.

Among all the Federal agency interactions affecting energy RD&D, perhaps the most important is that between ERDA and the Federal Energy Administration. It is here that a strong tie is established at the working level between national energy policy and national energy RD&D policy. ERDA's focus is the technological character of the energy system, while FEA's focus is the economic (price regulatory) and operational aspects of the energy system. The activites of the two agencies do, of course, overlap and complement each other.

In addressing technological problems, ERDA must recognize the possible institutional and social barriers to implementation of both existing and new technologies and, hence, must interact strongly with FEA as the companion agency that can mount attacks on such problems. In modifying the present energy system, FEA should recognize the existence of technological issues and, hence, must interact strongly with ERDA, the agency that can mount attacks on such problems.

The nature and importance of these interactions have been more and more strongly recognized by FEA and ERDA over the past year. As a result, the two agencies have agreed to increase their emphasis on joint program planning activities. Mutual involvement in the early phases of program planning will help ensure development of fully coherent national programs. Responsibility for implementing the programs will follow both the legislative direction provided the agencies and the capabilities in place in each agency to direct and integrate such activities with its related activities. ERDA and FEA are presently developing a memorandum of understanding (MOU) that will embody these principles and provide an overall framework for more detailed coordination on specific programs.

Of similar importance is a strong and interactive relationship between ERDA and the Environmental Protection Agency (EPA). This relationship is needed to assist ERDA in effectively integrating its approach to environmental consideration into technology design and to ensure a coordinated Federal approach to key environmental issues.

Eliminating Redundancies in Energy RD&D Planning and Implementation

Because of its scope, complexity, and number of participants, the Nation's energy RD&D program has the potential for significant redundancies and gaps if interaction and coordinated program planning and management are neglected. To avoid energy RD&D program redundancies and gaps and to ensure the coordinated implementation of the National Plan for Energy RD&D, three kinds of actions are being taken:

- **Obtaining input to Volume II of this Plan from other agencies involved in energy RD&D.** In assembling Volume II of the Plan (which describes in detail implementation plans for the total Federal energy RD&D effort) each year, ERDA interacts with the various primary agencies involved in energy RD&D. Specifically, other agencies review relevant sections of Volume II; examine the integrated program for omissions and overlaps; and provide feedback to ERDA on the results of their reviews.
- **Entering into formal agreements with other Federal agencies.** Some of the formal agreements that have been reached in the past year or will be implemented in the near future are of particular importance:
  - —**A memorandum of understanding (MOU) between ERDA and the National Aeronautics and Space Administration (NASA)** to perform basic and applied research at selected NASA centers in specified disciplines and technologies (e.g., photovoltaic systems, gas turbine technologies, fuel cell technology, hydrogen technology, wind-energy systems).
  - —**An MOU between ERDA and the National Bureau of Standards (NBS)** to cooperate in identifying and evaluating specific programs related to measurements and standards in fossil energy, environment and safety, solar energy, geothermal, advanced energy systems, national security, conservation, and other RD&D programs. Under a separate agreement, NBS will conduct an independent evaluation for ERDA of energy-related inventions to provide information on promising ideas that have been examined for their technical feasibility and worthiness for consideration for further support.
  - —**An imminent agreement between ERDA and the Small Business Administration (SBA)** to ensure small business concerns are provided a reasonable opportunity to participate fairly and equitably in Federal grants, contracts, purchases, and other activities related to energy RD&D.*
  - —**Agreements between ERDA and the Department of Defense (DOD)** to perform RD&D and support ERDA progress in areas such as solar heating and cooling, solar electric, ocean thermal, bioconversion, geothermal, and synfuel evaluation. A joint ERDA/DOD effort is planned to identify additional areas in which joint efforts will be mutually beneficial. A general MOU between ERDA and DOD is being prepared.
  - —**Four impending MOUs between the Nuclear Regulatory Commission (NRC) and ERDA** to provide for coordination between the two agencies on the Safeguards Program operational policy, contingency plans, and international responsibilities; Safeguards RD&D and testing activities; Emergency Preparedness response resources; and the sharing of nuclear materials information.
  - —**An imminent MOU between the Department of Housing and Urban Development (HUD) and ERDA** to coordinate activities pertaining to energy-related housing and urban programs.
  - —**An MOU between the Water Resources Council (WRC) and ERDA** to assess water resource requirements and water supply availability for energy technologies that are the subject of Federal RD&D efforts. The agreement calls for the establishment of a water-for-energy base program at the WRC, participation in ERDA's environmental and water resource assessments, and exchange of data between ERDA and the WRC. Initial involvement will emphasize programs in synthetic fuels, geothermal energy, and coal conversion demonstration plants.

* ERDA is also supporting a symposium in Washington, D.C., on March 24–25, 1976, under the auspices of the American Association of Small Research Companies, entitled "Opportunities at ERDA for Small R&D Companies."

- **Participating in the Federal Energy Management Program (FEMP).** The Federal Government itself is a significant energy consumer, representing over 2 percent of total national energy consumption. The Federal Government is also the largest single purchaser of energy in the Nation, thus providing a significant opportunity for direct savings and leadership in energy conservation.

  The Federal Energy Management Program was established in 1973 to achieve major reductions in Federal department and agency energy consumption. In 1974 and 1975, annual energy savings of approximately 25 percent were achieved, primarily through curtailment measures such as adjusting thermostats and lighting in Federal facilities and eliminating wasteful practices in the operation of ships, planes, and automobiles.

  This program has now been extended for 10 years to reduce energy use in the Federal Government through adoption of cost-effective technological improvements in Federal facilities. It is also expected to have the "spin-off" benefit of demonstrating life-cycle cost-effectiveness of conservation technologies not now in the marketplace. Developed under the policy guidance of the Energy Resources Council (ERC),* the program will be undertaken by:
  —FEA, which is responsible for management leadership
  —ERDA, which oversees the technological aspects of the program
  —GSA, which is charged with ensuring appropriate program implementation.

Strengthening the Private Interface

Decisions on energy RD&D programs will affect the life of every citizen and every institution in the country. Thus, all citizens should have the opportunity to influence those decisions. However, there are many "publics" who have interests—often conflicting interests—in energy RD&D. Other difficulties include the technical nature of the subject of energy; the long lead times involved in planning; the complexity of the energy-field participations and mission; and the proprietary nature of some of the information.

Ensuring that public opinion is represented in energy RD&D planning and obtaining support for implementation of its results require a two-way dialogue between informed citizens and receptive decision-makers. Government decision-makers must provide the public with timely and complete information, including background materials on the problems, needs, and concerns of energy RD&D programs and planning; possible solutions to the problems; and possible effects (social, environmental, economic, technological) of the programs, problems, and solutions. The informed citizens must be provided with and take advantage of various communications forums, including those listed in Table IV-1. Among the most important of these avenues of communication are:

- **Advisory committee.** ERDA has a number of advisory groups made up of individuals who represent a broad spectrum of technical expertise and citizen interest. The General Advisory Committee maintains a broad overview of ERDA's programs; seven other advisory committees deal with specialized areas: Advisory Committee on Geothermal Energy, General Technical Advisory Panel (Fossil),

* Subsequent to this action, the Energy Policy and Conservation Act (P.L. 94–163) mandated a 10-year conservation program for buildings owned or leased by the Federal Government. A part of the FEMP program will address this requirement.

Table IV–I Forums for Interaction

Interests Affected	Primary Forum for Soliciting Review and Comments
The general public, industry, state and regional energy representatives, special interest groups, and the academic community	• Advisory Committees • Consumer representation plan • Public hearings and meetings • Meetings with ERDA officials • **Federal Register** requests for comment • Publications and speeches • Environmental impact statement
The Congress	• Legislative hearings on ERDA-related programs and budgets • General Accounting Office reviews and other special study requests • Formal review of the National Plan for Energy RD&D by OTA and CEQ*
Other Federal agencies	• Joint planning activities throughout the year • Review of the Plan prior to publication and response to a formal ERDA request for programmatic information** • Environmental impact statement

* As stated in the enabling ERDA legislation, the Council on Environmental Quality (CEQ) is required to undertake an ongoing assessment of the adequacy of attention to environmental protection and energy conservation in the energy RD&D program. The Office of Technology Assessment (OTA) has also been requested by Congress to undertake a review of the annual report.

** See ERDA 76–1, Volume 2—**Program Implementation**, for other agency details on specific programs.

Historical Advisory Committee, Senior Utility Steering Committee, High Energy Physics Advisory Panel, Lignite Advisory Committee, and Atomic Energy Labor-Management Advisory Committee. Meetings of these groups are announced in advance and are open to the public.

- **Public hearings and meetings.** ERDA holds and participates in many public hearings, meetings, and conferences. For example, ERDA has initiated a series of regional public meetings to solicit comments on the National Plan for Energy RD&D in general and on the implementation of the Plan for the regions in which the meetings are held in particular. From these, important relationships are developed with concerned interest groups and state and regional policy makers. As a result of one of the early public meetings, ERDA will be supplied with a continuous flow of information and viewpoints from 16 southern states on the National Plan for Energy RD&D.

  Primary responsibility for conducting these meetings is being assigned to the regional ERDA organization, with the aim of establishing these offices as accessible contact centers. Public meetings will continue after the publication of the Plan to discuss its contents and its impact on the Nation from a regional and local perspective. Meetings have already been held in Atlanta and Seattle, and are being planned for Denver, Chicago, San Francisco, and Boston.

- **Environmental impact statements.** Programs to apprise the public and organized interest groups of the estimated environmental characteristics of alternative prospective energy systems and to provide open channels for responding to specific public concerns in the decision process are available. This communication is basically implemented through publication of environmental impact statements and through their associated public hearings.

  Environmental RD&D activities are directed through a sequential process, tailored for each energy alternative. At milestones in this process, where actions may be proposed that would significantly affect the quality of the environment, environmental impact statements are prepared. Environmental impact statements may be generic (program) or site-specific (project) in nature, depending on the state of technology development and nearness to demonstration. They explore sociological, aesthetic, and other public concerns and provide a basis for public review and discussions to ensure public input to the energy development process.

- **Consumer representation plans.** Interaction with the public at large can be the most difficult dialogue to establish but can also be the most rewarding as the public's concern for human health, safety, the environment, style and quality of life, and economic climate are paramount in a democratic society. Comprehensive consumer representation plans are being developed by all major Federal agencies to provide specific channels for consumer participation in major Federal-agency policy and program decisions. This effort is in response to the President's call for an examination of present and new procedures by which all consumers can receive an equal opportunity of being heard. Preliminary consumer representation plans have been published* and, after comments have been received in writing and at a series of public meetings, will be made final in 1976.

  ERDA's Consumer Representation Plan is being designed to ensure ERDA takes into consideration the effects of its programs on a multitude of consumers. Participation of energy consumers and producers in the decision-making of the agency is both necessary and desirable. ERDA's job is to assist private industry in the development of new or improved technologies that can be made commercially attractive. This implies the technologies must meet the requirements of the private marketplace in terms of needs, institutional compatibility, economics, and the requirements of the general welfare (i.e., environmental and social acceptability). Neither ERDA nor the Federal Government as a whole controls the marketplace or the Nation's environmental and social standards; in the final analysis, it is the consumer who does, through buying practices and the political process. For the consumer to participate in this decision-making process, he must know:

  —What decisions are planned, when they will be made, and who will make them

  —The technical, economic, environmental, and institutional facts and assumptions available to the decision-maker

  —The alternatives under consideration by the decision-maker

  —The analytical tools, methods, and results that are being used to assist in the decision-making process.

  An informed public can influence the Federal decision-making process if it can bring to light new or additional facts or assumptions, raise workable new or different alternatives, and provide new or additional analytical results. The ERDA Consumer Representation Plan is designed to ensure this flow of opinion and information.

Although these communication forums are generally available to all citizens and all institutions, specific avenues are being explored and important policy initiatives are being taken to establish specific interaction with industry and universities.

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* **Federal Register**, Volume 40, No. 229, November 26, 1975.

Table IV–2 Illustrative Jointly Funded Programs With Industry *

Program Area	Industry Participant	Percent of Total Estimated Cost Contributed by Industry
A. Fossil		
1. High-BTU Gasification		
a. Bi-Gas Pilot Plant	American Gas Association	32
b. Steam-Iron Pilot Plant	American Gas Association	33
2. Gas and Oil Extraction		
a. Miellar Polymer Flooding	Oil companies	65
b. Thermal Recovery and Solvent	Oil companies	52
B. Conservation		
1. Electric Energy Systems		
a. Battery Energy Storage Test Facility	Utility companies	54
b. Forced Cooling Test	Electric Power Research Institute (and a manufacturer of underground electrical equipment)	76
2. End-Use Conservation		
Stirling Engine—100 H.P.	Automobile manufacturing company	50
C. Fission		
Clinch River Breeder Reactor	Utility companies (and some reactor manufacturers)	14
D. Geothermal		
Thermal Loop Experiment with Hot Brines	Utility company	50

* See Table III–6 for the estimated total cost-sharing with non-Federal organizations.

Interaction with Industry

The ERDA mission is unique. Unlike other government agencies involved in RD&D, ERDA's mission is to research and develop new technologies and to assist the private sector in penetrating the market with their new technologies. To this end, ERDA programs are designed to involve industry at the earliest possible point in the RD&D process.

The traditional route of technology research and development is from basic and applied research laboratories and individual inventors through engineering facilities to the producers of goods and services for use by all consuming levels. It is obvious that industry, both large and small, is crucial to this process as the developer, producer, and marketer. Thus, the Federal Government/industry interface is as broad as industry itself.

Various forums are used to communicate with American industry. (See Table IV-1.) In addition, as shown in Table IV-2, ERDA is seeking jointly funded or jointly planned programs with industry and industrial organizations* to establish working relationships at the earliest possible developmental stage of new energy technologies.

* For example, a memorandum of understanding is imminent between the Electric Power Research Institute and ERDA to jointly review program plans, coordinate future activities, identify projects appropriate for coordinated parallel or sequential contracting, and identify efforts appropriate for joint funding.

ERDA, along with other government agencies, is also conducting a study to determine how the existing patent and licensing policy can be applied most effectively to enhance the private sector's incentive to engage in energy RD&D. Public meetings have been held at which much helpful criticism has been received from various industry representatives and public interest groups. An interim report was recently submitted to Congress, and **it is ERDA's intention to complete the patent policy study and to deliver a final report to Congress in 1976.**

The financial community has a critical role in the market penetration of new energy technologies since it is from this sector that much of the funds for RD&D investments will come. Without the financial backing of the banking and investment institutions, very few new energy technologies will come into general use. But before making the necessary loans, the financial community must be assured of the technical success of the energy option, its ability to capture a large enough share of the market to become profitable, and a government regulatory climate that will not impede or prevent market penetration of the technology. It is, therefore, imperative that ERDA maintain close liaison with the financial community to communicate the status of the energy RD&D programs and of government attitudes and, in turn, to understand the concerns and attitudes of the investors. During this year, ERDA will initiate such a relationship.

No summary of efforts to strengthen the relationships with industry would be complete without mention of the government's commitment to small business. Specifically, all government energy RD&D program managers aggressively seek out small business participation, and small companies are made aware of the existing project opportunities. In addition, an ERDA task force has been established to coordinate and monitor small business participation, and a cooperative agreement with the Small Business Administration is being readied for signature. Likewise, individual inventors will be assured full evaluation of their energy-related projects through a joint program of ERDA and the National Bureau of Standards.

Liaison with industry is also being furthered through the use of technology utilization representatives located in eight of the National Laboratories throughout the country. These representatives serve as local and regional points of contact with private industry on the availability of technologies, particularly those evolving from energy programs but having nonenergy applications.

Finally, the Office of Industry, State and Local Relations (ISL) advises ERDA programmatic and "corporate" management on better ways to obtain and use industrial views in the ERDA decision-making process. To this end, the ISL staff is in frequent communication with all segments of industry, with ERDA energy RD&D program offices, and with state and local governments. Since representatives of these groups frequently share common interests in energy resource development implications, this centralized organizational unit represents the interest of these groups in planning and policy formulation. Also, ERDA recently established an Office of Commercialization that is responsible for:

- Continuing the analyses and initiating program implementation efforts related to the synthetic fuels commercial demonstration program
- Identifying major constraints to commercialization of other selected energy technologies and analyzing the effectiveness of various incentives (such as in the Nonnuclear Act) in overcoming these constraints
- Examining mechanisms for speeding the introduction, in the near-term, of available energy technologies into the marketplace.

Interaction with Universities*

The Nation's academic community represents an important resource needed for the conduct of supporting research and technology development across the spectrum of energy RD&D, as well as a major contributor to the development of adequate manpower resources.

During FY 1975, contracts approximating $135 million** were signed with universities. ERDA expects this figure to climb to about $140 million** during FY 1976 and $170 million** in FY 1977.

ERDA is building on this base to establish a broad and effective partnership with universities in conducting research, training and developing skilled manpower, ensuring local concerns are incorporated in the National Plan, and strengthening the traditional role of universities in research and teaching. To this end, ERDA is in the process of developing a university program. The specific policy considerations for the effort are:

- Universities and colleges throughout the country will be encouraged to participate in the Nation's energy research programs to the maximum extent of their capabilities and interest.
- University activities supported by ERDA will be relevant to ERDA's mission and compatible with the interest, strengths, and activities of the university.
- ERDA will encourage participation in supported research by young faculty members and by students, as well as senior investigators, in ways that enhance and strengthen the universities' traditional educational and research mission.
- Team research of both an interdisciplinary and a multi-disciplinary nature on the part of faculty and students will be encouraged on appropriate scientific and technical related subjects, and on the broader social assessment of energy development and utilization.
- ERDA recognizes and will provide support to the extent practicable to the universities' primary educational role of training professional manpower to meet current and long-range energy needs.
- ERDA will encourage the submission from university investigators of unsolicited research proposals that are consistent with the specific mission and objectives of the program.
- Cooperative efforts among the universities, industry, and ERDA's National Laboratories and Energy Research Centers will be encouraged.

An ERDA University Conference was held in early November 1975 to acquaint universities with ERDA's programs and plans and to encourage open dialogue and feedback. Followup meetings are contemplated, as is the establishment of a University Advisory Committee to provide input on matters related to the ERDA/university interface.

* All nonprofit institutions of higher learning and educational nonprofit organization that are operationally affiliated or integrated with such institutions.

** Excludes funds (e.g., about $750 million for operating expenses in FY 1976) paid to universities and university consortia that operate ERDA facilities.

Expanding Interaction with State and Local Governments

State and local governments and regional groups are well aware of the Nation's energy problems and have major responsibility for finding their solutions. Their perceptions of the problems, the candidate solutions, and the possible local and regional impacts must become an integral part of the planning process for the energy RD&D program.

State and local governments can contribute significantly to energy RD&D projects by providing the general public with the information necessary to obtain sociopolitical consensus on energy matters and by encouraging the conservation ethic not only for energy but also for other natural resources. They frequently have the tools—taxation and siting authority—to ameliorate some of the inequities brought about by new technologies. These government units can make significant contribution in other ways as well; for example, 38,000 units of local government utilize enormous numbers of buildings, vehicles, and equipment and are among the largest energy consumers in the Nation. They can take the lead in implementing technology improvement and conservation methods. In addition, numerous municipalities are producers as well as consumers of electrical power, thus they have an immediate and direct interest in the execution and eventual implementation of RD&D projects.

Among the roles these organizations have are:

- Identifying the environmental, social, and economic impacts of energy projects within their geographical jurisdictions
- Developing and promulgating, when appropriate, revised local standards, taxing policy, and other incentives (such as construction and land-use planning) that facilitate and encourage energy conservation, the use of new fuel sources, and the expansion of the supply of existing sources
- Defining questions, problems, and alternative solutions with respect to resource extraction, transportation, and distribution
- Helping provide information and data to assist the public in arriving at an informed sociopolitical consensus on energy matters
- Participating in national energy RD&D planning
- Conserving energy in providing services and in operating government facilities within their jurisdiction.

Technical assistance is being provided to many state governments through the technology utilization program mentioned earlier. Technical representatives located in eight of ERDA's National Laboratories attempt to match state needs with technology available at the laboratories. The National Laboratories are working on regional assessment studies that will predict and evaluate the socioeconomic, environmental, and social impacts of energy resource developments. State governments are actively cooperating in these studies.

A regional studies program is being conducted to predict and evaluate the socioeconomic, human health, environmental, and institutional impacts related to the development of all on-line and prospective energy sources. Six ERDA laboratories are coordinating this program on a regional basis and have direct contact with state governments. This program provides not only information to ERDA on potential environmental issues but also feedback to the states for use in energy policy decision-making.

The states are already actively engaged in examining energy RD&D and broader energy matters. For example, under the National Governors' Conference, five subcommittees have been formed to deal with national coal policy. These subcommittees and their chairmen are: Surface Mine Reclamation, Governor Arch Moore (West Virginia); Water Requirements for Coal, Governor Richard Kneip (South Dakota); Coal Gasification/Liquefaction, Governor Dan Walker (Illinois); Coal Transportation Problems, Governor Julian Carroll (Kentucky); and Boom/Ghost Towns and Financial Problems, Governor Richard Lamm (Colorado). This work is being coordinated with the newly created Intergovernmental Coordinating Committee formed under the auspices of the Energy Resources Council. This committee will serve as a center for interaction among Federal, state, and local government officials in developing national energy policy, and is already working on synthetic fuels policy and coal policy. Specifically, the new committee will facilitate Federal interagency coordination for national energy programs. It will also provide a vehicle wherein state and local governments and their regional and national associations can be informed and consulted as policy plans are developed to ensure adopted policies will have the flexibility to fit various geographical situations.

Beyond participating in energy RD&D policy formulation and technical information activities, states and localities are carrying out specific energy RD&D projects. For example, the states of Texas and Louisiana are studying the characteristics and development potential of geothermal energy along the Gulf Coast. The City of Albuquerque, New Mexico, is involved in research on a pilot plant for thermoradiation of sewage sludge, while the City of Hobbs, New Mexico, is working on a community-wide energy management plan in cooperation with the University of Oklahoma.

The strengthening of Federal ties to regions, states, and localities is essential to the achievement of national energy RD&D goals. To this end, ERDA is actively building new relationships with regional bodies and with state energy offices. Workshops covering specific technology areas are now being planned. Information packets are being distributed regularly to all 50 states to keep state officials apprised of national energy RD&D policy and programs. Several technology transfer programs that would bring the Federal Government and the state together in a variety of cooperative activities are now under consideration. This increasing interchange will clearly result in greater input to and consensus on the National Plan for Energy RD&D.

Establishing the Regional Interface

The domestic energy problem and its solution are national, regional, and local in nature. The problem extends beyond traditional RD&D efforts and includes, as an essential ingredient, the market penetration of near-term technologies. Success or failure in meeting the Nation's energy needs will depend as much on the ability to resolve complex economic, social, political, and ecological issues at the regional and local levels as on the technical quality of the specific energy RD&D programs. The Federal Government must therefore be sensitive to local and regional needs. It must also reach public and private groups at these levels to provide information to them; to develop effective, productive communication links with regional, state, local, university, financial, and industrial representatives; and to receive feedback from them on the problems, progress, public acceptability, and overall effectiveness of ERDA's programs and the National Plan for Energy RD&D. To assist in achieving ERDA's overall energy mission and in carrying out its specific assigned energy pro-

NOTE: THIS MAP DOES NOT INCLUDE PILOT/ DEMONSTRATION PROJECTS, OR CONTRACTORS OPERATING OFF FEDERALLY OWNED OR LEASED SITES.

Figure IV–1 ERDA National Organization

gram responsibilities, an enhanced regional capability may be desirable.

ERDA is a nationwide organization (see Figure IV-1) created by the Energy Reorganization Act of 1974 from a combination of Federal energy RD&D units formerly residing with the Atomic Energy Commission, Department of the Interior, National Science Foundation, and the Environmental Protection Agency. These diverse elements brought with them considerable headquarters and field resources and a variety of management practices.

ERDA is composed of a headquarters facility consisting of approximately 3,000 people, and a nationwide field organization consisting of approximately 95,000, of which more than 90,000 are operating contractor employees. This field organization consists of:

- 55 laboratories and production facilities, with the major operating contractors including universities, university consortia, nonprofit organizations, and private industry. These facilities, most of which emanated from the former AEC or the DOI's Bureau of Mines, include 8 major multiprogram laboratories, 5 Energy Research Centers, 6 engineering laboratories, 7 specialized physical research laboratories, and 13 specialized biomedical research laboratories. There are also 9 nuclear material processing plants and 7 weapons production and testing facilities engaged in carrying out ERDA's important national security responsibilities
- 8 government-staffed field Operations Offices—from the former AEC. These Operations Offices are responsible primarily for contract administration, management, and review. This includes responsibility for administering the operating contracts for the government-owned, contractor-operated (GOCO) facilities in their region. Some Operations Offices also have direct operational responsibilities and, in a few cases, fulfill program management and execution functions.

The diversity of this interface and ERDA's role to assist the private sector in introducing new technologies to the marketplace, among other things, necessitated a management assessment of field resource utilization.

As a first step in this assessment, ERDA established an ad hoc group of experienced R&D managers from industry, academia, and the ERDA field structure to conduct a Field and Laboratory Utilization Study.* Based in part on the study group's recommendations and on other management considerations, ERDA is studying possible organizational and management actions, including:

- Delegating project execution authority to the field, on a case by case basis
- Assigning specific mission responsibilities to selected laboratories and Operations Offices
- Developing a coordinated approach to marshal the various technical resources in each region to help ERDA attain its energy research, development and demonstration objectives

Several task forces are now under way and will be reporting their findings and recommendations to ERDA management. These task forces must consider both the benefits and the consequences of such actions. In addition, alternative approaches, staffing and other resource implications, and possible disruptions during a transition period must be defined and evaluated. ERDA is taking initial actions, where they appear appropriate, to increase field responsibilities, but the scope and timing of these and possible future changes require and will receive careful review.

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* The results of this independent study are contained in ERDA-100, **Report of the Field and Laboratory Utilization Study Group**, December 1975.

Chapter V—Implementing The Plan: ERDA Planning System

Under the Energy Reorganization Act of 1974*, the Federal Nonnuclear Energy Research and Development Act**, and several other statutes, ERDA is assigned planning responsibilities that extend beyond those necessary to formulate the programs that the agency conducts directly. One of ERDA's major responsibilities is to update its National Plan for Energy RD&D annually. Recognizing that its planning responsibilities have impact on other Federal agencies, industry, and the public, ERDA believes it is important to document the Planning, Programming, Budgeting, and Review (PPBR) system it is developing to discharge its statutory mandates.

The overall objective of ERDA's PPBR system is to provide an integrated and disciplined approach to analyzing the Nation's future energy technology needs; formulating the Federal role in addressing those needs; designing targeted programs to conduct ERDA's portion of the Plan; allocating resources consistent with the Plan and program design; and ensuring that ERDA's programs are effectively managed. Accordingly, the PPBR system will address major issues such as:

- What new energy technologies should be pursued nationally to meet energy goals?
- To what extent will the private sector develop important technologies without Federal assistance?
- If Federal assistance is involved, what is the role of RD&D in comparison to regulatory, fiscal, or institutional solutions?
- If Federal RD&D is involved, what specific program goals are appropriate, who should manage the program, and at what cost?
- If ERDA is responsible for RD&D, what is the most cost-effective program plan and related budget?

* Sections 2(b), 103(1), and 103(4), among others, of Public Law 93–438.

** Sections 4(b), and 4(c), and 6(a), among others, of Public Law 93–577.

PPBR System Structure

The general features of ERDA's PPBR system are illustrated in Figure V-1. The system comprises analytical, planning, resource allocation, program implementation, and program evaluation activities. The analytical activities provide support for the planning activities, which focus on normative, strategic, and program planning. Strategic and program planning in turn help guide the resource allocation and program implementation activities. Program evaluation activities serve to check actual progress against planned progress and provide a basis for updating and changing planning goals.

Environmental planning is a key part of the ERDA PPBR system; environmental issues (including occupational and human health, safety and welfare, and ecology) are thoroughly considered and weighed throughout the analysis and decision-making process. Accordingly, environmental planning is being embodied in a formal structure within the PPBR to ensure that appropriate environmental RD&D priorities are maintained and that ERDA resources are allocated to produce environmentally acceptable energy technology options.

Planning Activities

PPBR activities focus on three types of planning—normative, strategic, and program—aimed at determining what **ought** to be done, **how** it can be done most effectively, and what **will** be done. Environmental planning is an integral component of these three major planning phases. Accordingly, this section discusses each of the planning phases and then describes ERDA's environmental planning process as it relates to normative, strategic, and program planning.

Normative Planning

Normative planning identifies preferred solutions to the national energy problem; that is, what **ought** to be done. The identified solutions are based on a number of analytic inputs and policy assumptions. As a

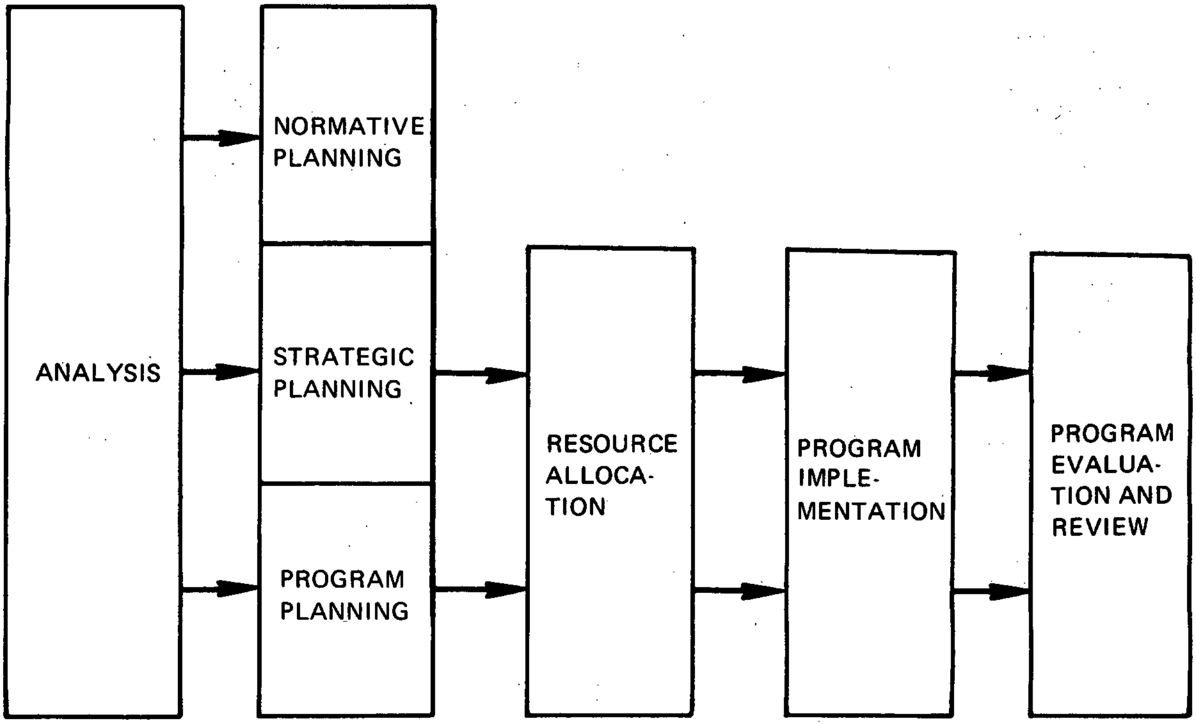


Figure V–1 General Features of PPBR System

first step, reference projections that indicate the future state of the energy system based on existing trends must be established. These projections serve primarily to define future problems and indicate the need for action.

Second, normative analysis involves the development of alternative cases and the use of models that replicate the dynamic behavior of the energy system. A series of cases that span the range of future likely conditions is developed by assigning reasonable values to changes in parameters such as resource availability, technological developments, absolute and relative costs of various fuels and technologies, environmental standards, status of control technologies, population distribution and makeup, GNP and its components, capital availability, industrial process, labor productivity and life styles. These cases developed will suggest alternative directions for the evolution of current energy system through time and define objectives toward which new strategic approaches and policy development could be oriented.

Examination and comparison of the cases can provide insights into policies, technologies, or other factors that are important regardless of the Nation's future direction. Normative analysis also identifies problems common to potential futures, defines common needs, and indicates the probable market size and likely timing range for new technologies. The reasonableness of these cases can be tested and the impact compared of any inhibiting constraints (e.g., resource, manpower, and financial requirements, regulatory processes, national interests and security, legal restrictions, institutional barriers, prevailing sociopolitical moods).

Once consequences of alternative cases have been assessed, choices can be made and action directed toward the ends that such choices dictate. **Thus, normative planning is not directed towards prediction, but rather towards goal-setting.**

Strategic Planning

Strategic planning defines how the goals outlined in the normative planning phase can be achieved most effectively. At the strategic level of planning, both the specific energy system options and the constraints to their market penetration must be analyzed in much greater detail than they were in the normative phase.

The keystone of strategic analysis is the replication of the private sector decision-making process to determine appropriate private and public sector roles. To the maximum extent possible, the analysis is based on a quantitative assessment of benefits, costs, and risks. Furthermore, the analysis must employ decision criteria and roles appropriate for the market sector in which the energy system option will be introduced.

The fundamental logic that underlies strategic planning is illustrated in Figure V-2. The private sector is the key instrument for achieving market

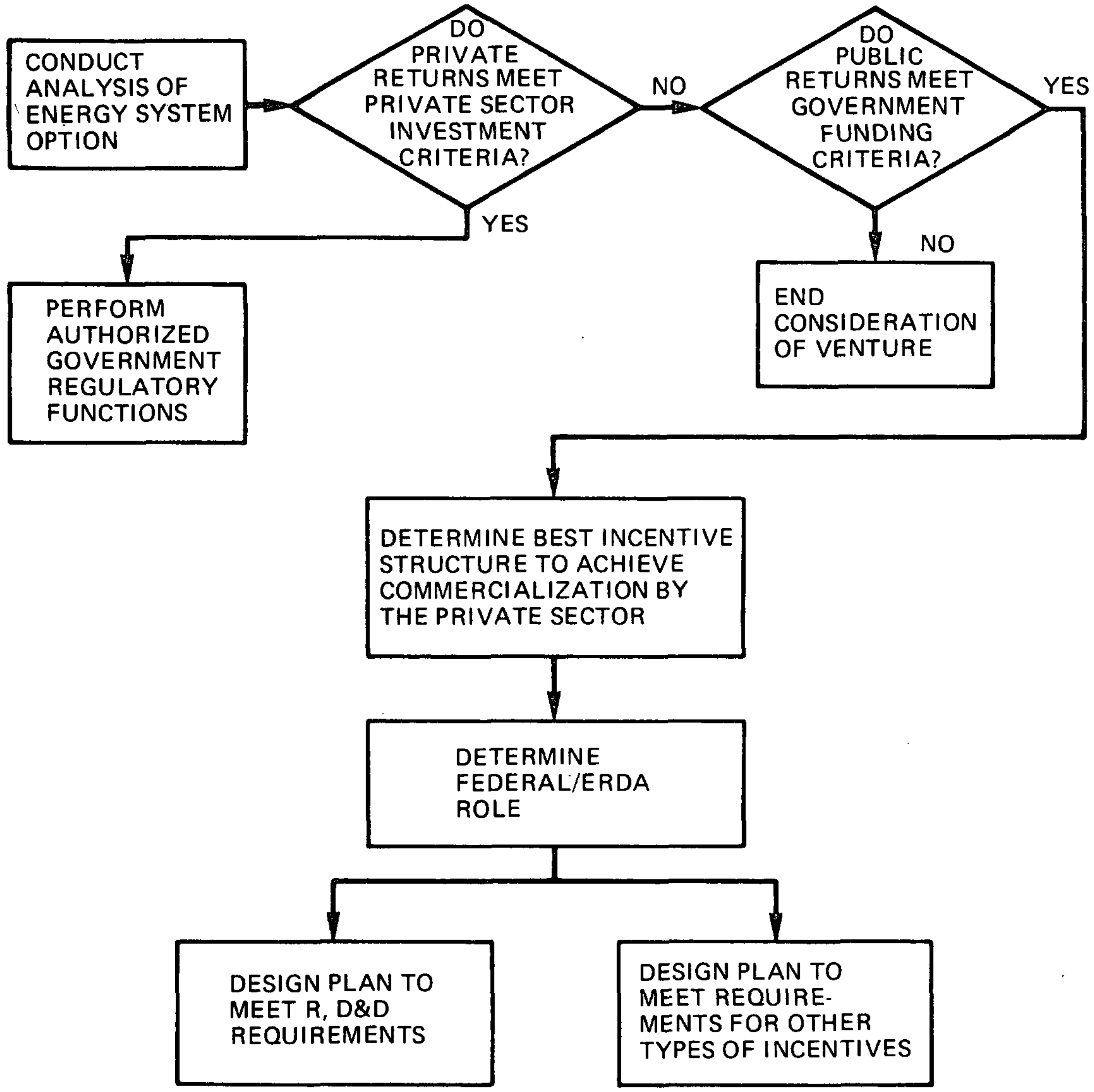


Figure V–2 Strategic Planning Logic

penetration of new energy technologies. Government RD&D involvement will be restricted to those energy technologies for which (1) private returns are too low or market barriers too high to induce private sector activity, and (2) public returns are sufficiently high to justify a government role.

If the private rate-of-return and other figures-of-merit for an energy system option do not meet requirements, the venture will not be considered for private funding. If the venture does meet the requirements and it seems likely that the private sector will fund the venture, then the government will perform only its legislated regulatory functions.

If factors that preclude sponsorship of the venture in the private sector are identified (e.g., high risk, high exposure, market fragmentation), it will be necessary to determine if the public rate-of-return is sufficiently high to justify government involvement. If the public rate-of-return is judged to be high, it must then be determined what type of government involvement is appropriate. The Federal Government can use various incentives (e.g., guaranteed loans, capital grants, price supports, research and development funding) to induce the private sector to innovate or to accelerate the rate of introduction of new products in the marketplace. The most effective incentive(s) can be determined by repeating the private sector decision analysis and determining which incentives result in the venture meeting the private sector's investment criteria. Those incentives most likely to induce private sector participation at the least cost to the government can then serve to define the primary government role.

Outputs of the strategic planning process include a listing of energy system options ranked according to their relative importance within the ERDA program, and a definition of ERDA activities and resource levels required to assist the private sector in the market penetration phase of the various energy systems. These outputs provide the basis for long-term (e.g., five-year) resource allocation among the various strategic alternatives.

Program Planning

Program planning describes the detailed means by which the ERDA program defined in the strategic planning phase will be implemented. Decisions are made concerning what "will" be done by ERDA to satisfy the national "oughts" specified in the normative planning phase through the "hows" described in the strategic planning phase. The key outputs of this phase are technology program plans (e.g., fossil, geothermal) that set forth in detail what will be accomplished; these plans serve as a key input to the resource allocation, program implementation, and program evaluation activities.

Environmental Planning

ERDA recognizes the need to ensure that environmental planning and performance are reviewed at the highest levels of decision-making. Environmental and health goals are addressed at each decision point (i.e., concept, research, pilot plant, demonstration) and related to the technological and economic goals for energy production alternatives. In this way, energy RD&D alternatives are designed to have minimal environmental impacts and energy development decisions can be approached with full cognizance of their environmental implications.

The environmental planning process results in several major outputs: an Environmental Development Plan, a Balanced Program Plan, and an Assessment of Environmental Impacts. The keystone of the process is the **Environmental Development Plan** (EDP), which is prepared to accompany the program plan for each major technology thrust. The program plan and the EDP for a given technology guide the research that ERDA must coordinate to ensure that the technology is environmentally acceptable. The purpose of the EDP is to ensure consideration of (1) the health, environmental, safety, and control technology requirements that must be met for the technology to become acceptable, and (2) the social and institutional implications of the technology. These issues are often neglected until the technology is well advanced, leading to costly delays at a time when the technology may seem most promising.

The EDP documents the planning, budgeting, management, and review processes for the environmental aspects of each energy technology, and also:

- Assesses the current status of understanding with respect to environmental and institutional problems
- Identifies major problem areas and topics requiring research
- Designates significant milestones
- Specifies requirements for performance monitoring and supporting research.

Definition of the EDP requires close interaction between those responsible for developing the energy technologies and those responsible for ensuring their environmental acceptability. This close coordination will provide the necessary visibility to ensure that all components are compatible.

The **Balanced Program Plan** (BPP)* is, in effect, the program plan for ERDA's environmental research. Environmental research must normally be conducted along disciplinary (as opposed to energy technology) lines. Using the information collected in the EDPs, the BPP defines the disciplinary research that must be performed to meet the needs of all energy technology development.

The remaining component of the environmental planning process is the **Assessment of Environmental Impact**, which culminates in the preparation of environmental impact statements at major decision points in a technology's development. This process provides the primary means for identifying and documenting the environmental, technological, economic, and other factors considered in decision-making. As public communication is an essential part of this process, activities are structured to inform the public and organized interest groups of estimated impacts and to provide open channels for ERDA to respond to specific public concerns in the decision process.

Resource Allocation Activities

Resource allocation activities are based on:

- Federal role and objectives defined through strategic planning
- Relative program priorities and long-term resource requirements based on strategic planning and an estimate of future budget constraints
- Status of the current program (e.g., study phase, pilot operations, demonstration plant) including the work to be done, as described through program planning and the degree of private-sector cost-sharing being achieved
- Size and relative priorities of the Federal budget, as determined by the President and Congress based on total budget constraints and competing demands for Federal funds.

On the basis of this information, trade-offs aimed at allocating ERDA resources to the most important activities can be clearly defined.

* ERDA-116, **Balanced Program Plan Analysis of Biomedical and Environmental Research.**

Program Implementation Activities

Program implementation activities focus on the development of an operating plan that delineates the specific activities to be accomplished within approved budgets. Through program implementation, ERDA management:

- Approves program execution, including annual operating plans for specific programs
- Establishes the controls that govern implementation by the operating elements
- Establishes the milestones or other means for management review considered essential to control the program
- Prescribes the framework for timely reporting against these milestones.

Program Evaluation Activities

The overall PPBR process is dynamic and adaptive. Managerial action is initiated in response to specific problems, defined as an identified difference between an existing situation and a desired situation (e.g., perceived actual progress versus scheduled progress on an RD&D program).

The program evaluation process produces exception reports that identify differences between the desired conditions specified in the operating plan and the current actual conditions. Actions to eliminate or reduce serious differences are then defined. The program evaluation process is conducted monthly.

Annually, a summary review is conducted to evaluate program progress vis-a-vis program objectives and approved milestones specified in the operation plan. In addition, in-depth evaluation of selected key programs are conducted each year, with all major programs receiving an in-depth review every three to four years. Program evaluation feeds back to program design and resource allocation decisions.

PPBR System Outputs

The PPBR system generates seven key documents, the first of which is the **National Plan for Energy RD&D.** The Plan documents the normative planning work performed by ERDA. For example, Chapter II summarizes the goals and priorities that help define what ought to be done if the energy problem is to be resolved through technology development, and Chapter VI describes some of the initial analytical work undertaken to support normative planning.

The **ERDA Budget** is the other important comprehensive document. The budget presents near-term priorities and the annual allocation of resources.

The five remaining documents are developed for each technology program:

- **Program Strategy.** This document explores the need for a Federal role and the effectiveness of RD&D and other programmatic solutions. A program strategy for the market penetration of energy systems options is presented, and the major goals and milestones for programs necessary to implement that strategy are established.
- **Program Plan.** The program plan charts the detailed course of the program over a period of several years, including major programmatic decisions (e.g., should a demonstration phase be undertaken?).

  The plan specifies elements such as management structure and roles of other agencies, and definies the most cost-effective Federal program for achieving the agreed-upon objectives.
- **Environmental Development Plan** (EDP). A companion document to the program plan, the EDP outlines the program of environmental research that must parallel technology development, and details a program for resolving those issues in a time period consistent with the rate of technology RD&D.
- **Program Approval Document.** The PAD is a primarily internal ERDA document that functions as an operation plan. A one-year slice of the program plan, the PAD's purpose is to provide a baseline for monitoring program operations during a given fiscal year. The PAD also contains some summary program plan material to provide a context for fiscal year operations.
- **Environmental Impact Statement** (EIS). Within the structure of the National Environmental Policy Act, ERDA intends to use the EIS as a major input to decision processes. Where required, an EIS describing major program decisions is prepared. The EIS contains a summary of the information developed by the EDP and addresses environmental and other issues raised in the EDP. In tihs way, environmental issues are identified at the beginning of an appropriate program phase and systematically addressed throughout the planning process.

A variety of analyses link the National Plan and the individual program planning documents. Economic considerations, for example, help establish the relative costs and benefits of technological change. Net energy analyses, energy system studies, and energy-environmental trade-off studies help distinguish the relative priorities of discrete technologies within a class of technologies. The status of ERDA's ongoing efforts in the areas is discussed in Chapter VI of this report.

ERDA believes that its overall planning process will benefit from comment and consultation by others. To facilitate this interchange, the key steps in ERDA's planning must be understood. Accordingly, ERDA intends to publish descriptions of its PPBR system as they become available.

DEVELOPING THE PLAN

Chapter VI—Factors Influencing the Evolution of the Plan

The National Energy RD&D Plan must be responsive to continuous changes in the world, both with regard to energy and non-energy events and policies. For example, changes in private investment and technology development, in oil and gas reserves, in energy demand levels, in economic conditions, in environmental considerations, and in life styles affect the basis on which the Plan is drawn.

In arriving at this revision of the Plan, ERDA has examined a number of factors, falling into three principal areas:

- An assessment of the basis on which the earlier version of the Plan was predicated, including: domestic and world energy resources; and energy, economic, environmental, legislative, and other developments.
- An assessment of the comments and criticisms of ERDA-48 by: industry; the general public; regional, state, and local interests; other Federal agencies; and Congress. These useful comments have materially influenced the Plan.
- An assessment of recent energy system analysis studies aimed at: understanding the relationships between energy, economic growth, and environmental impact as a result of the introduction of new energy technologies and other energy policy initiatives; calculating the net energy aspects of energy technologies; and supporting market penetration initiatives through specific market studies. Although most of these studies have not yet been completed, it appears that they will be extremely useful in: selecting the most promising from among the large number of individual energy technologies being proposed; and materially assisting in clarifying the degree of Federal participation, if any, required to develop and introduce new technologies. They do not yet suggest the need for a sharp revision in the basic goals and strategies of this Plan.

Subsequent sections of this chapter review each of the above assessments, and describe their implications for this Plan. In future Plan revisions, ERDA will continue to make and report on similar assessments.

International and Domestic Events

The fundamental strategy of this Plan is to broaden the domestic energy resource base through the introduction of new energy technologies in the private sector. This strategy is based on the observations that worldwide supplies of oil and gas are finite, that domestic production of oil and gas has entered a stable or declining phase, and that other domestic energy resources are available in significant quantities. Events of the past six months, which are reviewed below, support this appraisal. Moreover, clarification of U.S. energy policy by the President and Congress, although very important for the near term, does not alter the fundamental problem of imbalance in the Nation's use of energy resources.

Geographical Concentration of World Energy Resources and Reserves

Although world energy fossil fuel reserves are very large, their geographical concentration is an important consideration in assessing availability. Petroleum and natural gas reserves are largely concentrated in the Eastern Hemisphere, with over half of the world's total in the Middle East and North Africa, and most of the remainder in the Soviet Union. The U.S. has the next largest reserves of oil and gas. But in spite of the large Canadian and Venezuelan producing industries, the oil and gas reserves of the Western Hemisphere represent only 13 percent of the world total.

Reserves are essentially the proven inventory that producers must have on hand to continue operations. Based on world rates of production in 1974, the total reserves of petroleum would last for another 35 years and the world coal reserves would last for about 175 years. Of course, these global averages are deceiving because not all producers have equal call on the existing stock, and, further, demand can be expected to increase in the future.

The level of reserves is not static and it is generally expected that additional **resources** will be located and moved into the reserve category in the established producing areas. Resource estimates (usually several times as large as the reserve estimates) include extrapolations not only of additions in existing proven areas, but speculations about potential new discoveries elsewhere. In the Middle East, some estimates suggest that the presently published petroleum reserves may ultimately be at least twice as large. The U.S. Geological Survey estimates that ultimately there may be from two to four times the current demonstrated U.S. reserves of liquid fuels. Even more speculative, but of great current interest, is the growing potential of offshore production of oil and gas, particularly in the U.S., the North Sea, and the Canadian offshore (including the Arctic).

Unless properly interpreted, however, data on resource estimates can be misleading. These resources are not ensured sources of supply, since in many cases, technological advances are required to locate, develop, and use them in economically and environmentally acceptable ways. Appendix A provides a more detailed discussion of the world energy resource picture, including data on the geographical concentration of reserves and on the magnitude of total reserves and resources.

It seems reasonable to conclude that the geographical distribution of fossil energy resources will not be radically different from the distribution of today's reserves. In this regard, the U.S. has about 8 percent of the world's recoverable oil and gas reserves and about 35 percent of the recoverable coal reserves. Discovery of new reserves can stretch the world's finite fossile resources, and that is desirable; but, new discoveries are unlikely to result in changes in the location of new reserves. To the extent that a nation wishes to draw on domestic energy resources, the long-term problem remains.

Continuing Worldwide Dependence on Oil and Gas

In spite of rising costs, the worldwide trend toward greater dependence on oil and gas has continued since the original National Plan. This trend is expected to continue unless affirmative action is taken to increase the use of coal and develop alternative sources.

Developed countries, other than the centrally planned (Communist) economies, and the less developed countries rely on gas and oil, particularly imported oil, for three-fourths of their energy needs. Reliance on coal is minimal in the less developed regions, except in a few countries such as India and Korea. The centrally planned economies, however, rely on coal for over half of their total energy supply and on oil and gas for most of the remainder.

In many countries, there are few alternatives to imported oil. The prospects for coal are not encouraging in some countries since incentives and advantages will continue to favor rapid development of oil and gas until new energy sources are available. The less developed countries would benefit greatly from new technologies to use solar and other renewable resources. Developed countries can undoubtedly be of assistance in transferring and applying such technologies.

Thus, the inertia of an infrastructure devoted to oil and gas, the difficulty of converting to other resource bases, and the absence of alternative domestic energy resources in some countries (e.g., Japan) will all contribute to a continuing or increased worldwide dependence on oil and gas. Short-term variations in petroleum supplies should not obscure the fact that in the long run a finite resource will, in the absence of action to the contrary, be subjected to increasing demand.

Continuing U.S. Dependence on Oil and Gas

The problem of continued heavy reliance on the least abundant resources remains. The current reliance on oil and gas in the U.S. is reflected in recent statistics on energy consumption. As shown in Table VI-1, these two sources accounted for approximately 75 percent of total consumption in 1974. Based on early estimates, these fuels accounted for about the same percentage of total consumption in 1975.

Dependence on imported oil has not decreased significantly even though U.S. oil demand has remained well below the level of just two years ago. The decline in energy demand in the U.S. has been about 2 percent in each of the last two years, while the level of imported petroleum has also fallen slightly and is not greatly below the level of 1973. In spite of increased OPEC prices, the import dependence on OPEC countries in general and the Arab countries in particular has grown during the past year. Imports now account for about 37 percent of total oil consumption, with OPEC countries accounting for about two-thirds of all imports.

The normal economic expectations that higher prices would bring forth marginal supply and add diversity among export sources have not materialized, at least in the short term. Recent increases in domestic drilling and exploration activity should, however, lead to new fields and additional production in the future.

Import dependence on OPEC production is not likely to decline in the near term. Western Hemisphere sources have not proven reliable offsets to Middle East and other Eastern Hemisphere production. Canadian crude oil exports to the U.S. are scheduled to be cut by one-third in 1976 as compared to 1975, and to be phased out entirely in 1981. Venezuela, which had long been regarded as a favor-

Table VI–1 U.S. Gross Consumption of Energy (10^{15} BTU)*

Energy Source	Household and Commercial	Industrial	Transportation	Utility Electricity Generation	Misc.	Total Energy Inputs (1974)	Percentage of Total (1974)	Total Energy Inputs (Estimated for 1975)	Percentage of Total (Estimated for 1975)
Coal	0.314	4.406	0.002	8.520	—	13.241	18.2%	13.394	18.8%
Natural Gas (Dry)	7.518	10.018	0.685	3.512	—	21.733	29.8%	20.173	28.4%
Petroleum**	6.061	5.907	17.720	3.480	0.246	33.414	45.8%	32.701	46.0%
Hydropower	—	0.037	—	3.253	—	3.290	4.5%	3.158	4.4%
Nuclear Power	—	—	—	1.202	—	1.202	1.6%	1.652	2.3%
TOTAL	13.893	20.368	18.407	19.967	0.246	72.880	100.0%	71.078	100.0%

Source: U.S. Bureau of Mines

* Data may not add to total because of independent rounding.
** Including natural gas liquids and refinery gases.

able source of oil supplies for the U.S., plans to hold its long-term production to about 2 million barrels per day although its current daily producing capacity is in excess of 3 million barrels. Other Western Hemisphere sources have little export potential and the U.S. expects no sizable additions to domestic production until North Slope oil starts to flow in 1977. Consequently, U.S. dependence on the Middle East and other Eastern Hemisphere sources may increase even more in the near term.

In the near term, it is physically possible for foreign sources to supply our needs. Spare producing capacity in OPEC countries was recently estimated at 10 million barrels per day. OPEC production had fallen from a quarterly peak of 32 million barrels per day prior to the Arab oil embargo to a low of 26 million barrels per day in the spring of 1975. Higher levels of production and exports in the third quarter, prior to the October 1 increase in OPEC prices, were followed by sharp cutbacks after the 10 percent increase took effect. At the same time, with economic recovery under way in the major importing countries, it is likely that energy demand will increase and the decline in OPEC production will be halted.

As economic and energy growth resumes in the U.S., there is a danger of slipping back into the same pattern of meeting incremental supply needs with imported oil. The current upturn of economic activity in the face of declining domestic oil and gas production will probably lead to higher imports initially. Domestic crude oil production was at a rate of 8.4 million barrels per day in 1975—more than a 10 percent decline from the level prior to the embargo in 1972. Domestic production of natural gas peaked in 1973 at 22.6 trillion cubic feet; in 1975, production was around 20 trillion cubic feet.

National determination to conserve in energy use, to develop new sources of energy supply, and to shift demand from oil and gas to more abundant energy forms will be tested as economic growth resumes. A measure of this difficulty is available from the recent experience during the recession, when the decline in total energy use was comparable to the decline in economic activity. It appears that in addition to a general slowdown in economic growth, conservation also contributed to the decline in energy use. FEA has estimated that, in 1975, 3 million barrels of oil per day less were consumed as compared to historic expected projections of demand, and that conservation efforts accounted for a substantial portion of the reduction. Yet the proportion of imported oil changed very little.

The short-term reliance on oil and gas is compounded by the obstacles to using those resources which could be expended relatively quickly—coal and nuclear power. Technical, environmental, and institutional factors come together to inhibit increased utilization of these resources. The prospect of increased reliance on imported energy to meet domestic energy needs argues strongly for technology developments in general, and for near-term conservation and fuel substitution initiative in particular. In addition, it is important that the efforts of individual nations be coordinated through mutually reinforcing international cooperative programs, as discussed in Chapter IV.

New Assessments of Domestic Resources

The U.S. has both the domestic resources and the technical capability to provide alternatives to oil and gas. Periodic assessments have indicated the extent of these resources. Resource assessments in the U.S. are much more thorough and soundly based than in most of the rest of the world. The frequency of resource surveys, formalized documentation procedures, and the use of high-technology exploration equipment all enhance the reliability of the resource estimates.

Nonetheless, new assessments are made periodically and significant changes in estimates of the resource base do appear. As a result of new assess-

Table VI-2 **Recoverable Energy Resources of the United States (In Thermal Equivalents)**

Resource	Units	Data in ERDA-48 Report	Data from Recent Official Reports: Demonstrated Reserves	Additional Resources	Total	Source and Explanation
Coal	Quads	12,000	4,900	16,500	21,400	ERDA-48 excluded hypothetical resources and those in areas likely to be closed to mining
Natural Gas	Quads	775*	244	706	950	Estimates based on "Mean Values" of USGS range of undiscovered resources
Petroleum**	Quads	800*	246	704	950	Estimates based on "Mean Values" of USGS range of undiscovered resources
Shale Oil	Quads	1,200	727	473	1,200	Western and Alaskan shales yielding 25–100 gal/ton
Uranium***	Quads	1,800	900	900	1,800	Utilized in LWRs
Geothermal	Quads	400	102	3,332	3,434	Recoverable heat with present or near-term technology

* ERDA-48 data based on the USGS "High Probability" estimates but excluding resources that may be produced through techniques to enhance recovery rates.
** *Crude oil and natural gas liquids.*
*** The use of uranium in breeder reactors could expand the resource base to about 130,000 quads.
Note: See discussions in text and bibliography for detailed references.

ments reported since ERDA-48, the estimated domestic resource base has risen significantly for coal and more thorough appraisals have been made of geothermal and other resources. **These new assessments are primarily the result of different interpetations of previously presented data and, in the case of coal, of major additions to the more speculative resources. Nonetheless, they tend to confirm the belief that the U.S. has significant domestic energy resources that could be used to reduce dependence on oil and gas.** Table VI-2 shows the new estimates as compared to those in ERDA-48.

In a new U.S. Geological Survey study,* the total coal resource base was increased 25 percent from 3.2 trillion short tons to nearly 4.0 trillion short tons. The bulk of the increase was in hypothetical resources (587 billion tons), while identified resources were increased by 11 percent (171 billion tons). Coal resources currently considered recoverable account for less than one-third of the nearly 4 trillion tons, reflecting quantities in seams too thin to be mined economically and providing for a recovery rate of 50 percent. Hypothetical resources and those in areas likely to be closed to mining operations were not included in the ERDA-48 analysis.

Since the U.S. Geological Survey had completed a new study** of oil and natural gas resources prior to the preparation of ERDA–48, it was possible to use these new USGS estimates in that analysis. A follow-on study planned for completion in mid-1976 will reappraise oil and gas estimates in light of the recent changes in price-cost relationships that were not taken into account in the 1975 study. These important price effects could change the outlook in several ways: (1) some resources formerly uneconomic to recover may now be recovered, (2) the percentage rates of recovery may improve, and (3) reserves may be produced at a more rapid rate.

The rate at which the existing and newly established reserves of oil and gas will be produced is the most crucial short-term variable. If producers' prices are high and expectations for further price increases are lessened, there could be a strong incentive to deplete reserves much more quickly than previously estimated. However, unless the basic resource estimates are in error, the result may be simply to ease the short- and mid-term problems and aggravate the problem in the long term. Expanding the application of enhanced oil and gas recovery techniques is a key program initiative for achieving the goals of the National Plan for Energy RD&D. These aspects of this initiative were discussed in greater detail in Chapter III.

An extensive evaluation of uranium resources is now under way that will be based on detailed nationwide geological, geophysical, and geochemical studies and surveys. The evaluation will take several years to complete, but information will be made available as it accumulates. A preliminary report published in January 1976 indicated a 50 percent in-

* USGS Bulletin 1413 (Averitt), "Coal Resources of the United States, January 1, 1974," Washington, GPO, 1975.
** USGS Bulletin 725 (Miller et al.), "Geological Estimates of Undiscovered Recoverable Oil and Gas Resources in the United States," 1975.

crease over earlier estimates, but the ERDA-48 analysis had been based on the later estimates, which were then unpublished.

A new assessment of geothermal resources was recently completed by the USGS in cooperation with ERDA.* For each identified geothermal system, the parameters used in calculating volumes, heat content, and recoverabilities are listed. The preliminary estimates disregard costs, and they will be revised as more data and better methods of evaluation become available. The geothermal potential that will eventually be realized is dependent upon the development of new technologies for exploiting the various systems in economic and environmentally acceptable ways. Estimates of the total potential would vary with the combination of resource systems employed and with variations in the technologies to be used and the rate of exploitation within each of the four major categories. For example, the estimates for hot dry rock and magma are based on assumptions of relatively low heat extraction and conversion efficiencies. Higher efficiency assumptions would increase these several times. The estimated resources are shown in Table VI-3, on a heat equivalent basis.

In the long term, thorium resources could also be important, but they do not seem likely to represent a significant alternative energy source in the near term. Thorium is a relatively abundant element (6 parts per million in the earth's crust vs. 2 parts per million for uranium), and resources are more than adequate to meet any foreseeable needs. No new estimates of thorium have been prepared in recent years.

Table VI-3 Geothermal Resources—Estimated Recoverable Heat with Present or Near-Term Technology
(In Quads)

Resource Type	Known	Inferred	Total
Hydrothermal Convection			
Vapor Dominated (>150 degrees C)	2	2	4
Liquid Dominated			
High Temp. (>150 degrees C)	20	110	130
Low Temp. (90-150 degrees C)	80	250	330
Geopressured			
Electrical Utilization	100	230	330
Methane Production	500	1,500	2,000
Hot Dry Rock	80	240	320
Magma	80	240	320
Total	862	2,572	3,434

NOTE: Does not include (1) normal gradients of heat in the earth, or (2) hydrothermal convection systems less than 90 degrees C.

Source: Definition Report: Geothermal Energy Research, Development and Demonstration Program (ERDA-86), October 1975, pp. 1–7.

Other Events and Developments

There are many legislative and environmental developments which potentially will affect the National Plan and program implementation. Recent legislative initiatives address automotive, consumer, and industrial conservation; the development of fuel supplies from lands subject to federally controlled mineral rights; strategic storage of petroleum fuels; changes in the pricing structure for oil; and Federal encouragement of new technologies. Environmental initiatives, particularly at the state and local level, must be taken into account in fostering the development of nuclear power and the extraction of fossil fuels.

The Energy Policy and Conservation Act,** recently signed and passed into law, has major implications for the Plan. This is especially true in the conservation area, as discussed in Chapter III. In general, the Act stresses conservation and the use of coal—policies which are entirely consistent with the Plan.

The legislation also establishes a framework for the gradual, but complete, removal of oil price controls. This partial resolution of uncertainties concerning price should allow the private sector to plan more meaningfully for additional domestic energy production. The exploration for and development of not only petroleum but all competing energy sources can proceed more smoothly, including the enhanced oil and gas recovery and synfuel initiatives discussed earlier.

Other developments have more effect on broad aspects of energy policy. These developments are important, nonetheless, to the extent that they influence the choice of new energy technology options at some future time period. Expanded oil and gas supplies from areas where the mineral rights are controlled by the Federal Government and the proposed deregulation of natural gas are examples.

Environmental developments are critical to the evolving Plan. Several current environmental initiatives are generic in nature (e.g., nondegradation legislation, state implementation plans for meeting national ambient air quality standards), with potential effects on all energy implementation plans. Other initiatives are program-specific (e.g., water rights for use in coal slurry pipelines, statewide moratoria on new nuclear power plants).

The implications of these developments on the Plan relate primarily to the need to identify the major environmental and other issues in the context of specific programs, and to incorporate the resolution of these technical and non-technical issues into technology development plans. This implies a strong requirement for inter-agency cooperation (discussed in Chapter IV) as environmental standards and techni-

* USGS Circular 726 (White and Williams), "Assessment of Geothermal Resources of the United States—1975," 1975.

** Public Law 94–163

cal RD&D programs are modified to meet changing requirements.

Assessment of the Plan by Others

The importance of the review of the National Plan by others is expressed in Congressional requirements. In 1975 Congress requested the Office of Technology Assessment to conduct a formal review of the National Plan.* Also, The Non-Nuclear Energy Research and Development Act directs the Council on Environmental Quality to undertake an ongoing assessment of the adequacy of attention to environmental protection and energy conservation in the energy R&D programs. In conducting this assessment CEQ is to hold annual public hearings, which in 1975 focused on a number of aspects of the National Plan.** In addition, the external review of the Plan includes the solicitation of comments from state and regional energy representatives, public and special interest groups, industry, the general public, and other government agencies. This section summarizes the most important comments and discusses how they influenced the Plan. Other government agencies provided initial input to the first National Plan in the area of program implementation. (Summaries of their energy RD&D programs were contained in Volume 2 of ERDA-48.) In the current Plan, other agency input and review to Volume 1 (The Plan) and Volume 2 (Program Implementation) were solicited.

Review by OTA and Public Hearings Held by CEQ

The OTA review and CEQ hearings on the National Plan for Energy RD&D produced the most comprehensive and wide ranging comments on the Plan. In general, the review and comments were most useful in highlighting those areas where the Plan could be made more responsive to the energy problems facing the country. The comments can be grouped according to three primary issues:

- **The basis for planning and program execution and the resulting priorities should be reexamined.** Criticisms included: excessive reliance on a hardware-oriented approach; inadequate emphasis on conservation; too little attention to nontechnical impacts resulting from technology development; too little focus on near-term energy problems; imbalance between energy supply and demand RD&D; overemphasis on high technology, capital-intensive energy supply alternatives such as electrification; inadequate emphasis on solar energy; inadequate emphasis on commercialization; lack of established goals for the basic research program; lack of importance given to environmental control and protection; and management policies that appear inadequate to achieve goals.
- **The degree of cooperation and coordination with others should be increased.** Criticisms included: insufficient provision for coordination and cooperation with international concerns, Federal agencies, state and local governments, and the general public in energy planning and policy making.
- **The analysis supporting the Plan should be more comprehensive.** Shortcomings were noted in: economic and socioeconomic analysis; cost/benefit analysis; resource assessment; foreign policy options; physical, environmental, institutional, and social constraint analysis; and net energy analysis.

The current Plan reflects the OTA comments and criticisms, and comments expressed to CEQ at its hearings, particularly in the sections dealing with near-term initiatives; the conservation program priority; major environmental issues; increased coordination with others; analysis of energy and economic relationships, including constraint and net energy analysis; and the role of basic research. However, many of the issues raised are complex, and have not been resolved in this document. ERDA will continue to incorporate these comments in future revisions of the Plan.

Other comments obtained from the OTA review and the CEQ public hearings indicated that the Federal mission, as expressed in the goals of the Plan, was too narrow. A related issue was the need for an expanded national energy RD&D program reflecting circumstances following the Arab oil embargo. A significantly higher budget was suggested to accommodate the adoption of a broader mission and the urgent need for energy solutions. These issues were underscored in the OTA review:

> ERDA's Plan in many instances acknowledges the need for such a broad perspective and program. In fact, the problems are not so much within the Plan itself—which is a serious and praiseworthy initial effort—but in the lack of a broad commitment and coordination when the Plan, Program and Budget are considered together.***

Chapter III summarized the ERDA portion of the national energy RD&D budget and program implementation. The funding levels in this program implementation plan reflect the Administration and Congressional assessments of the current energy situation subject to the effective utilization of manpower, facility, and budget resources.

Certain issues highlighted in the OTA review and CEQ hearings (e.g., the desirability of greater

* United States Congress, Office of Technology Assessment, **An Analysis of the ERDA Plan and Program,** October 1975.

** Council on Environmental Quality, **Summary Report on 1975 Public Hearings:** Environmental Effects and Energy Conservation Aspects of the Nonnuclear Energy RD&D Programs, January 1976.

*** United States Congress, Office of Technology Assessment, **An Analysis of the ERDA Plan and Program,** October 1975, p. 4.

energy independence as an energy policy goal) require broad public policy discussion since they affect large segments of U.S. society. Decisions on these issues cannot be made singularly by government agencies or by narrow segments of society. The Plan can, however, help focus on these issues by providing supporting analysis and forums for discussion. For example, preliminary conclusions regarding the impact of energy policy on other sectors of the economy are presented later in this chapter in a separate discussion on energy systems analysis studies.

ERDA Regional Public Review

The public review of the Plan provided important insights into specific regional energy issues. In the two public meetings that were held,* regional concerns were expressed about the future potential of various energy sources. These comments reflected the uniqueness of regional environments and were tied to local perceptions of the nature and importance of problems associated with development of energy alternatives.

The other main issues addressed by the participants in the public metings were:

- The goals of the Plan should be more realistic and should consider such regional constraints as resources, capital, and manpower.
- The degree of coordination between the Federal Government and state, local, and regional concerns should be improved to ensure successful and acceptable energy policies and programs.
- Criteria for ranking technology priorities should consider the impact of technology development on economic, environmental, social, and political systems. The budget should reflect these priorities.
- The nuclear alternative should be assessed more carefully in terms of environment, health, and safety.
- Government incentives should be available to ensure commercialization of new technologies.
- Conflicts of water use between energy and non-energy uses should be resolved.
- In view of finite resources, an ever-increasing rate of energy growth should not be encouraged.
- Economic and net energy analyses should be used in assessing alternative energy sources and technologies.
- The importance of short-term energy planning should be emphasized. Conservation and other alternatives such as solar, geothermal, biomass conversion, and hydrogen should receive higher priorities.

Another form of public review was provided by interaction between industrial representatives, trade associations, state energy offices, public interest groups, and Federal program planners. These groups were asked (by letter from ERDA**) to provide their views on energy RD&D. As a result of this solicitation and the regional review process, ERDA program managers and their staffs met with representatives from industry, public interest groups, and state and regional energy groups.

The comments elicited from the public review process have been carefully examined and evaluated. **These comments have helped shape the current National Plan, most notably in the areas of program priorities (e.g., the new emphasis on conservation) and coordinating activities with state, regional, and local groups (e.g., the emphasis on establishing a national energy organizational infrastructure).** In addition, energy analysis conducted at the state and regional level will be useful in focusing the energy systems analysis efforts which influence the Plan.

Energy Systems Analysis Studies

Subsequent to the development of ERDA-48, several studies were undertaken to address issues raised by the Plan and related comments. For example, it was clear that more analysis of economic effects, and energy-environmental trade-offs was required. Similarly, ERDA believed that the cumulative impact of technology change in the utility industry deserved more study, as did the situation posed by other countries that sustained a high economic growth with relatively low energy consumption.

These studies are nearing completion, will be published for external review and comment, and are expected to provide important insights for future planning. At this point, the study results are preliminary, but appear consistent with the Plan. Specifically:

- The new emphasis on conservation and the reliance on technological solutions to achieving energy goals are reinforced by results obtained from a study of the **relationship between energy and economic growth.**
- The choice of energy RD&D technologies is reinforced by a study which indicates that, of the technologies investigated to date, all are supportable on the basis of a **net energy analysis.**
- The difficulty of quickly changing the Nation's consumption patterns to show improved energy-economic efficiency is highlighted in a study of **foreign energy consumption patterns.**
- Finally, the importance of emphasizing the coal and light water reactor nuclear initiatives, discussed earlier in Chapters II and III, is highlighted in a **market study of the electric utility industry.**

* The first meeting was held in Atlanta (October 1975) and the second in Seattle (December 1975). The Bibliography lists the publications for these meetings.

** Via letters from the Assistant Administrator for Planning and Analysis to representatives of these groups in March and July 1975.

In addition to the four study areas above, the conceptualization of energy, economic, and environmental trade-off analysis and the analysis of economic constraints to energy growth are being investigated.

The study of energy systems is dynamic. As more is learned about the role of energy in society, both the problems being addressed and the tools and techniques of analysis are subject to change. This section presents selected preliminary results and conclusions from ongoing energy systems studies.

The purpose of the analysis, highlights of emerging conclusions, and references to existing and planned detailed reports are presented for the energy studies.

Each study is summarized in the balance of this section. The conclusions and results are based on a series of independent analyses. The supporting studies are only indirectly related to each other, primarily through the common input assumptions related to possible energy futures (i.e., the ERDA–48 scenarios). New and continuing studies are, however, a key ingredient of the ERDA planning system, as discussed previously in Chapter V.

Relationship Between Energy and Economic Growth

The effects of alternative future energy scenarios on the U.S. economic system must be better understood. This need is underscored by concerns over the impact of rising energy prices on overall economic growth, energy demand, inflation, and employment. Other areas of interest include the impact of new technology introduction on the economic system and on the cost of providing energy.

The relationship between energy and economic growth are complex but must be addressed to ensure the compatibility of energy policy goals with other societal goals. Accordingly, the main purposes of analysis efforts in this area are to:

- Develop methods for measuring the interrelationships between energy production and consumption and economic growth. The interrelationships include those among: energy demands, prices, and income; energy supplies, prices, and domestic economic output; and energy RD&D impacts, inflation, labor requirements, and capital requirements.
- Provide information on the economic impacts of energy technology introduction. Impacts such as changes in material, labor and capital requirements, aggregate GNP and its distribution to consumption, investment, and foreign trade are important to permit evaluation of alternative energy policies.
- Differentiate between the energy-economic effects of energy RD&D policies and those of other policies. For example, it is important to provide information on the effects associated with policies aimed at increasing energy supplies (such as through expenditures on new technologies) as compared to those associated with policies aimed at curtailing demand (such as demand reductions through price increases).

New technologies designed to exploit the Nation's abundant domestic resource base are expected to be available at different times and in varying quantities over the next two decades. Contributions to energy supplies are expected from oil shale, coal liquefaction and gasification, geothermal energy, and solar electric and direct solar applications. To the extent that these technologies can compete with existing energy sources, including imports, they can reduce the Nation's dependence on foreign energy supplies. Therefore, one strategy for meeting the Nation's energy policy goals relies on increased domestic supplies. Another strategy involves reductions in energy consumption.

Four models were utilized to describe the interreactions existing between factors of energy supply and demand and economic activity. These models, discussed at the end of this section, were used to test alternative supply and demand policies against a base or reference case. This case assumed the continuance of present economic and energy practices and conditions; the only exception was the assumed decontrol of oil and gas prices.* The alternative policies were evaluated in terms of their effects on economic growth and on the achievement of prespecified import targets. These policies were based on the following:

- A supply policy was based on the introduction of the new technologies mentioned above. The estimates of the maximum energy flows that could be expected from the new technologies were based on the technical calculations (scenarios) contained in ERDA-48. Import target levels were set as a declining percentage of total domestic energy use.
- A demand policy was based on rising energy prices (via taxes and tariffs only). Demand measures (rising energy prices) were used to eliminate any supply/demand gap still remaining after the introduction of new technologies. The procedure used was to increase the prices of energy supplies grad-

* During the conduct of these evaluations, ERDA and FEA collaborated closely on the energy projections generated by FEA through its Project Independence Evaluation System (PIES) model. ERDA believes that the FEA modeling efforts provide a very logical and detailed approach to evaluating economic interactions for the 1975–1985 time frames. Thus, ERDA has chosen not to duplicate these efforts, preferring instead to work with FEA to produce a mutually agreed upon set of projections for the next decade. Conversely, ERDA has taken the lead role for examining the energy-economic interactions for the 1985–2000 time frame, with FEA providing advice and review. The evaluations in this section cover only the 1985–2000 period and were closely calibrated to the FEA results for 1985 to provide the initial point of departure.

ually (which resulted in lower demands) until the specified import target levels were reached. The 1985 import target level was 10 percent of total energy consumption and the 2000 target level was 5 percent.

The preliminary results obtained to date relative to the base case have some important implications for research and development activities and for the implementation of new technology in the market place:

- **The introduction of new energy-producing technology has a significant positive effect on the level of GNP and on the economic well-being of the country.** The discounted value of future GNP restored by adding to supplies (through technology introduction), instead of increasing prices to reduce demand, is several-fold larger than the discounted value of accumulated expenditures on RD&D.
- **Higher prices (30 percent above those otherwise expected in 2000) could be required to achieve the specified energy demand reductions, and this appears to be an undesirable cost to the Nation.** Implementation of more efficient energy using and producing devices would be the preferable way to achieve the import reduction. The price increases needed to achieve a sufficient demand reduction are half as large when new supply technology is available as when it is not available. Energy demands are rather inelastic, with a 10 percent increase in price required to produce a 2.5 percent demand reduction in 1985 and a 4.5 percent demand reduction in 2000.
- **Increases in the inflation rate occur as a result of energy price changes.** In addition to the introduction of new technology, high taxes and tariffs (over 150 percent on oil and 20 percent on gas) are required to achieve the specified lower demands; this leads to a long-term increase in the general inflation rate of about 0.3 percentage point.
- **The effects of higher prices and new technology result in a slowing of the rate of increase in the output of the domestic economy.** The rate of increase in real GNP declines, resulting in a small drop in the level of real GNP (about 2 percent lower in 1990 and 3 percent lower in 2000).
- **Changes in labor requirements result in an increase in unemployment.** A lower real GNP produces a lower demand for labor inputs to the economy. The restructuring of the economy to reduce energy use offsets this somewhat through increased demands for labor as a substitute for energy inputs. The overall result is a long-term increase in the unemployment rate (for both policy alternatives) of from one-half to one percentage point higher than for the base case.
- **New technologies are only marginally competitive with existing technology in the short-run but compete successfully by the end of the century.** New technologies (primarily oil shale, geothermal, and direct solar) may account for 16 percent of total energy in 2000 as compared to only 4 percent in 1985.
- **There is an improvement in energy-economic efficiency (as measured by the energy/GNP ratio).** Preliminary results indicate a 2 to 3 percentage point improvement for each 10 percent change in energy prices.

The set of analytical tools applied to these problems represents an advancement in the state-of-the-art for models of this type. It is the first time a macroeconomic growth model has been linked to an inter-industry sectoral model* and subsequently linked to an energy technology oriented resource allocation model.** These efforts are being jointly pursued through contracts with ERDA.*** It also represents the first time that changes in energy technologies and patterns were introduced into the economic models to determine the new configuration of economic activity and indicators. The relationship among the separate models is expressed in the logic diagram shown in Figure VI-1. Each of the four models have been previously examined and critiqued. Certain adjustments have been made to develop compatible definitions of parameters. The initial results of this ongoing study are to be published by Brookhaven National Laboratory and Data Resources, Incorporated, and will be disseminated for review and comment at approximately the same time that this Plan is published.

These efforts are an integral part of the planning, program, and budget review process now being structured within ERDA. The treatment of other areas of energy-economic analysis—sectoral elasticities, regional considerations, and the sensitivities of individual technologies—has yet to be worked out. Other policy variations (e.g., non-price induced conservation) will be investigated. Additional results and studies will be forthcoming as they are completed.

Net Energy Analysis: The Energy Required to Produce, Distribute, and Conserve Energy

Net energy analysis is the term commonly used to signify the energy expenditures required to pro-

* For additional details see "U.S. Energy Policy and Economic Growth, 1975–2000," Edward A. Hudson and Dale W. Jorgenson, **The Bell Journal of Economics and Management Science**, Volume 5, Number 2, Autumn 1974, pp. 461–514.

** For additional details see "A Methodology of Technical Analysis with Application to Energy Assessment," K. C. Hoffman, ASME Paper 75-WA/TS-8, American Society of Mechanical Engineers, New York, 1975.

*** With Data Resources, Incorporated (macroeconomic and inter-industry sectoral models) and Brookhaven National Laboratory (input-output and resource allocation models).

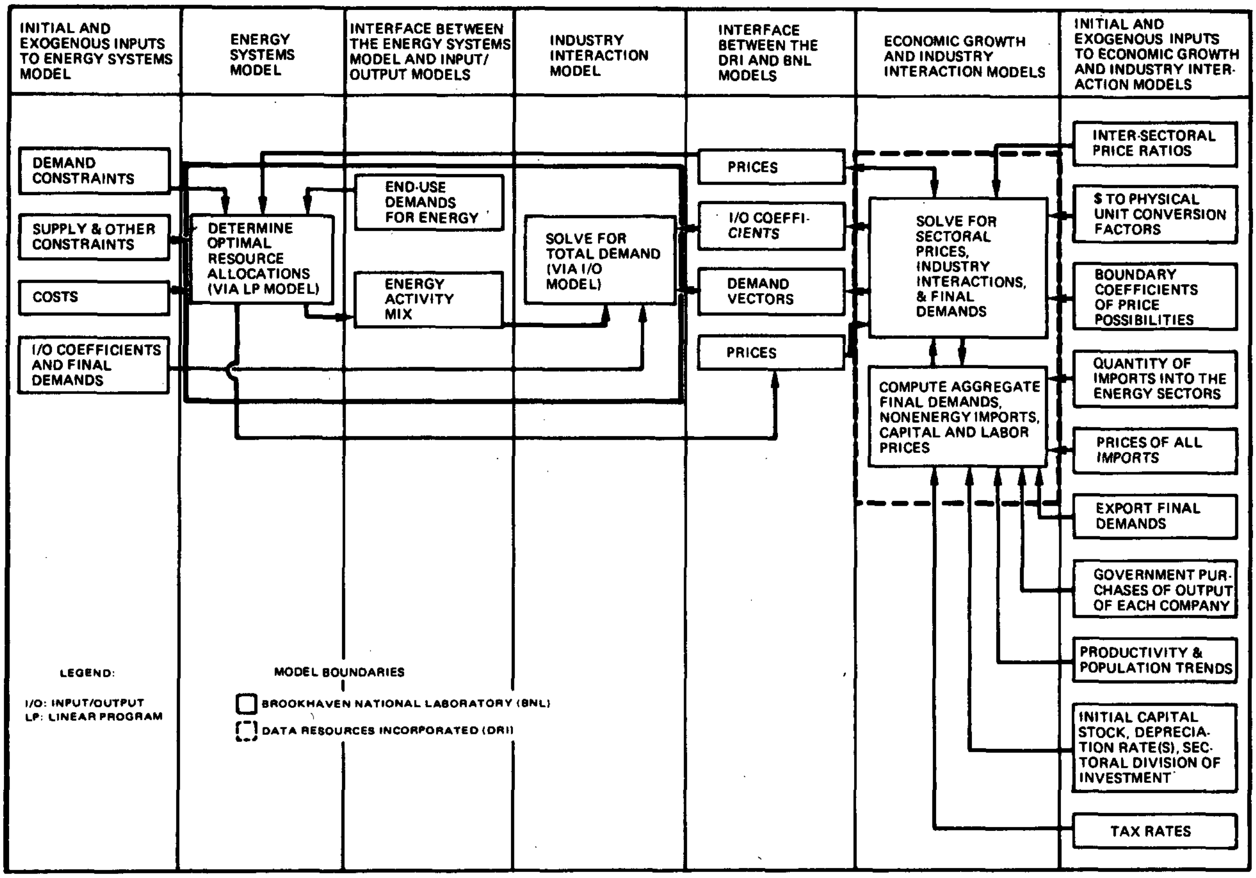


Figure VI–1 Integration of Economic Growth, Industry Interaction and Energy Systems Models

duce and distribute energy in various forms or to reduce energy consumption in a particular demand process. It is the difference between energy output and the sum of direct and indirect energy inputs. Net energy is a subset of the broader area of energy analysis which seeks to identify and interpret the energy flows in society—both direct and indirect—which are required for the production and distribution of various goods and services. Net energy analysis is an aid to program planning, as it supplements existing economic and technical analysis and provides additional information for evaluating technical programs and project priorities.

Net energy analysis of individual technology options is important for several reasons:

- To determine how much energy must be invested to develop, construct, and operate new technologies
- To supplement economic studies aimed at evaluating the energy resource base and analyzing the cost of new technologies
- To provide a better understanding of the relationships of energy-producing sectors of the economy to each other, to other economic sectors, and to the environment
- To identify significant indirect economic benefits from careful energy management, such as preservation of the environment and conservation of energy resources for future generations.

Net energy analysis is still in an early stage of development and lacks a well-established set of rules and conventions. Substantive questions arise as to:

- Which energy expenditures or resource commitments should be included in the analysis, and what system of measurement should be used
- How energy of different forms (and with different economic values) or energy of like form expended at different times should be aggregated
- Whether a single quantitative value (and if so, which one) can adequately express the significant results of the analysis.

Even if there were no uncertainty in the magnitudes of the various energy inputs, very large apparent discrepancies in reported total energy inputs per unit of net output would still result from different responses to the above questions. These questions can be answered only after additional studies in net energy analysis have been conducted.

Recognizing these difficulties, ERDA used two studies* to prepare conclusions on the net energy of seven basic technologies for producing electricity and nine technologies for producing non-electrical energy. Based on the results to date, the conclusions are as follows:

- **With the exception of very low-grade energy resources, no technologies appear to be "losers" from a net energy standpoint.** These low-grade deposits have not been included in the assessment of the resource base presented earlier.
- **Most technologies return from 4 to 10 times the external energy (i.e., the direct plus indirect energy inputs) expended for energy production.**** That is, the external energy inputs amount to 10-25 percent of the energy output. However, for some conventional fuel supply systems the external energy required is less than 5 percent, while for combinations of processes (e.g., oil from shale used to produce electricity) the requirement can be 40 percent or higher.
- **Nuclear electric power returns about 4 times the external energy required.** A detailed study of the nuclear option is summarized in Appendix B.
- **Net energy analysis is a supplement to, not a replacement for, other more widely used tools of analysis.** Considering the current state-of-the-art, ranking of technologies on the basis of net energy calculations is not as instructive as performing the analysis on specific technologies. The use of questionable assumptions and the lack of comprehensive data preclude extensive reliance on the comparison of results.

Other major technologies will be analyzed and reported on during the year. In addition, future efforts will consider energy demand options and complete supply-to-demand pathways, including the transformation process efficiencies at each step along the pathways.

Foreign Energy Consumption Patterns

Guidance for domestic energy policy will also come from experiences of other nations. Most instructive will be those countries which have achieved a high standard of living with lower rates of per capita energy consumption than those in the U.S. Most notably, several European countries (e.g., Sweden, Denmark, Switzerland, West Germany) have these characteristics.

Studies on foreign energy use and economic growth are needed to:

- Evaluate the level and mix of energy consumption within different sectors and gain understanding of the basic relationship between foreign energy consumption and economic growth
- Identify opportunities for conservation which are applicable to the U.S., and evaluate the extent to which life style changes may be required to achieve lower per capita energy consumption rates
- Form a basis for determining both efficient and wasteful energy consumption practices in the U.S.

Sweden was selected for the first study*** because it has a similar economic performance to the U.S., as measured by per capita gross national product (GNP) and per capita income, and a significantly lower per capita energy consumption rate.

The results of this study plus research by others indicate that major structural changes and efficiency improvements would be required to promote a significant transfer of Swedish energy consumption patterns to the U.S. The major differences are in:

- Makeup of the Economy and Industrial Efficiency: Sweden imports a significant quantity of energy-intensive products (e.g., refined petroleum and agricultural goods), which the U.S. produces internally. The aluminum and petrochemical industries, two important energy-intensive U.S. industries, constitute a smaller proportion of the Swedish industrial mix. On the other hand, Sweden produces significantly higher quantities of paper and pulp than the U.S. and exports large quantities of metal, machinery and transportation equipment. In addition, the energy efficiency of many industrial processes appears to be higher in Sweden than in the U.S.
- Transportation Efficiency: The Swedish automobile fleet, for example, averages over 60 percent better fuel mileage than the U.S. counterpart. Similarly, the Swedish people make greater use of mass transportation.
- Housing Patterns and Efficiency: Swedish homes are much better insulated than in the U.S., resulting in greater efficiency of energy use. Also, little or no air conditioning is required in Sweden. Moreover, one out of five houses in Sweden is heated by hot water distributed from fossil electric power plants; in the U.S., this heat is discharged into the environment and lost.
- Geography and Demography: Urban density is appreciably higher in Sweden and production centers are closer to markets.

* Two studies have dealt with a wide range of energy technologies: "Transition," sponsored by the State of Oregon, Office of Energy Research and Planning, Office of the Governor, 1975; and "A Study to Develop Energy Estimates of Merit for Selected Fuel Technologies," Development Sciences, Inc., September 1975. Originally sponsored by the Department of the Interior, this latter study was subsequently included in ERDA's program. Several other studies are referenced in the Bibliography.

** See Appendix B for a further discussion of the terms used in net energy analysis.

*** A. Doernberg, "Comparative Analysis of Energy Use in Sweden and the United States," Brookhaven National Laboratory, September 1975.

Some changes are under way in the U.S. that promise improvements in per capita energy consumption along the lines suggested by the Swedish experience. For example, efficiency improvements in the U.S. transportation fleet will be forthcoming as a result of the recently signed Energy Policy and Conservation Act. Specifically, auto manufacturers are required to bring their fleet average up to 20 miles per gallon (mpg) by 1980 and 27.5 mpg by 1985. For comparison, the U.S. average of all autos was 13.5 mpg in 1972 while the Swedish average was in the low 20's. In addition to auto efficiency, the Act also provides impetus to future improvements in industrial energy efficiency.

On the other side, however, it is possible that energy consumption patterns in Sweden have not stabilized. The amount of energy used to support and produce economic activity, as measured by the energy/GNP ratio, has increased in Sweden during the last ten years. The U.S., which uses more energy per unit of GNP, has experienced a flatter trend over the same period. Thus, over time and under favorable supply conditions, Swedish patterns in energy use may approach present U.S. patterns. The current emphasis of Swedish energy policy, however, appears to be toward even greater efficiency improvements and slower growth rates in the future. In addition, the gap between the American and the Swedish standard of living may be different than indicated by the per capita GNP figures, due to the interpretation given GNP as a measure of economic wealth.

Another study* prepared for FEA reinforces the conclusion that structural changes and efficiency improvements in the U.S. economy would be required to obtain the lower energy consumption patterns achieved by some foreign countries. Differences in per capita energy consumption between West Germany and the U.S. are greatest in the household and commercial sector, and the transportation sector. For example, significantly smaller houses, negligible use of air conditioning, point-of-use hot water heating, and other differences result in lower per capita consumption in the West Germany household sector (i.e., about 48 percent of the U.S. level in 1972).

In the automotive sector, per capita energy use per passenger-mile and per capita miles driven are both around 50 percent of the U.S. levels. These factors account for a large portion of the lower per capita consumption in the transportation sector (i.e., about 27 percent of the U.S. level in 1972).

Lower energy consumption in the West Germany and Sweden transportation sectors must, to some extent, reflect the high retail price of fuel. In West Germany, for example, the average retail price of gasoline was more than twice that in the U.S. in 1973.

Additional studies of other countries are planned for the future. These efforts will be undertaken in cooperation with the selected foreign countries and with the International Energy Agency.

Energy Market Analysis

Analysis of the marketplace is necessary to understand how new technologies can have a reasonable chance of competing with other, more established technologies. Successful competition has two main components that are investigated by market analysis: first, the economics associated with energy recovery, transformation, and distribution; and, second, the timing of market introduction and the degree of market diffusion. These studies are patterned after private sector practices, supplemented when necessary by other supporting national and regional analyses.

The Electric Utility Study, started in the summer of 1975 by ERDA, is an example of a specific market study currently under way. This study is the first of several that seek to assess the Plan's overall RD&D objectives, goals, and program priorities from the viewpoint of the industry most directly affected by implementation of new energy technology.

A four-step approach is used in the utility study. First, a range of electric growth futures is established on a regional basis. Provision is made for both high and low total growth rates in electric energy demand. Second, the technical options available to utilities are documented, along with estimates of time schedules and economics. Third, the likely market penetration and resulting benefits of each technology are assessed through an analysis of economic attractiveness from the industry's perspective. This assessment may be repeated for several energy policy scenarios. Fourth, the applicable government RD&D programs are evaluated in light of the market study results to determine whether the program priorities and goals are appropriate.

Tentative findings in the first stage of the study—based primarily on comparisons of technology economics and environmental characteristics—suggest that:

- Conventional coal plants with scrubbers and light water reactors will continue to provide the bulk of base generated power for the rest of the century; gas turbines will provide some power during peak periods.
- The existing and newer technologies will have to compete against these technologies—although few can now be said to offer clear-cut economic advantages (even considering the large uncertainties in cost projections) over coal and nuclear alternatives.
- Three aspects of new technologies make them attractive to pursue: first, the potential for improved

* Richard L. Goen and Ronald K. White, "Comparison of Energy Consumption Between West Germany and the United States," Stanford Research Institute, June 1975.

economics—even small improvements in technology economics can make a large difference when viewed from a national perspective (in light of very large projected markets under all likely growth scenarios); second, the capability of new technologies to meet future, potentially more stringent environmental standards; and third, the ability of some new technologies to shift generation away from oil and gas.

- The RD&D on new technologies now being pursued by the Nation provides more competitors in each area than are likely to be developed by vendors or implemented by utilities.
- One objective of the study will be to lay out an RD&D strategy that provides sufficient technology alternatives in critical areas, but that minimizes investments beyond basic research stages in the less crucial areas. This strategy should provide sufficient alternatives to meet potential future constraints such as the possibility of a nuclear moratorium, major restrictions on western coal mining, or severe constrictions on current environmental standards. In so doing, the strategy should also provide for treating substanial cost uncertainties.

The report on the first stage—indicating preliminary conclusions—will be published in spring 1976; the final report a year later.

The results of the utility study are generally applicable to other energy technology areas as well. They serve to reinforce the commitment to assess all aspects of technology and the barriers to market penetration, as highlighted in this National Plan. In addition, while an adequate set of options must be available to meet unique market needs, priorities within program areas should be established, with emphasis on those options with the highest chance of achieving market success.

Energy, Economic, and Environmental Trade-Offs

The economic and environmental impacts associated with the national energy system and the interrelationships among economic and environmental factors need to be considered jointly. The addition of new energy and supporting systems will cause changes in these impacts, based largely on the mix of technologies that constitute the energy system in future years.

The purposes of the analysis of these trade-offs are to:

- Subject alternative energy scenarios, such as those contained in ERDA–48, to further testing and evaluation.
- Establish a frame of reference for understanding choices among environmental values, energy use, and economic growth subject to conditions of uncertainty.
- Provide information for public discussion on the relative magnitude and interdependence of the impacts associated with energy futures.
- Provide information to program managers and energy planners responsible for developing technological options to achieve energy goals. The emphasis here should be on providing information (such as a set of trade-off curves) that depicts the available options; the sensitivity of options to changes in technology mix, demand levels, and other variables; and the extent to which RD&D can provide solutions to energy, economic, and environmental issues.

The trade-off analysis undertaken by ERDA so far incorporates five factors associated with energy activity: total annual energy costs, including amortized investment, fuel, and operating costs; resources consumed; domestic and imported crude oil requirements; environmental effects; and capital requirements. The analysis is based on various combinations of technologies which could be utilized to satisfy the end-use demands specified in the ERDA-48 scenarios for 2000.

Defining appropriate quantitative measures for the four non-environmental factors above is fairly straightforward even though there are uncertainties in the values. Developing information needed to measure environmental impact is significantly more difficult for several reasons: the multiple types and quantities of environmental damage resulting from particular technologies, the spatial patterns of releases in conjunction with variable natural dilution effects, and the uncertainty concerning the level and costs of specific environmental residuals.

Environmental information with the required degree of precision is not currently available. In addition, damage functions defining the costs to the public of various levels of the pollutants resulting from the full range of different technologies are not available. For this reason, the analysis works with total costs of delivered energy only, rather than with total public cost (with the latter incorporating the external effects of different levels of emissions, as discussed in Chapter II). The results of the trade-off analysis presented here highlight the energy and economic factors.

The first step in the analysis was to determine the lowest possible value for each of the factors given various technology options. In each case, that combination of energy supplies was chosen (subject to the implementation constraints associated with an assumed scenario) which minimized each factor in succession. This analysis is based on meeting a fixed set of end-use demands through variations in fuel substitutions from a given set of energy technologies.

Table VI-4 shows the results of this minimization step. The various technologies used to satisfy end-use demands produced significant variations in the

Table VI–4 Some Preliminary Trade-Off Analysis Results—Effect of Independently Minimizing Each Factor

	Value of All Factors When Each Factor Minimized				
Factor Unit	Annual Cost	Capital	Imported Oil	Domestic Plus Imported Oil	Resources
Total Annual Cost, $\$ \times 10^9$	<u>296</u>	388	304	304	340
Capital Requirements, $\$ \times 10^9$	1343	<u>735</u>	1197	1479	1364
Imported Oil, Btu $\times 10^{15}$	0	50	0	0	23
Domestic Plus Imported Oil, Btu $\times 10^{15}$	20	70	20	<u>16</u>	43
Resources Used, Btu $\times 10^{15}$	215	131	123	124	<u>114</u>

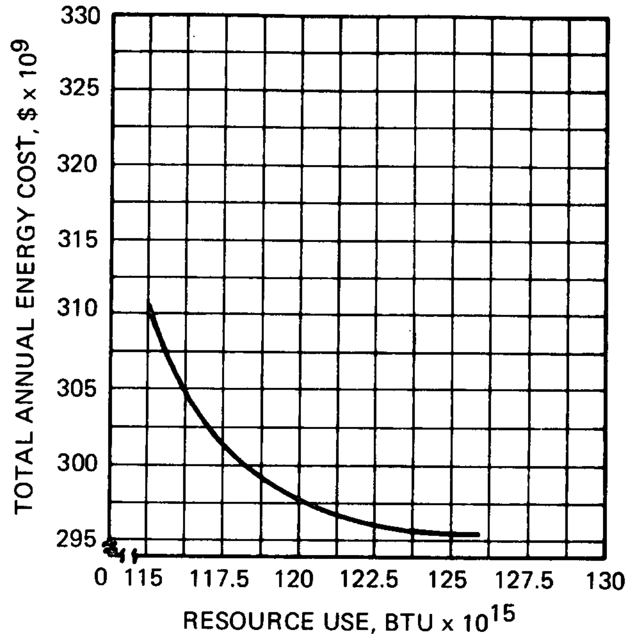
Basis for Calculations: ERDA–48 Scenarios for the year 2000. Underlined values are the absolute minimum values for each factor.

values of some factors and fewer variations in other factors. For example, annual cost has a maximum value of 30 percent above its minimum value while capital requirements exhibit a 100 percent variation and resources consumed only a 15 percent variation.

In the trade-off analysis cases completed so far, total annual costs were minimized subject to constraints on other factors. This process can best be illustrated by considering, for example, the trade-off between the desire to achieve minimum annual costs subject to limits on the amount of resources used. This relationship is illustrated in Figure VI-2. The trade-off presented is typical of those completed to date, with each relationship containing a range of values where small reductions in the constraint cause slight cost increases and further tightening of the constraint causes a more significant cost rise.

The trade-off curves plus the underlying analysis point up several important conclusions:

- **In carrying out its overall mission, ERDA views its job as one of trying to shift the trade-off curve to the left through technology advances.** One example is the achievement of a more desirable (lower) level of resource consumption for lower cost without sacrificing the high standard of living.
- **The interrelationships among environmental quality, energy costs, and public costs need to be examined in much greater detail.** There are many subjective views on what constitutes an adequate level of environmental quality, what additional environmental improvements should be sought, and what the total public cost will be at various levels of energy production and environmental protection. Much more information needs to be developed on environmental/energy/economic interactions, and trade-off curves may be a useful approach for this purpose.



BASIS: ERDA-48 SCENARIOS. THE SHAPE OF THE CURVE REFLECTS THE SUBSTITUTION OF OFF-PEAK ELECTRICITY FOR OIL IN VARIOUS END-USE SECTORS. ELECTRICITY GENERATED OFF-PEAK IS LESS COSTLY THAN OIL BUT CAUSES HIGHER TOTAL RESOURCE CONSUMPTION.

Figure VI–2 Relationship Between Resource Use and Total Annual Cost

Trade-off studies with a more narrow focus are equally important in the context of individual technology programs. Within each program, numerous technical options influence the amount of energy produced or conserved, the associated costs, and the amount of environmental impact. Trade-off studies will be useful in narrowing the list of options to be pursued in the energy RD&D program.

Capital, Manpower, and Industrial Constraints to Energy Growth

The most critical impact of technology introduction on energy and supporting industries will be on certain economic resources (e.g., capital, labor, material, and equipment) associated with facility construction and operation. Constraint analysis addresses the physical constraints associated with these resources and how these resources might influence and be influenced by energy growth and the introduction of new technology. Both technical and nontechnical barriers to technology introduction are important in this analysis. A constraint analysis is being conducted to:

- Identify future changes in economic resource consumption patterns likely to arise from changes in the energy system, especially those likely to require changes in industry infrastructure
- Identify potentially severe disruptions, such as markedly increased needs for skilled craftsmen, to sectors of the economic system
- Provide for a systematic way of analyzing resource requirements (e.g., steel, labor, and money) from energy and non-energy sectors of the economy.

The current effort examines the capital, manpower, material, equipment, and construction requirements associated with the alternate supply and demand policies discussed previously in the energy/economic growth section. The required resource levels were obtained from a model developed by the Bechtel Corporation.*

The constraint analysis effort is just beginning. Based on the initial calculations, it appears that:

- The ratio of energy capital investment to total business investment (historically between 25 and 30 percent) would remain relatively constant over a broad range of near-term (to 1985) energy futures. In one scenario examined, heavy investments in synthetic fuel facilities were offset by declining transportation investments (e.g., tankers) for imported oil and gas.
- A tight labor market will continue for certain construction trades—namely, pipefitters, welders, boilermakers, and electricians. However, overall manpower demands by energy industries should not have severe effects on the total manpower market.
- The current ability of industry to modify existing manufacturing and other production facilities to reflect the requirements associated with new energy technologies is not clear and must be more thoroughly investigated. For example, new technology places large demands on special products such as heavy steel plates, but this appears to require relatively small additional capital investments in the energy sector.

The results of this constraint analysis will highlight areas where more detailed and narrowly focused studies are appropriate; for example, studies that address specific industries, products, or skills. Planned ERDA efforts include the development of an overall manpower data base for energy-related activities and sources, and the analysis of manpower requirements for future energy technologies. These efforts will be coordinated with other Federal agencies having ongoing programs in manpower-related areas.

Need for Continuing Studies

The results of all of these continuing studies and analyses simultaneously provide a perspective for planning, an opportunity to test or to make concrete some of the underlying assumptions of the Plan, and a means for extending the understanding of the attributes of different approaches and outcomes through time to deal with the energy problem. Missing information and uncertainties highlight the need to acquire the specific data or to define the specific relationships. Studies throughout the Federal structure, in universities, in the private sector, and in other countries all contribute to this process. As with all analyses, these approaches need external discussion and the discipline of the peer review process. The desired end results are greater knowledge and a guide to effective future action.

* M. Carasso, J. M. Gallagher, K. J. Sharma, J. R. Gayle, R. Barany, "The Energy Supply Planning Model," Bechtel Corporation, San Francisco, California, August 1975, Volumes I and II.

Chapter VII—Future Evolution of the Plan

The National Plan for Energy RD&D is designed to provide the framework for carrying out governmental policy in the development of conservation and energy supply technologies. ERDA-48 set forth the fundamentals of the Plan, including a diagnosis of the national energy problem, the five major national goals related to energy, and the energy technology goals. Further, the Plan presented a strategy for achieving these goals, along with broad program objectives. Finally, the Plan included the judgmental priorities for developing the major sources of energy.

In ERDA-76-1, the Plan has been expanded in scope and in depth of coverage. The basic goals and strategy have been refined somewhat, but remain essentially intact. ERDA-76-1 emphasizes the operational aspects of implementing the Plan, particularly in the areas of market penetration of new technologies, Federal interaction with other institutions of the national economy, and an overall approach to detailed analyses and planning of Federal RD&D programs.

But no one document can cover all the areas that make up the complex energy RD&D spectrum; not even in the aggregate can the two documents (ERDA-48 and ERDA-76-1) claim completeness. Thus, future planning efforts will build on these efforts, adding new information as it becomes available and gradually incorporating more of the elements that must be considered in creating a unified Plan. Although it is too early to state with certainty what will be included in future reports, three activities are essential to ERDA's own planning and will likely be included in the next Plan update: (1) developing energy RD&D costs and benefits; (2) establishing priorities for component programs; and (3) analyzing energy RD&D activities in the private sector.

Developing Energy RD&D Costs and Benefits

The major energy technologies have not been subjected to a detailed review of costs and benefits, although cost-benefit studies of some options have been done. Such assessments are complicated by the fact that alternative technologies cannot easily be compared with each other, since each tends to interact simultaneously with many others. The ERDA-48 scenarios exemplify this problem. However, tools for overcoming these complexities—tools such as venture analysis, economic impact analysis trade-off studies, net energy analysis, and constraint studies—are becoming available. **It is ERDA's goal to apply these tools during 1976 to achieve a more systematic approach to quantification of the costs and benefits of selected energy technologies, and to report the results of this work in the next Plan.**

Establishing Priorities for Component Programs

The Program Planning, Budgeting, and Review (PPBR) system discussed in Chapter V is being designed to increase the relevance and effectiveness of ERDA's programs. One of the key results of this process is the ability to establish more definitive priorities for energy system technology options. Currently, only the major categories of energy conservation and supply technologies have been ranked. Future efforts will focus on ranking, in order of priority, component programs aimed at the same or similar markets. For example, the electric utility study currently in progress and summarized in Chapter VI is aimed at ranking technologies that compete for the electric utility market; future analysis will analyze other market sectors. For example, there are a number of technological approaches to producing low-Btu gas from coal; these and other technologies need to be evaluated further to identify their relative merits for the gas utility sector. However, because of the multiple uncertainties existing in many of the program areas, a comprehensive ranking cannot be achieved within the next year. ERDA is initiating the task and will pursue the assessments as rapidly as possible. **It is ERDA's goal in 1976 to take the first step—more definitive analysis of component programs in a number of key areas aimed at the same or similar markets.**

The results of this analysis also will enable ERDA to specify more accurately the objectives of each component program and of the overall technologies. These refined objectives will be more specific with respect to achieving control of environmental releases, costs of energy production, and improving reliability and efficiency. These assessments will apply to all energy RD&D projects, whether they are being developed primarily in the private sector, in ERDA, or in other government agencies; consequently, they should help in deciding the extent and timing of private and/or public assistance necessary for the development of energy technologies. Nevertheless, the market will ultimately determine the attractiveness of implementing any one technology.

Analyzing Energy RD&D Activities in the Private Sector

Private sector RD&D activities are critical to the development and the ultimate market penetration of energy technologies. However, because government may need to reinforce and assist these private activities, those who design government policies and programs must understand where the private sector is using its own RD&D funds.

This objective necessitates an ongoing analysis of private sector energy RD&D activities. The results of this analysis, coupled with federally derived information, will be a factor in planning the optimal allocation of resources required to finance the projects and programs that will meet national energy RD&D goals and objectives.

Present data collection and analysis methods need to be supplemented to provide more meaningful analysis of the private sector RD&D effort in energy. An appropriate framework will be designed for collecting additional data. Among the important elements of the framework are the problems the effort addresses; the goals of the research effort; its relationship to the broader plan and to other research efforts under way; broad project characteristics and descriptions; funding and cost estimates; time period over which success is sought; and plans for future efforts.

ERDA will initiate a dialogue with and solicit the voluntary cooperation of industry and industrial organizations to develop factual information that will provide ERDA with needed insights, yet protect sensitive or proprietary information of private companies. ERDA welcomes private sector views on appropriate mechanisms for collecting this information.

It is ERDA's goal to initiate in 1976 a more intensive effort to acquire knowledge of private sector RD&D efforts in energy; to apply the knowledge to Federal RD&D planning; and to provide an interim report in the Plan issued next year.

Appendix A
Perspective on World Resources

Following the events of October 1973, the world energy crisis was viewed as a problem of immediate shortage. Attention soon shifted, however, first to the issues of pricing and other terms of availability, and then to the broader issues of international economic relations and world monetary problems. Although these issues have not yet been resolved, energy problems are beginning to be viewed from a longer term perspective. Triggered by less specific events, the oil crisis is also being interpreted as symptomatic of changes long in the making. Attention is finally being redirected to the more fundamental issues posed by a growing world population demanding ever-increasing amounts of energy.

One element of the energy problem is the geographical location of energy resources and their availability for development and worldwide distribution. The importance of regional availability to the consuming countries was made manifest by the assertion of control over energy operations by producing and exporting countries. Table A-1 summarizes the present situation with respect to world

Table A–1 Estimated Recoverable Reserves of Coal, Petroleum,* and Natural Gas

Region	Coal	Percent of Total Coal	Petroleum	(In Quads) Natural Gas	Total Oil & Gas	Percent of Total Oil & Gas	Total Coal, Oil & Gas	Percent of Total Coal, Oil & Gas
United States	4,900	34.3%	246	244	490	7.6%	5,390	25.9%
Other North America	142	1.0%	71	80	151	2.3%	293	1.4%
South America	50	0.3%	157	65	222	3.4%	272	1.3%
Subtotal, Western Hemisphere	5,092	35.6%	474	389	863	13.3%	5,955	28.6%
Middle East	35	0.2%	2,343	700	3,043	46.8%	3,078	14.8%
North Africa	neg.	0.0%	227	260	487	7.5%	487	2.4%
Middle Africa	69	0.5%	169	65	234	3.6%	303	1.5%
South Africa	292	2.0%	neg.	neg.	neg.	0.0%	292	1.4%
Western Europe	1,374	9.6%	150	210	360	5.5%	1,734	8.3%
Eastern Europe	1,073	7.5%	17	20	37	0.6%	1,110	5.3%
U.S.S.R.	3,325	23.3%	480	580	1,060	16.3%	4,385	21.1%
China	2,222	15.6%	145	25	170	2.6%	2,392	11.5%
South & East Asia	351	2.5%	110	75	185	2.9%	536	2.6%
Oceania	460	3.2%	13	45	58	0.9%	518	2.5%
Subtotal, Eastern Hemisphere	9,201	64.4%	3,654	1,980	5,634	86.7%	14,835	71.4%
World Total	14,293	100.0%	4,128	2,369	6,497	100.0%	20,790	100.0%
Percentage of Total	68.7%		19.9%	11.4%			100.0%	

* Includes natural gas liquids when data were available.

Tabular data derived from the following sources:

(1) All data for the United States are from the U.S. Geological Survey.
(2) World Energy Conference, 1974.
(3) "Changes Restructuring World Oil," **The Oil and Gas Journal,** December 30, 1974.
(4) "Productive Capacity Grows as World Demand Falters," **World Oil,** August 15, 1975.

Note: Data generally include measured and indicated reserves as of January 1, 1975, although in some regions data are not sufficiently well defined to assure the intended comparability. Coal data are reported in energy units. Where other reserve data were not reported in energy units, conversion from physical units was based on standard conversion factors per barrel of oil or cubic foot of gas.

recoverable energy reserves of conventional fossil fuels by type and by geographical location. These data refer to known or already discovered quantities that can be economically recovered with existing technology.

The outstanding feature of world fossil fuel reserves is their pattern of geographical concentration. For example, petroleum and natural gas reserves are largely concentrated in the Eastern Hemisphere, with over half of the world's total in the Middle East and North Africa, and most of the remainder in the Soviet Union. The U.S. has the next largest reserves of oil and gas. However, despite the large Canadian and Venezuelan producing industries, the oil and gas reserves of the Western Hemisphere represent only 13 percent of the world total.

Energy Consumption Patterns

The most important aspects of the world energy situation are (1) the dependence of most of the world on petroleum, and (2) the concentration of both oil and other fossil fuel resources in relatively few countries. Developed countries, other than the centrally planned (Communist) economies, rely on oil and gas for three-fourths of their needs. The same is true of the less developed countries, but with their limited access to natural gas, oil alone accounts for over 60 percent of their total commercial energy supplies.

Coal is still a principal energy source in the centrally planned economies, where it supplies about one-half of the total energy consumed. At the same time, the use of oil and gas has been increasing rapidly, rising from about one-fourth of total energy use in Communist countries in the early 1960's to almost one-half of the total currently.

In spite of rising costs, the worldwide trend toward greater dependence on oil and gas is likely to continue unless affirmative action is taken to increase the use of coal and development of alternative sources. The prospects for coal are not encouraging in many countries since the incentives and advantages continue to favor rapid development of oil and gas resources. Many other countries without coal or other fuel resources have no tenable alternative to imported oil due to their limited capability to develop other sources or the new technologies needed to use renewable resources such as solar energy.

Problems of Trade and Distribution

World consumption patterns reflect the geographical location of energy resources and the system of trade or distribution that has served to link consuming and producing areas. The highly integrated and efficient global systems of transport, processing, and distribution of petroleum that developed after World War II were, in many ways, more remarkable than the development and expansion of the oil-producing operations. If this distribution system were to break down or become a less effective means of linking producers and consumers, global problems of balancing supply and demand would appear as segmented regional problems, with persistent shortages in some areas and surpluses in other—especially producing—areas.

This was apparent in the situation in 1975, when widespread oil surpluses were a result of higher costs to countries with payment difficulties and the world-wide slowdown in economic growth. The rapid introduction of supplies from new producing areas, such as the Alaskan North Slope and the British and Norwegian sectors of the North Sea—each scheduled to deliver about 2 million barrels daily by 1980—could reinforce and extend the surplus situation. While such a surplus situation is likely to be of limited duration, it may lead to improper interpretations of basic energy supply prospects for the longer term. All of the underlying difficulties and elements for future crises will remain unless there are continuing efforts to reduce the heavy dependence upon relatively scarce world petroleum resources.

As Dr. V. E. McKelvey, Director of the U.S. Geological Survey, recently pointed out, one of the wide-ranging effects of the oil crisis:

> . . . has been to convey an appreciation of the fact that a steadily expanding petroleum supply is not something to be taken for granted. . . . Whatever else it may have done, the Organization of Petroleum Exporting Countries' action served as a timely reminder that even the fabulously productive fields of the Middle East are exhaustible, and that plans must be made for an orderly transition to other sources of energy as the inevitable process of depletion makes oil progressively more scarce and costly. The timing and course of the transition depend heavily upon the relative availability of the various energy sources, including petroleum. (McKelvey, 1975, p. 27)

Obligations of the Industrial Countries

While the majority of the less developed countries of the world must import the bulk of their energy (mainly oil), the industrialized countries of Western Europe, the U.S., and Japan account for about 75 percent of the total intercontinental trade (imports) of petroleum. If oil and natural gas reserves are to be extended through either conservation in use or the development of alternative sources, this extension must be effected in the highly developed industrialized countries. In the U.S. and to a lesser extent in Europe, coal is available as an alternative fuel. Neither Japan nor most of the less industrialized world has this alternative.

The prospects for imported coal becoming a practical alternative to oil seem very unlikely for countries lacking their own domestic coal sources. Aside from the problems inherent in the geographical location of the surplus reserves, extraordinary difficulties are involved in moving and using coal in most of the resource-deficient countries. While Japan imports a sizable quantity of coal, it is mainly for special use in the steel industry and not as a basic general-use fuel.

Most energy-deficient countries have found no readily available alternative to continued imports of oil, and no alternative is likely unless initiatives are taken through vigorous R&D programs in the most technologically advanced countries. Successful development of alternatives could ease the world energy situation in several ways:

- First, if conservation and new technologies were vigorously applied in the industrial countries, the total world demand on the reserves of the Middle East and other export areas could be decreased significantly.
- Second, technologies developed in the industrial countries, especially those using renewable resources such as solar energy, wind, and water power, might be adapted for use elsewhere.
- Third, some of the lower quality energy sources still undeveloped, such as oil shale and tar sands, might be exploited with the assistance of those countries that are technological leaders.
- Finally, improved methods of exploration and development of conventional fossil fuel resources could expand the world's reserves and improve distribution.

It is possible that extensive resources of the conventional fuels can be found outside of the established producing areas. Estimates of undiscovered recoverable resources indicate that the ultimate production of oil, gas, and coal will be far beyond that implied in the estimates of reserves in Table A-1.

Estimates of World Resources

Reserves are essentially the proven inventory that producers must have on hand to continue operations. Therefore, the most surprising characteristic of existing world reserves is not how small but how large they are. Based on world rates of production in 1974, the total reserves of petroleum would last for another 35 years and the world coal reserves shown in Table A-1 would last for about 175 years. Yet, these global averages are deceiving because not all producers have equal call on the existing stock, and, further, demand can be expected to increase in the future.

It is generally expected, however, that additional resources will be located and moved into the reserve category in the established producing areas. For example, in the Middle East where the potential producing areas are generally well defined, some estimates suggest that the presently published petroleum reserves of some 400 billion barrels may ultimately be at least twice as large ("Middle East Oil Reserves," 1975, pp. 369–371). The U.S. Geological Survey estimates that in addition to the 45 billion barrels of U.S. proven reserves of liquid fuels there may be some 30 billion barrels of inferred reserves and another 60 to 150 billion barrels of undiscovered resources. Similarly, estimates of the undiscovered South American potential are about double the current reserves.

There is great current interest in the growing potential of offshore production of oil and gas. The U.S. Geological Survey estimates that U.S. offshore recoverable oil resources yet to be discovered may range from 10 to 50 billion barrels.* In the North Sea, where published oil reserves are generally shown to be 20 to 25 billion barrels, ultimate recoverable resources are being placed at 45 to 78 billion barrels (Turner, 1975, p. 158). Estimates of ultimate recoverable oil resources for the Canadian offshore, including the Arctic, are many times their current reserve estimate. There is also considerable interest in developing the offshore resources in other parts of the world.

Total resources of coal are much more easily authenticated than oil or gas resources. The total world coal resources have been estimated at more than seven times the world reserves. Table A-2 summarizes some of the available resource estimates and compares them to reserve estimates. In a comprehensive survey of world energy resources (World Energy Conference, 1974), world coal resources were estimated at 12 trillion short tons, perhaps one-half of which would be recoverable. Others (Averitt, 1975) have indicated that the world total, including "hypothetical resources," could exceed 16 trillion tons, with some 4 trillion tons located in the U.S. Coal resources occur mainly in areas above 30 degrees N. latitude, with more than one-half of the total in the Soviet Union and China. North America, Europe, and Australia account for most of the remainder.

As Table A-2 indicates, total resources of each mineral fuel are estimated to be a multiple of (usually several times) the volume of reserves. This is to be expected since resource estimates include extrapolations of amounts in existing proven areas and speculations about other potential discoveries. Unless properly interpreted, however, data on resource estimates can be misleading. For example, not only is the existence of these resources uncertain but, in many cases, great advances in technologies are required before the resources can be located, devel-

* Included in the 60 to 150 billion barrels of undiscovered recoverable resources noted above.

oped, and used in environmentally acceptable ways. It is vitally important that these technologies be developed in a timely fashion and that science and technology be committed to the more challenging tasks of finding ways for efficient and economic use of renewable and essentially inexhaustible resources.

Table A–2 World Reserves and Resources of Mineral Fuels

Resource	Units*	Reserves	Total Recoverable Resources**	Sources
Coal	10^9 tons	665	6,000–8,000	(1)(2)
Crude Oil	10^9 bbls.	700	1,300–1,880	(3)(4)(5)(6)
Natural Gas	10^{12} cu. ft.	2,300	3,000–6,000	(3)(4)(8)
Oil Shale	10^9 bbls.	500	1,125–16,000	(1)(7)
Bitumen Rocks	10^9 bbls.	350	1,000–2,500	(1)(8)
Uranium (U_3O_8)	10^3 tons	3,500	5,000–6,500	(1)(9)
Thorium (ThO_2)	10^3 tons	400	2,500–3,450	(1)(9)

Note: Comparisons between and among the resource categories on a common-unit basis such as quads are not advisable because of the widely varying methods of estimating and reporting data and the fundamental differences as to the technical feasibility of exploiting and using the several mineral fuels.

* Conventional U.S. units
** Including reserves
(1) World Energy Conference, **Survey of World Energy Resources,** 1974.
(2) Averitt, U.S.G.S. Bulletin 1412.
(3) "Changes Restructuring World Oil," **The Oil and Gas Journal,** December 30, 1974.
(4) "Productive Capacity Grows as World Demand Falters," **World Oil,** August 15, 1975.
(5) Lawrence and Farrar, 1975, p. 63.
(6) Linden, Institute of Gas Technology, 1975.
(7) Culbertson and Pitman, U.S.G.S. Professional Paper 820.
(8) McKelvey, "World Energy Reserves and Resources," **Public Utility Fortnightly,** September 25, 1975.
(9) Energy Research and Development Administration estimates.

Appendix B
Net Energy Analysis of Nuclear Power Production

The purpose of this appendix is to present the first of a series of net energy analyses on the major energy technologies being pursued by ERDA. Nuclear power has been the subject of much recent discussion and was chosen for the first study. The analysis addresses the amount of electricity generated by a nuclear plant relative to the amount of external energy required to construct, fuel, and operate the plant.

This appendix briefly discusses the underlying concepts of net energy analysis; presents the analysis of electrical power from a light water nuclear reactor; and reports the results of studies by the State of Oregon, the Center for Advanced Computation of the University of Illinois (Pilati and Richard), Development Sciences, Inc., and the Institute for Energy Analysis.*

The present analysis draws from these studies and arrives at the same general conclusion—that a nuclear power plant produces substantially more energy than is required to construct, fuel, and operate the plant. The major conclusions are:

- The direct and indirect external energy inputs are about 26 percent of the energy output. This value is within the range of values for electrical generating facilities fueled with conventional fossil fuels.
- Uranium enrichment, using the diffusion process, accounts for about 91 percent of all direct energy inputs and for 72 percent of all direct and indirect energy inputs. Use of the gas centrifuge process now being developed would significantly reduce the energy required for enrichment. The construction and operation of the power plant account for another 16 percent.
- The internal energy loss due to the thermodynamic efficiency of a nuclear plant is about 68 percent. This means that the nuclear fuel must generate 3,000 Btu of energy in order to produce 1,000 Btu of output as electricity.
- According to two 1975 studies (Development Sciences, Inc., and Oregon), 6,000 to 7,000 Btu of resource base must be available in order to have the 3,000 Btu energy input to the reactor. This additional resource base is necessary to allow for uranium not recovered during mining or lost during processing, and the fissionable uranium left in the tails during the enrichment process. However, all the 3,000 to 4,000 Btu of energy remaining are not irrevocably lost or consumed; much of the energy may be utilized in the future if the economics of processing these resources become attractive.

* See the bibliography for detailed references.

General Methodology

In net energy analysis, selection of the appropriate boundaries for the analysis is difficult.** A simplified boundary categorization cuts the issue into horizontal and vertical sets. The horizontal set encompasses the energy production (transformation) processes from resource extraction to point of distribution. The boundary of this set can be extended at the point of extraction to include the resource base that was not recovered during extraction. At the other end, the boundary can be extended to incorporate the local distribution of energy and the energy losses in the end-use devices.

The vertical set centers around the direct energy inputs, either electrical or thermal, externally *** re-

** In addition, the analysis may be either static or dynamic with respect to the time-phased aspects of the energy expenditures and outputs.

*** External energy is the energy required from sources **outside** the transformation process being investigated. For electric power plants (the final production transformation process in a sequence that starts with mining the fuel resource), the external energy required includes the energy used to build, equip, and operate the plant, but does not include the internal energy lost (as waste heat) in the conversion of thermal energy to electrical energy. That is, the energy content of the burned fuel is not counted as an external energy input. The energy content of the fuel is counted, however, in calculations on the amount of resource base required to provide a certain level of energy in the desired form (in the example here, electrical energy).

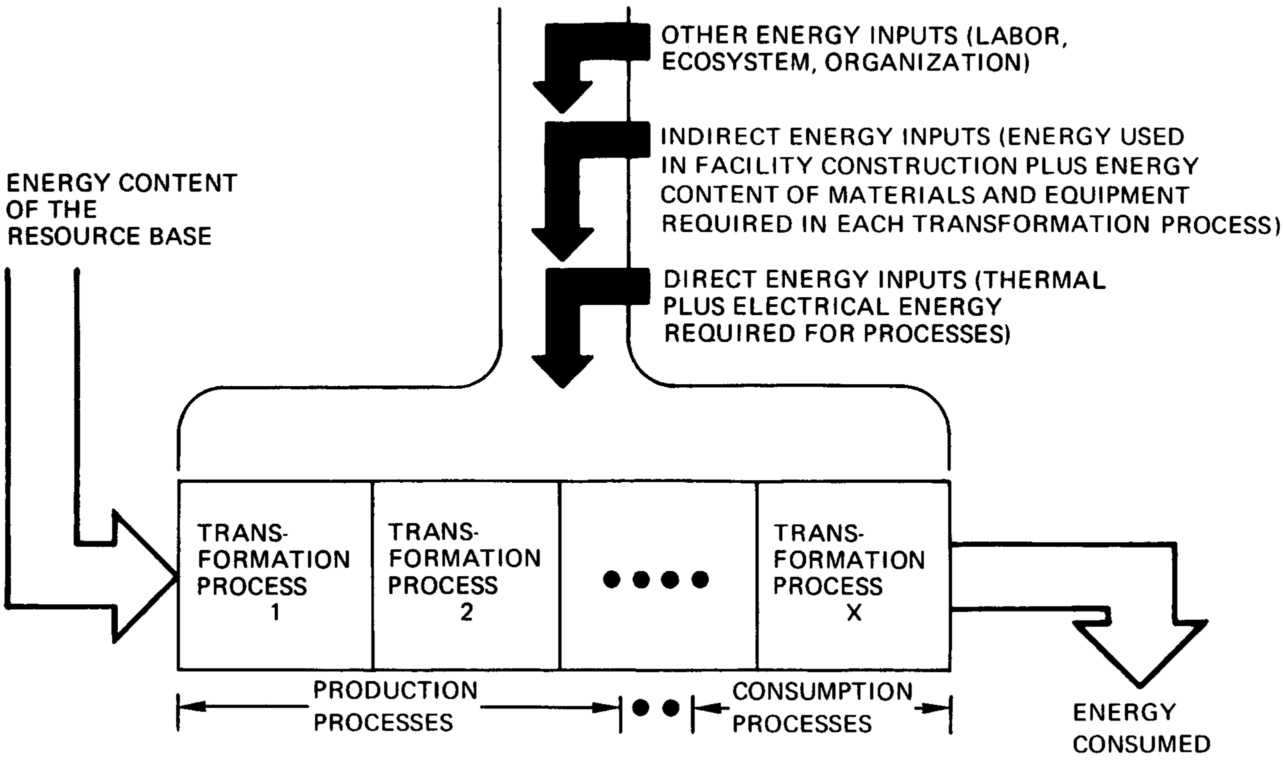


Figure B–1 Conceptual Boundaries for Net Energy Analysis

quired to execute a step in the horizontal set. The boundaries of the vertical set can be extended to include the indirect external energy required for facility construction and the energy required to produce materials directly employed in the processes. These items include the energy used in producing equipment and materials (e.g., steel, paper, sulfuric acid) that are then used to build and operate an energy producing plant, and the energy lost during process stages (e.g., scrap fuel, thermal conversion, transmission). The vertical boundary can also be extended to include the energy embodied in the labor, the ecosystem, and the organizational infrastructure that was necessary to support the energy production process at each stage. Figure B-1 shows the boundary possibilities.

Multiple definitions of energy systems boundaries, combined with legitimate differences in assumptions and concerns about the addition of different energy forms (with different preference values), cause net energy results to vary. Several studies have attempted to define a variety of ratios, net summations, or other measures that are closely related to a particular question about energy efficiency. However, too heavy reliance on a single number, or ratio, to define the net energy of a particular technology misses the most important point of net energy analysis—to provide information on technology options as a supplement to other important economic and technical data and analysis.

Specific Methodology for Nuclear Power

For the example case on nuclear power, the net energy calculations include the first-order effects of direct fuel inputs and the second-order effects of energy losses and energy inputs into equipment and materials. These are the external direct and indirect energy inputs. The direct effects are calculated through the use of process analysis, where the quantities of energy used for each activity in the production process are determined. In some instances, these figures have been determined using an engineering flow sheet of the process; in other cases, an estimate is obtained by measuring the expenditures for energy during a period of time and dividing by the average price for energy during the same time period.

The indirect energy requirements are computed through the use of a 357-sector Input-Output model* that relates each fuel-producing and fuel-consuming sector to each other one. The model can be manipulated mathematically to account for energy requirements from the many sectors that contribute to the

* C. Bullard and R. Herendeen, **Energy Costs of Goods and Services, 1963 and 1967.** Document 140, Center for Advanced Computation, University of Illinois Urbana, 61801, March 1975.

equipment and materials used in the nuclear fuel process. This tool saves the effort that would be expended to conduct a process analysis for every production sector of the economy.

The energy embodied in labor, ecosystems, and organizational infrastructure is not included in this example. Early results (see University of Oklahoma, 1975, Appendix B to Chapter 15) from an analysis of the ecosystem energy inputs on another technology tend to show that the ecosystem energy contribution is of a lower magnitude than the other energy inputs. Also, labor and infrastructure energy inputs are not well documented.

The steps of the nuclear power production process included in the case example are: mining, milling, conversion, enrichment, fuel fabrication, power plant construction and operation, fuel storage, waste storage, and transportation for each stage of process.

The energy requirements for each of the nine process stages are shown in Table B-1 in terms of the three components of external energy inputs: direct fuels, energy for construction, and energy for materials. This disaggregated presentation serves two purposes: (1) to permit the determination of the quantitatively important items as compared to items that are less significant and (2) to begin focusing attention on those processes where efficiency improvements can be made.

The energy content of the uranium left in the ground relative to the amount recovered under present extraction techniques is not included in this example. Most uranium mining is open pit and almost all of the uranium is captured in the mining process. For deep mining, significant uranium resources would remain in the ground, but it is not clear whether this value should be added to the other values. This uranium reseource has not been lost or used up and can be recovered, at some higher cost, in the future. Further discussion of this point is presented later in this Appendix. In addition, the analysis does not consider the net energy implications of electricity usage beyond the electric generating station. Thus, transmission losses and the efficiency of end-use devices are not included. However, for the purpose of comparing various fuels for supplying electricity these losses would be identical, and therefore, would not affect any conclusions based on these analyses. The analysis also does not include plant decommissioning requirements, but they are thought to be small. Also not included is the residual energy still available in the plant and fuel after 30 years of operation.

Detailed Calculations

The energy required for each step in the fuel cycle (Table B-1) has been determined for a 30-year life,

Table B–1 Energy Requirements for a Large Nuclear Power Plant

1000 MWe Pressurized Water Reactor—No Recycle—0.20% Enrichment Tails Assay
30 Year Life—61% Average Capacity Factor—160,300,000 MWh Output (547 Trillion Btu)*

		Electrical Inputs, In MWh			Thermal Inputs, In Millions Btu			Total Inputs,
Process	Quantity	Direct	Materials	Construction	Direct	Materials	Construction	Billion Btu **
Mining	3909 MTU	47,760	22,050	6,210	1,005,000	621,500	441,500	2,935
Milling	3909 MTU	67,430	16,140	2,780	1,310,000	621,500	121,200	3,037
Conversion	3909 MTU	39,830	16,620	620	4,826,000	426,000	29,000	5,334
Enrichment	3124 × 10³ SWU	8,778,000	18,120	24,050	1,048,000	428,000	1,016,400	103,037
Fuel Fabrication	683 MTU	67,750	137,200	600	147,900	1,579,000	26,000	4,096
Power Plant Construction and Operation	30 years	0	256,500	205,000	378,000	8,179,000	9,583,000	23,401
Fuel Storage	683 MTU	7,280	2,430	3,880	4,560	64,300	174,300	240
Waste Storage	30 years	130	4,560	320	2,080	158,200	22,950	398
Transportation								
—Natural	3909 MTU	0	410	0	31,900	24,470	0	61
—Fuel	693 MTU	0	1,546	0	120,300	92,290	0	230
Totals		9,008,000	475,600	243,460	8,874,000	12,195,000	11,414,000	142,769

*Electricity converted to thermal equivalent at 3413 Btu per kilowatt hour
Legend: MTU—Metric tons uranium
SWU—Separative work units (directly proportional to the energy required in the enrichment process)

**Electricity converted to thermal equivalent at average heat rate of 11,400 Btu per kilowatt hour

Note: The conversion of electrical to thermal units plus the addition of thermal inputs from different energy sources ignores the quality aspect of preferred fuels. This is a serious shortcoming, as there is no single factor that is satisfactory for converting different energy sources to an equivalent base.

Source: Institute for Energy Analysis with adjustments by ERDA.

Table B–2 The Energy Requirements for Light Water Reactor Nuclear Fuel Cycle Elements

Process	Equivalent Thermal Energy (Trillion Btu)	Percentage of Total
Mining	2.935	2.1
Milling	3.037	2.1
Conversion	5.334	3.9
Enrichment	103.037	72.1
Fuel Fabrication	4.096	2.9
Power Plant Operation	23.401	16.4
Fuel Storage	0.398	0.3
Waste Storage	0.240	0.2
Transportation		
—Natural U	0.061	0.1
—Fuel	0.230	0.2
Totals	143*	100*

* Rounded

1,000 Megawatt electric (MWe), pressurized water plant utilizing conventional uranium ores and a 0.20 percent enrichment tails assay. It is assumed that the spent fuel is **not** reprocessed to recover the unused uranium and plutonium. These energy requirements include the direct and indirect inputs of both electricity and thermal energy. Indirect requirements cover the energy content of the materials required plus a prorata share of energy used to construct the plants needed for the fuel cycle. Energy requirements for third and higher orders of processes, obtained by tracing the energy content of materials and equipment back to the resource base, have been found to be very small compared to these first- and second-order energy inputs, and have therefore been ignored. It is assumed that the plant generates electricity on the following capacity schedule:

1. Five-month period prior to being declared commercial—40 percent
2. First two years as a commercial plant—65 percent
3. Years 3 through 15—70 percent
4. Last 15 years—decreases 2 percentage points per year from 68 percent in year 16 to 40 percent in year 30.

The lifetime output of the plant while operating according to the assumptions used here is 160,-300,000 MWh, or 547 trillion Btu. The external energy inputs required are 143 trillion Btu, or 26 percent of the output.

Table B-1 shows that the uranium enrichment step is clearly the dominant energy consumer of all the nuclear fuel cycle steps. It consumes 97 percent of direct electrical inputs and accounts for 91 percent of total electrical requirements. If all energy inputs are summed by converting electrical inputs to thermal equivalents, the enrichment step is found to require 72 percent of all energy inputs. This is shown in Table B-2. Construction and operation of the power plant account for 16 percent of energy requirements and all other steps combined account for about 12 percent.

Conclusions

The nuclear option is clearly a net producer of energy. The results of this analysis are for the case where plutonium and spent uranium are stored rather than recycled and with an average lifetime capacity factor of 61 percent. The system as described requires 262 units of input to provide 1,000 units of output to the bus bar. Recycling spent fuel, improving plant utilization, and operating the enrichment plant at a tails assay above the assumed 0.20 percent would improve the energy efficiency. For example, a capacity factor of 75 percent instead of 61 percent reduces the energy input requirement by 5 percent. An enrichment tails assay assumption of 0.30 percent instead of the 0.20 percent used would lower energy input requirements by 15 percent.

The results of studies by others are similar to those reported in this analysis and are summarized in Table B-3.

The most promising area for improving the net energy position of the light water reactor system is to reduce the energy consumption of the enrichment step. The data used for this exercise assume enrichment by the current gaseous diffusion process. Development is well along on the centrifuge process, which is expected to reduce the direct requirement for electricity by a factor of ten. Other more advanced processes are in the conceptual stage. The introduction of recycle would also reduce energy input requirements since less enrichment would be required and smaller quantities of ore would need to be mined.

The net energy discussion above has focused on the quantity of external energy that must be invested in extracting, processing, and transporting fuels, and building and operating the industrial complex used to

Table B–3 Comparison of Net Energy Results

Investigator	Units of External Energy Input Per 1,000 Units of Output
Development Sciences, Inc.	238
State of Oregon Study	194*
University of Illinois, Center for Advanced Computation (Pilati and Richard)	210
Institute for Energy Analysis	248
ERDA–76–1	262

* Adjusted to comparable basis

generate energy. Other analysis approaches are also useful for understanding energy transformation processes. Two approaches, dynamic net energy analysis and analysis of the resource base, are discussed below.

Dynamic Analysis

A dynamic analysis of the direct and indirect external energy expenditures and the energy output of nuclear power plants as a function of time has been completed. This analysis indicates that:

- The external energy expenditures required to build, fuel, and operate each plant are recouped early in the second year of commercial operation.
- The net energy obtained from nuclear power from 1973 to 1985, under an assumed construction schedule based on ERDA-48 scenarios, is strongly positive.

External energy expenditures start about 5 years prior to plant operation, when major construction activities begin. The expenditures accelerate in the third year prior to commercial operation due to mining, milling, transport, and conversion of uranium needed for the initial reactor fuel core. Uranium enrichment and fuel fabrication expenditures occur during the second year prior to commercial operation. During the first year prior to commercial operation, a slight positive flow of energy takes place as a result of the electrical energy generated during pre-commercial operation testing. This energy exceeds that required to complete construction, operate the plant for five months, and provide for mining, milling, transport, and conversion of the uranium needed for the first reload.

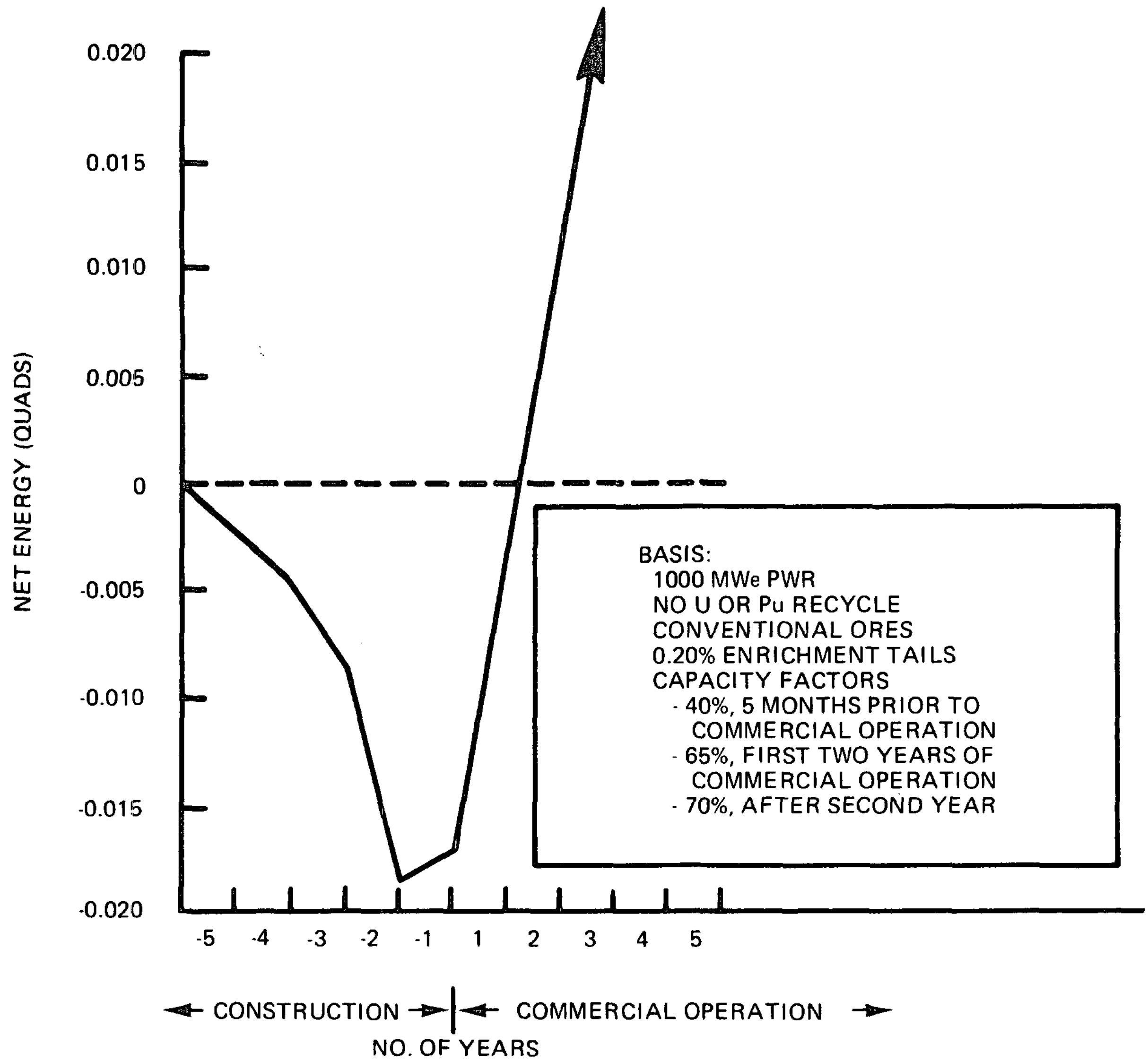


Figure B–2 Dynamic Net Energy Analysis of Nuclear Power

From the time of commercial operation onward, the energy flow of the nuclear plant is strongly positive. Early in the second year of operation, all energy investments have been repaid and four units of energy are returned for each energy unit required to operate the plant and all associated fuel cycle steps. Figure B-2 illustrates the net energy flows, as a function of time, for a single 1,000 MWe plant. The assumptions are the same as those contained in earlier discussions in this appendix.

By the end of 1985, 185,000 megawatts of nuclear power could be in commercial operation (see ERDA-48 scenarios). At the end of 1975, 52 nuclear plants were in commercial operation with a combined potential capacity of 37,000 megawatts. Thus, over the next 10 years an average of 15 plants per year (of 1000 MWe each) must be brought on line in order to meet the 185,000 megawatt level.

The external energy required to build, fuel, and operate these new additions to the Nation's electric system is substantial.* But the energy produced by the plants, both during pre-commercial testing and commercial operation, is much greater. Figure B-3 illustrates the net energy trend of the assumed nuclear electric system from 1973 to 1985. Each point on the curve represents the difference between the total nuclear system energy output (electrical) and the total external energy inputs (electrical plus thermal) for each year. The values for 1973, 1974, and 1975 have been adjusted to reflect actual plant operating experience. The capacity factor trend established during this period is assued to continue for the years 1976, 1977, and 1978. Thereafter, the calculations reflect the assumed capacity factor schedule listed earlier in this appendix.

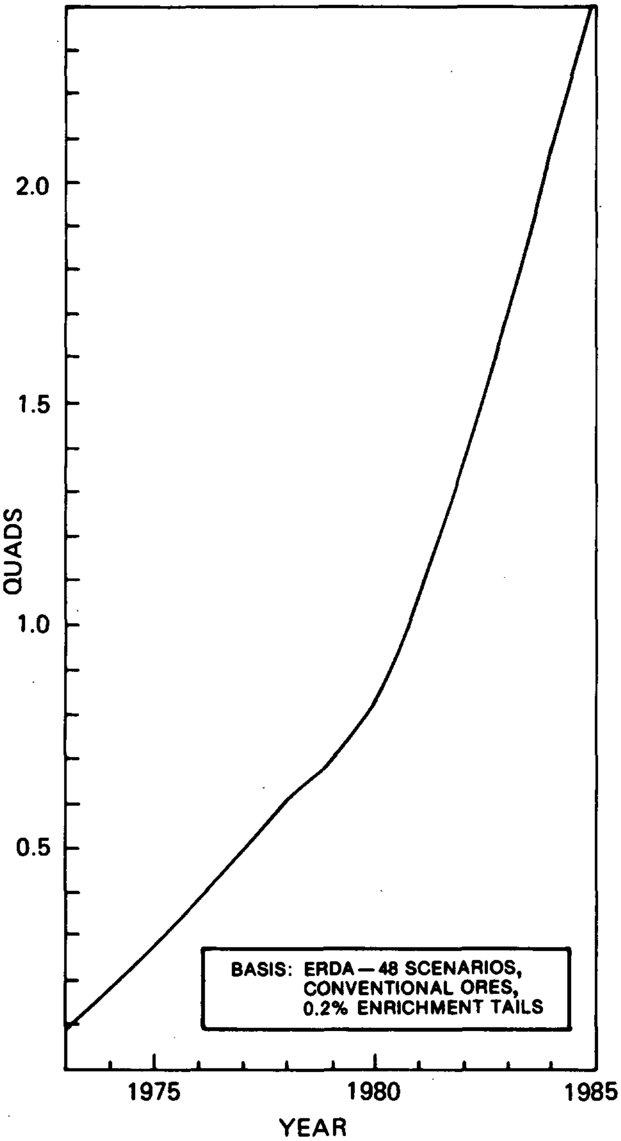


Figure B–3 Net Energy from Nuclear Power: Annual Energy Outputs Minus Annual Energy Inputs

Resource Base Analysis

This analysis requires the use of broader boundaries to include, as energy expenditures, the loss or non-use of uranium from point of extraction through the remaining steps of the fuel cycle, and the thermodynamic loss of useful energy in converting the thermal energy to electricity. The amount of initial resource required to provide a given quantity of energy reflects the ultimate potential of that resource to provide future energy needs based on current technological use patterns. For uranium, the longest non-use of resource occurs in the fissionable material which remains in the depleted uranium after the enrichment process. In addition, smaller amounts of uranium are lost in each stage of fuel cycle mining and other processing. Another major loss of resource use occurs in the nuclear generating plant where, like fossil electric plants, about one-third of the thermal energy obtained from the uranium is converted into electrical energy. Analyses performed by Development Sciences, Inc. and the State of Oregon indicate that from 6,000 to 7,000 Btu of energy resource input are required to produce 1,000 Btu of electricity.

The net energy of nuclear electric power by this measure could be substantially improved if the economics of the transformation processes were more favorable, such as by extracting more of the fissionable uranium during the enrichment process or by the more efficient use of the exhausted energy from the power plant (e.g., for process heat).

* The energy expended for plants constructed prior to 1985 but not going into commercial operation until after 1985 is also included.

Glossary

RD&D Technology Programs

Breeder Reactors

The development, design, construction, and operation of components and systems that use nuclear fuels for producing power or process heat, in which fissionable material is produced at a faster rate than it is consumed. The program focuses on the development of a liquid metal fast breeder reactor system, and is also investigating the concepts of gas-cooled, and light water breeder reactors.

Coal—Direct Utilization in Utility/Industry

The development, design, construction, and operation of advanced components, systems, and processes involved in the combustion of various types of coal; transfer of the heat produced to steam or other working fluids for process or power use; and reduction or control of the generation of pollutants during combustion. The program includes the development of new combustion methods (e.g., fluidized-bed combustion), design of more efficient boilers, and use of additives during combustion. (Stack gas cleaning technology is covered under Environmental Control Technology.)

Conservation in Buildings and Consumer Products

The development, design, construction, and operation of buildings and consumer products that minimize energy consumption. The technology includes types of insulation and fenestration and systems of control to minimize energy requirements, as well as consumer products such as appliances, televisions, and heating, cooling and ventilating systems that use less energy.

Electric Conversion Efficiency

The development, design, construction, and operation of advanced devices for converting heat to electricity. The program focuses on mechanical, electrochemical, and thermodynamic devices (e.g., fuel cell, thermionic, thermoelectric, magnetohydrodynamic, and turbine systems) that employ working fluids other than steam and combustion gas, frequently in combination with conventional cycles.

Electric Power Transmission and Distribution

The development, design, construction, and operation of systems to transport electrical energy from the generation station to the eventual utilization device. The technology includes extra-high-voltage AC, DC, underground, and cyrogenic systems, as well as system security and load management.

Electric Transport

The development, design, construction, and operation of transportation methods that use electrical energy as the source of propulsion power. The technology includes electric automobiles, trucks, and rail transport systems.

Energy Storage

The development, design, construction, and operation of advanced devices for storing energy until needed. The technology includes devices such as batteries, pumped storage for hydroelectric generation, flywheels, and compressed gas.

Fuels from Biomass

The development, design, construction, and operation of systems and processes for the conversion of biological materials to energy sources. The technology includes such processes as the conversion of wood or other plants to alcohol, and the fermentation or decomposition of organic by-product materials to produce methane or other fuels.

Fusion

The development, design, construction, and operation of systems and processes for combining or fusing particles of the lighter elements into elements of higher atomic weight as a means of producing usable power. The program is currently investigating several methods to induce fusion, including lasers and magnetic confinement systems.

Gaseous and Liquid Fuels from Coal

The development, design, construction, and operation of components, systems, and processes that will convert various types and ranks of coal to other fuel forms. These forms include clean gases of either high or low energy content; and oils and other clean liquid fuels or solid fuels that have higher heat content, less ash, and fewer impurities than natural coal. Gaseous fuels production includes both above-ground and *in situ* processes.

Geothermal

The development, design, construction, and operation of systems and components to extract and convert the heat energy contained in geological formations to power. Geothermal resources include hot rocks, dry or wet steam, hot brines with associated methane, and magma.

Hydrogen in Energy Systems

The development, design, construction, and operation of systems, components, and processes for producing, transporting, storing, and utilizing hydrogen as a substitute fuel. The technology focuses on the development of non-electrolysis processes for generating the hydrogen product from non-fossil sources and on methods for storing and transporting it.

Industry Energy Efficiency

The development, design, construction, and operation of industrial processes and equipment to minimize the energy requirements of fabricating, forming, converting, or producing industrial or agricultural products.

Nuclear Converter Reactors

The design, construction, and operation of components and systems which use nuclear fuels to produce power or process heat and which consume fissionable material at a faster rate than it is produced. The program focuses on the high temperature gas cooled reactor (HTGR) and the continued development and improvement of basic technologies associated with light water reactors (LWR). (See also Support to Nuclear Fuel Cycle.)

Oil and Gas Enhanced Recovery

The application of improved techniques, processes, and methods that permit extraction and recovery of additional amounts of oil or gas. These applications include hydraulic fracturing methods, the injection of solvents and heat to increase yield, and other advanced methods to enhance recovery.

Oil Shale

The development, design, construction, and operation of systems, components, and processes for extracting hydrocarbon products from shale and converting the product to liquid or gaseous fuels or other chemical commodities. The program includes the development of *in situ* methods for product extraction.

Solar Electric

The development, design, construction, and operation of systems to collect and transform the radiant energy of sunlight into electrical power. The technology includes the use of various collector (e.g., mirror concentrators) and conversion systems (e.g., photovoltaic devices) as well as solar-derived energy (e.g., wind or ocean thermal gradients).

Solar Heating and Cooling

The development, design, construction, and operation of systems that utilize and/or store the radiant energy of sunlight to provide comfort control and heated water for household, industrial, or agricultural use.

Transportation Efficiency

The development, design, construction, and operation of more efficient transport systems. The technology focuses on ships, planes, trucks, autos, trains, and pipelines, as well as the power systems involved.

Waste Heat Utilization

The development, design, construction, and operation of systems that use the waste or rejected heat incident to the production of electrical power or industrial products. The technology focuses on bottoming cycles as well as integrated total energy systems employed in residential, commercial, and industrial complexes.

Waste Materials to Energy

The development, design, construction, and operation of systems and processes for converting the energy contained in waste or refuse into power or heat. The technology also includes processes for recovering and recycling non-energy resources.

Broad Supporting Technologies or Programs

Basic Energy Science

A broad-based program of scientific investigation into the fundamental nature of the universe to develop greater understanding of the nature and behavior of matter. The program includes research in the molecular, material, nuclear, and biological sciences.

Biomedical and Environmental Research

The scientific investigation of the health and environmental effects of radiation and other pollutants on the environment and its inhabitants. This program includes the study of ecological relationships and the development of systems and methods to measure the release of noxious or harmful substances.

Information Dissemination

The preparation and widespread distribution of the technical information and data developed through the energy program to encourage broad public knowledge, understanding, and application.

Manpower Development

The training and education of personnel to ensure an adequate pool of trained and knowledgeable manpower to design, construct, and operate new facilities and systems resulting from the development or commercialization of new energy technology.

Safety

The development, design, construction, and operation of systems, components, and devices to protect the public and workers from the health hazards associated with energy production and utilization. The program focuses on the development of devices and designs to prevent accidents or to mitigate the consequences of potential accidents.

Systems Studies

The development and application of methods and techniques for analyzing and assessing programs, activities, and projects to review and assess efforts to date and to determine future courses and directions. These studies include cost/benefit analysis, environmental impact analysis, assessment of the likelihood of technical success, forecasts of possible futures resulting from specific actions, and guidance for energy program planning and implementation.

Specific Supporting Technologies

Environmental Control Technology

The development, design, construction, and demonstration of processes and systems to control the amount and type of pollutants discharged into the environment as a result of energy conversion, extraction, or use. The technology includes such systems as scrubbers, filters, washers, and precipitators to remove noxious gases or particulates from combustion processes; methods to control or remove radioactive gases or particulates from nuclear processes; converters to modify exhaust from automobile engines; and cooling towers and other means to permit the dissipation of waste heat with minimum adverse environmental impact.

Exploration and Resource Assessment

The development and application of advanced technologies to locate, identify, and assess the amounts and types of energy resources or other useful material in geological formations. The technologies include such methods as magnetic and gravimetric measurement, seismic and acoustic scanning, aerial and space photography, drilling, and sample analysis, as well as the compilation, analysis, and reporting of resource data.

Fossil Fuel Transportation

The development, design, construction, and operation of advanced systems and components to transport fossil fuels from point of origin to point of use. The technology focuses on such systems as unit trains, pipelines, and conveyor systems.

Mining and Beneficiation

The design, construction, and operation of systems and processes to extract useful resources from geological formations, and the development of techniques and methods to concentrate or upgrade ores to a higher content of the desired material. The technology includes both underground and surface extraction techniques.

Nuclear Safeguards

The development, design, construction, and operation of systems, methods, and devices to account for and control nuclear materials, and to prevent sabotage, theft, or other uses that could threaten life or property.

Support to the Nuclear Fuel Cycle

The development, design, construction, and operation of facilities, systems, components, and processes to recover fissionable material from the chemical processing of spent nuclear fuels from power reactors, and to refabricate that material into fuels for reinsertion into the reactor systems. The technology focuses on the management and control of the radioactive waste produced incident to the recovery of fissionable material, and is applied to light water reactors, gas-cooled reactors, and breeder reactor systems.

Uranium Enrichment

The development, design, construction, and operation of systems, processes, and components to permit isotopic separation and enrichment of the isotope U-235 in uranium for use as nuclear fuel. The technology includes such processes as gaseous diffusion, centrifugation, and advanced systems involving lasers and aeronozzles.

Waste Management

The development, design, construction, and operation of systems and components to permit the safe management, transport, storage, and eventual disposal of radioactive wastes in an environmentally acceptable, nonhazardous manner. The technology also includes the management of noxious wastes resulting from the use of other energy resources.

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ERDA 76-1

A NATIONAL PLAN FOR ENERGY RESEARCH, DEVELOPMENT & DEMONSTRATION: CREATING ENERGY CHOICES FOR THE FUTURE 1976

VOLUME 2: PROGRAM IMPLEMENTATION

ENERGY RESEARCH & DEVELOPMENT ADMINISTRATION

USA

UNITED STATES
ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION
WASHINGTON, D.C. 20545

June 30, 1976

The President of the United States

The President of the Senate

The Speaker of the House of Representatives

Sirs:

Enclosed for your consideration is Volume 2 of "A National Plan for Energy Research, Development and Demonstration: Creating Energy Choices for the Future."

As we made clear in Volume 1, the plan summarizes ERDA's current views on the energy technologies the nation will need to achieve longer-term energy independence. In this regard, the private sector has primary responsibility for the development and commercialization of new energy technologies. Federal programs are being established to assist industry in accelerating the market penetration of energy technologies with near-term potential. Conservation (energy efficiency) technologies are also the focus for increased attention, and are now ranked with several supply technologies as being of the highest priority for national action.

The large increase in funding requested in the President's 1977 budget (a 30% increase over 1976) places particular emphasis on accelerating those programs directed at achieving greater long-term energy independence, and on encouraging cost-sharing with private industry to avoid federal funding of projects more appropriately the responsibility of the private sector, and providing support for the commercial demonstration of synthetic fuels production through the use of loan guarantees.

Volume 2, Program Implementation, identifies those actions that can be taken to implement the plan described in Volume 1. The document contains descriptions of the federal energy RD&D programs now underway, as well as possible future efforts. It also provides greater depth of coverage than the 1975 report, and includes financial data for Fiscal Years 1975, 1976, and 1977. Industry activities are included if they are supported in part by federal funds.

AMERICAN REVOLUTION BICENTENNIAL 1776-1976

The description of actions proposed in Volume 2 represent the considered judgment of Federal agency management as to which projects are reasonable to pursue based on information now available. The actions selected, including specific program objectives and strategies, will be reassessed frequently based on the analysis of energy requirements and resources, technological developments, economic situations, eventual commercial attractiveness of options, and environmental and social conditions. These criteria for program assessment will help eliminate programs that have less promise, reveal new opportunities, and permit the efficient allocation of resources for the pursuit of solutions to the Nation's energy problem.

Respectfully yours,

Robert C. Seamans, Jr.
Administrator

ERDA 76-1

A NATIONAL PLAN FOR ENERGY RESEARCH, DEVELOPMENT & DEMONSTRATION: CREATING ENERGY CHOICES FOR THE FUTURE 1976

VOLUME 2: PROGRAM IMPLEMENTATION

ENERGY RESEARCH & DEVELOPMENT ADMINISTRATION

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PREFACE

Volume 2, Program Implementation, of *Creating Energy Choices for the Future,* a proposed National Plan for Energy Research, Development and Demonstration, is a companion to Volume 1, The Plan (ERDA 76–1), and describes programs now underway and supported by the federal government. It does not include energy research and development (R&D) underway in industry or elsewhere unless federal funds are involved. Together with Volume 1, it describes technologies being investigated and activities underway and planned in federal energy research, development (RD&D) programs. It presents ERDA's views on the courses of action that the federal government should take in assisting the private sector in finding solutions to the national energy problem.

The primary responsibility for bringing into use new technologies for energy conservation and expanding domestic energy production rests with the private sector. The federal government's responsibility is to assist the private sector in the development and market penetration of new energy technologies by establishing an appropriate policy environment for private sector action, sharing risks with the private sector in some cases, and conducting a supporting RD&D program.

Overall, the federal energy RD&D program provides assistance to industry in developing and using new or improved energy technologies when such innovations are in the public interest but cannot be accomplished either in a timely manner or at all by industry acting alone. Accordingly, it is the federal government's intent to minimize the public financial commitment and to press for the highest possible levels of industry cooperation and involvement in all technologies. This approach has been chosen in order to accelerate the development of new technologies, to make maximum use of industry's expertise and speed the process of bringing technology into use.

The private sector has the primary responsibility for developing and bringing into use the technology needed to fulfill our energy needs. Accordingly, we believe that industry should play a significant part in the development of future plans and programs. We are encouraging the participation of the private sector to help ensure the economic viability of proposed RD&D efforts supported by the government.

Volume 1 of ERDA 48, the first Plan, noted that subsequent plans would include "Deeper Analysis of Key Uncertainties." Such uncertainties include; the extent of fuel resources, technological feasibility of options, eventual commercial attractiveness of options, degree of environmental and social impact, and future energy requirements. Lack of precise information in these areas has led ERDA to conclude that decisions made now must relate to the current level and content of the RD&D efforts. They do not represent unvarying commitments for the future conduct of either development or implementation actions. These later decisions will be taken sequentially and they will be constantly reexamined. Thus, this Program Implementation document does not commit the federal government to support specific large demonstrations, but identifies projects that may have potential and warrant further consideration.

It should be understood that the wording of the descriptions in this document when describing possible future events does not necessarily imply that a decision or commitment has been made or will be made to follow the course of action described. These plans and programs will be reevaluated often—particularly when it is time to determine whether the proposed action has sufficient merit and priority to be proposed to the President and the Congress for federal funding. The same general kind of qualifications apply to the descriptions of objectives, strategies, federal role, international cooperation, implementation and projected future milestones or events.

The document is divided into five parts:

Part I Energy Technology Programs
Part II Supporting Technology Programs
Part III Energy-Related Supporting Activities
Part IV Special Analyses
Part V Appendix

Parts I, II, and III contain, in total, 76 program descriptions, hereafter referred to as "Building Blocks." In addition to being a program description, each Building Block corresponds to a line item in the ERDA budget. At the minimum, each represents the energy research, development and demonstration activities of a single federal agency; the majority, however, describe the activities of two or more federal agencies.

Generally, each building block is structured to contain the following elements as appropriate:

(1) a statement of the federal government's assessment of desirable objectives in the near-, mid-, and long-term;
(2) a listing of the national energy technology goals which are supported;
(3) the strategy, or approach, chosen by the federal government to achieve the objective(s);
(4) a justification for and the extent of federal participation and role, and an indication of how and when industry is expected to assume responsibility for the activity;
(5) a description of international cooperation and collaboration;
(6) a summary of the program's current technological status and the problems requiring solution by scientific or engineering activity;
(7) a description of the current status and primary problems of a non-technical, institutional nature (economic, socio-economic, legal, policy-related, jurisdictional, industry-related, and regulatory) which may be key factors affecting commercialization;
(8) a description of the status and primary problems related to the environmental effects, both technical and nontechnical, and environmental control processes and devices associated with each individual technology program;
(9) program activities and major projects, when relevant, planned by the individual federal agencies to implement the selected strategy with schedules and/or milestone charts as appropriate;
(10) budget data (Authority and Outlays), when available, for each federal agency for the fiscal years 1975, 1976 and 1977. (The financial data presented in Volume 2 may vary slightly from that in Volume 1 due to different levels of data aggregation and rounding practices.)

Part I

Part I Building Blocks describe federal program activities whose objectives are oriented toward a single energy technology. The 62 Building Blocks contained in Part I are grouped into nine major program areas, all but one introduced by an executive summary. The nine major program areas are: Fossil Energy, Solar Energy, Geothermal Energy, Conservation, Fusion Power, Nuclear Fuel Cycle R&D and Safeguards, Fission Power, Environmental Control Technology, and Synthetic Fuels Commercial Demonstration. The degree of integration of the federal agency activities into the Building Block discussions varies from Building Block to Building Block. The specific details of the degree of integration of the Building Blocks are discussed in the related executive summaries.

Parts II through V

The Building Blocks in Parts II and III describe programs whose objectives are supportive in nature and often cut across several energy technologies. The eight Building Blocks contained in Part II are divided into two major program areas: Environmental Research and Safety, and Basic Energy Sciences. The six activities contained in Part III are not unique to energy RD&D but are necessary for achievement of its objectives.

Part IV consists of three tables. They contain cross-referencing data that will allow the reader to examine the Building Blocks from the different perspectives of the National Energy Technology Goals, Volume 1 Technologies, and Federal Agency Involvement.

Part V, the Appendix, contains a glossary of acronyms and abbreviations.

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EXECUTIVE SUMMARY

PART I

ENERGY TECHNOLOGY PROGRAMS

Fossil Energy

Research, development, and demonstration activities are supported by the federal government to assist industry in developing and bringing into use technologies to extend the recoverable base of domestic oil and natural gas resources, and to make coal and oil shale more economically and environmentally attractive.

The coal program comprises several RD&D activities designed to assist industry in developing second generation technologies to convert coal to more widely useful and cleaner synthetic fuels; develop environmentally acceptable and economic methods to burn coal; and find more efficient means to generate electric power from coal resources.

Petroleum and natural gas programs are being conducted jointly with industry to determine the optimum application of tertiary recovery and stimulation techniques to the multiplicity of domestic resource reserves.

The unique aspects of in-situ resource recovery techniques are being explored and developed for potential application in coal gasification and shale oil recovery in another program receiving federal support.

Programs in resource appraisal and extraction technologies seek to determine the extent and quality of domestic fossil fuel resource and improved methods for mining that incorporate greater efficiency and safety and enhance environmental integrity.

Solar Energy

Solar heating and cooling is comprised of those technologies that make use of the radiant energy of the sun on a decentralized basis to provide space conditioning and hot water for a variety of uses. The technologies are now at a sufficient level of sophistication to allow for practical application, but have failed to achieve effective market penetration owing to a number of constraints, notably economic and institutional. The federal effort is largely centered on demonstration programs in cooperation with industry designed to show the applicability of solar heating and cooling systems to a number of uses and in a number of environments. These include residential and commercial space conditioning and hot water production, and agricultural crop drying.

The longer-range goal of harnessing the sun's radiation for centralized energy production is being approached simultaneously in a variety of ways: solar thermal collection, wind power, ocean thermal gradient, and fuels from biomass.

Several types of solar thermal collection techniques are being brought to the pilot plant phase of development to test systems concepts and validate economic projections. These include a 5 MWe solar thermal test facility and the conceptual design of a 10 MWe central receiver pilot plant, both to be completed in FY 1977.

A photovoltaic program aimed at systems definition and cost reduction of photovoltaic cells represents another unique approach to the development of solar energy technology for electric power production. A price of less than $2000 per peak kilowatt (its present cost) for planar solar cells and the establishment of the viability of the technology by 1982 are primary objectives of the ERDA program.

The wind power program will build and test successively larger wind-powered electrical-generating machines to determine applications and economic feasibility.

Ocean thermal gradients offer potential for energy production in several forms. The federal program for this technology currently emphasizes system studies, criteria development for testing facilities, and component design and testing.

Agricultural and forest residues and marine biomass offer potential for clean fuels and industrial chemicals. The federal program emphasizes the demonstration of an economically feasible technology for the development of this energy source.

Geothermal Energy

Program efforts are intended to aid in the establishment of a geothermal industry to encourage the commercial use of existing technologies to recover useful energy from low-salinity hydrothermal resources. Federal support includes geothermal resource exploration and assessment, the development and demonstration of improved plant components, and a loan guaranty program.

Other program highlights consist of advanced technology development activities designed to improve means to recover energy from higher-salinity hydrothermal resources, including verification of the use of binary cycles, demonstrating the feasibility of removing useful energy from hot dry rock sources with circulating fluids, and continuing research on concepts for economical extraction of energy from geopressured zones.

Federal coordination is effected through a Geothermal Advisory Council. The Council advises on the direction and relevance of the research, studies, educational programs, land leasing policies, environmental standards development, and the other federal agency activities that must be coordinated to bring about viable technical and industrial bases for geothermal energy development.

Conservation

Federal programs in this area attempt to assist industry in developing technology to aid in reducing wasteful patterns of energy consumption and increasing efficiency of equipment used in energy conversion, distribution and consumption. The aim is to encourage more efficient patterns of energy use through the development of new technologies and approaches that will have a major impact on energy consumption in the future.

The RD&D Conservation efforts are supported by the following programs: Electric Energy Systems, Energy Storage Systems, Industry Conservation, Buildings Conservation, Transportation Energy Conservation, and Energy Conversion.

Representative ongoing activities include: testing of alternative energy-saving building designs; development of building design standards; testing of devices to reduce energy losses in existing structures; improvement in the energy efficiency of processes (such as distillation) common to many industries; development and testing of alternative transportation vehicle propulsion systems; testing of approach to improve driver operation and maintenance practices; development of electrical system management techniques and components to meet future needs for efficient and reliable operation and exploration of processes and components (e.g., storage devices, heat recuperators, and combustion processes) fundamental to end-use energy efficiency in a number of areas.

Fusion Power R&D

The Fusion program comprises two substantially different technological approaches to the production of usable energy from controlled thermonuclear reactions: magnetic confinement, and inertial confirnment. FY 1977 funding (Budget Authority) for the program has increased a substantial 57 percent over FY 1976 levels, most of which is required to sustain the technical directions already in progress. Primary programmatic emphasis is shifting from basic physics research towards more practical systems development. Such a transition inherently involves costlier equipments and facilities, and larger and more diverse technical staffs.

The magnetic confinement approach has recently achieved reactor-level temperatures and a ten-fold increase in plasma confinement conditions in a magnetic mirror device. A similar advance was achieved in a tokamak device. Current work includes further testing of a superconducting magnet system for plasma confinement, and completion and operation of a rotation target neutral beam source for plasma heating.

Nuclear Fuel Cycle R&D and Safeguards

This effort consists of six major program activities: Uranium Resource Assessment, Support of the Nuclear Fuel Cycle, Waste Management (Commercial), Nuclear Materials Security and Safeguards, Uranium Enrichment Process Development, and Advanced Isotope Separation Technology. The program activities in this effort are wide in scope. For example, activities are directed toward assessing the extent of uranium resources, and assisting industry in overcoming technical and institutional uncertainties in the areas of fuel reprocessing and recycle and waste management, and developing and demonstrating efficient and effective safeguards systems for the light water reactor and advanced fuel cycle systems.

Other activities are directed toward continuing the development of gaseous diffusion technology for use in increasing production capacity at existing gaseous diffusion plants, continuing the development of gas centrifuge technology to be available for early use by an expanding domestic uranium enrichment industry. Finally, there are activities to investigate and develop additional isotope separation processes which have the potential for significantly reducing the cost of enriched materials and enhancing the introduction of these technologies into the marketplace.

Fission Power

There are six major program areas: Liquid Metal Fast Breeder Reactors; Water Cooled Breeder Reactors; Gas Cooled Reactors; Light Water Reactor Technology; Supporting Activities; and Reactor Safety Facilities.

Near-term increases in the amount of energy produced from nuclear sources may be possible through cooperation with industry to improve licensability, constructability, and operating availability of light water reactors, which are now being marketed by industry and operated by the utilities.

Mid-term impact is possible on both energy supply and energy resources through continued improvements in these reactors which make more efficient use of available nuclear fuel. Long-term impact on energy resources will be realized with the successful commercial introduction of breeder reactors which have the capability to increase energy available from the reactor by a factor of sixty. The availability of breeder reactors can assure our nation clean and economic energy for centuries.

Substantial involvement of the private sector is necessary to ensure that the technologies which are being developed and improved are commercially viable. A major federal involvement is necessary because of the long-term payoff inherent in the program. Safety and environmental research activities are uppermost in the development program due to public concern, although the safety record of fission power is unequaled by any other industry.

PART II

SUPPORTING TECHNOLOGY PROGRAMS

Environmental Research and Safety

Environmental Research and Safety Programs conduct supporting research to ensure that the energy-producing technologies developed are environmentally and socially acceptable, and adequately consider the health and safety of the public and of the workers involved in energy production. Efforts include: research required to identify and characterize hazards, determination of how they are transported into the environment and their effect on man and the biota; assessment of energy-related developments to ensure that adverse health, environmental, and societal impacts of energy activities are minimized; ensuring consistent and adequate occupational health and safety programs in energy RD&D; and assessing environmental control technology for waste management, energy systems and materials transport, and for disposal of contaminated surplus facilities.

Basic Energy Sciences

The Basic Energy Sciences' activities include programs in Materials Sciences, in Molecular, Mathematical and Geo-sciences and in Nuclear Sciences. The Materials Sciences program provides guidance and input to on-going applied materials programs, a strengthened foundation for planning future materials development programs, tentative solutions or models for unanticipated materials problems, and new materials for future applications.

The Molecular, Mathematical, and Geo-sciences program contributes to improved understanding and generates new concepts for a broad range of energy-related processes.

The Nuclear Sciences program emphasizes continued development of a base of nuclear data for neutron and charged particle interactions in energy regions important for fusion power reactors. It also supports the gathering of data to provide estimates of heat production by radioactive decay for use in waste management and reactor development programs, and the gathering of fundamental data on research quantities of heavy elements.

PART III

ENERGY-RELATED SUPPORTING ACTIVITIES

Broad-based supporting activities associated with each of the previously described energy and supporting technology programs include: Information Services, General Systems Studies, General Technology Transfers, and Manpower. These activities have been formalized by the federal agencies to ensure that the energy programs are integrated and implemented with maximum effectiveness. The goals of these programs are to provide advice, support, and direction to the energy technology programs where appropriate, as well as provide the basis for the design and implementation of the programs at the agency level.

FEDERAL ENERGY RD&D BUDGET

($ MILLIONS)

	FY 1975		FY 1976*		FY 1977	
	Budget Authority **	Budget Outlays ***	Budget Authority	Budget Outlays	Budget Authority	Budget Outlays
Energy Technology Programs						
Fossil	404.3	175.6	477.6	403.5	561.8	523.7
Solar	41.9	14.9	114.7	86.0	160.0	116.0
Geothermal	38.9	31.3	43.4	41.8	56.0	55.7
Conservation	40.6	22.2	80.3	62.6	121.2	92.9
Fusion	183.3	151.2	250.3	223.9	392.1	304.5
Nuclear Fuel Cycle R&D and Safeguards	124.0	126.3	187.3	176.1	371.6	305.8
Fission	624.7	588.5	681.0	590.2	912.9	789.3
Environmental Control Technology	89.1	25.4	70.3	88.8	72.0	91.8
Supporting Technology Programs						
Environmental Research	274.8	193.7	318.6	301.5	334.8	326.6
Basic Energy Sciences	274.6	219.8	304.2	249.5	327.8	292.0
Energy-Related Supporting Activities (1)	27.9	24.8	35.5	35.0	32.5	36.0

(1) These were not included in the budget tables in Volume 1 of ERDA 76–1.

* Funds for FY 1976 Transition Quarter are not included.

** Hereafter referred to as BA.

*** Hereafter referred to as BO.

PART I — ENERGY TECHNOLOGY PROGRAMS

INTRODUCTION

This first Part of Volume 2 contains sixty-two energy technology building blocks, grouped into nine major program areas as follows:

- Fossil Energy
- Solar Energy
- Geothermal Energy
- Conservation
- Fusion Power R&D
- Nuclear Fuel Cycle R&D and Safeguards
- Fission Power
- Environmental Control Technology
- Synthetic Fuels Commercial Demonstration

These building blocks contain information on the energy RD&D activities of sixteen federal agencies, namely:

- Department of Agriculture
- Department of Commerce
- Department of Defense
- Department of Health, Education and Welfare
- Department of Housing and Urban Development
- Department of Interior
- Department of Transportation
- Energy Research and Development Administration
- Environmental Protection Agency
- Federal Energy Administration
- General Services Administration
- National Aeronautics and Space Administration
- National Science Foundation
- Nuclear Regulatory Commission
- Tennessee Valley Authority
- United States Postal Service

FOSSIL ENERGY EXECUTIVE SUMMARY

The overall Fossil Energy RD&D objectives are to develop technical options to enhance the availability of fossil energy sources and to ensure the development of national fossil energy resources on a technically sound, economically feasible, and environmentally acceptable basis. These overall RD&D objectives are accomplished through the Fossil Energy Coal, Petroleum and Natural Gas, In-Situ Technology, Extraction Technology, and Resource Appraisal Programs.

Near-term objectives for Fossil Energy RD&D include: the stimulation of petroleum and natural gas production; the improvement of processes for the direct combustion of coal to be used for steam and electric power generation and industrial process heat; the development of improved processes for the conversion of coals to liquid and gaseous fuels; the development of in-situ processes for generating low Btu gases from coal; the development of in-situ processes for the production of shale oil; the improvement of extraction technologies of coal and oil shale; and the assessment of coal, petroleum, natural gas, oil shale and water resources.

Mid-term objectives include: support for the commercialization of mature technologies and the development of advanced processes for the combustion of high sulfur coals; the development of advanced processes for the combustion of high sulfur coals; the development of advanced electric power generation systems directly utilizing coals; the demonstration and transfer to industry of the technology for commercial-scale production of low to intermediate Btu gas from coal; continued improvement of extraction technologies of coal and oil shale; and to extend resource assessment techniques to currently less-desirable and/or unproductive resource areas.

Long-term objectives include the development and demonstration of advanced technologies for the generation of electric power and process heat at increased efficiency, and the development of in-situ recovery techniques for fossil energy resources not recoverable by currently available technologies.

The national Fossil Energy RD&D approach is intended to ensure that advanced fossil technology will be rapidly developed and eventually be commercialized by the private sector. Thus, the program is oriented more towards accelerating and stimulating activities in the industrial sector than to initiating independent federal programs. Equally important other factors that also must be considered when orienting and stimulating new technologies include inputs from the consumer. Such inputs include: the nature of the new product marketplace; any socioeconomic impact of the new industry; and the many and various environmental regulations to be implemented.

Fossil Energy RD&D strategy for accomplishment of program objectives calls for the concurrent development of technology options that hold promise of long-term payoff. When sufficient technical information is generated by the development programs, selection among competing technologies will be made to determine processes that should be demonstrated for commercialization. Additionally, the strategy includes plans for data exchange between development program elements to promote coordination of alternatives into an optimum system for extracting, transportating, processing, and using domestic fossil fuels.

Fossil Energy RD&D strategy is implemented by a logically phased approach to the programs. The phase and schedule progression of each program is determined by the maturity of the technology employed. Exploratory efforts in the initial phase include basic research, feasibility and systems studies, component development and bench/laboratory testing. As positive initial phase results are obtained, process development tests or technology readiness efforts are started. Next, a pilot plant or a full systems testing phase is conducted. Demonstration plants may then be constructed and tested when R&D results, or industry-developed processes, so indicate. The degree of industrial participation and cooperation will increase from a minimal level during the initial phases to a complete government/industry partnership during the demonstration phase.

In order to ensure an acceleration of activity in the private sector, a primary focus in future Fossil Energy program development will be to increase the sensitivity and responsiveness to the needs of industry.

FOSSIL ENERGY

Federal Energy RD&D Budget

($ Millions)

	FY 1975		FY 1976*		FY 1977	
Building Block	**BA**	**BO**	**BA**	**BO**	**BA**	**BO**
Coal Liquefaction	94.7	35.2	89.9	92.9	73.9	79.5
High Btu Gasification	59.8	36.0	53.4	37.3	45.2	59.3
Low Btu Gasification	50.0	23.3	24.6	36.0	33.1	40.0
Advanced Power Systems	4.1	1.7	10.0	7.5	22.5	12.8
Direct Combustion	35.9	10.6	38.1	32.6	52.4	52.1
Advanced Research and Supporting Technology	23.3	7.8	35.4	32.1	37.1	36.6
Demonstration Plants	13.0	1.9	51.9	23.2	107.2	80.9
Magnetohydrodynamics	14.3	4.0	29.6	18.4	37.6	27.4
Gas and Oil Extraction	26.4	8.7	41.5	32.9	35.2	30.5
Supporting Research	1.8	2.0	1.8	1.6	1.8	1.8
Oil Shale	3.8	4.0	14.0	10.1	23.4	14.4
In-Situ Coal Gasification	6.6	2.4	6.1	7.6	8.2	6.7
Supporting Research (In-Situ)	1.0	1.0	1.3	1.1	1.4	1.4
Extraction Technologies	52.2	20.1	61.8	52.3	65.6	63.3
Resource Appraisal	17.4	16.9	18.2	17.9	17.2	17.0
Total	404.3	175.6	477.6	403.5	561.8	523.7

* Does not include funds for FY 1976 Transition Quarter.

FOSSIL ENERGY

Coal

LIQUEFACTION

Objectives

Near-Term:
(–1985)

- To develop second generation technologies as candidates for commercialization, which will convert domestic coal into boiler fuel, distillate heating oil, gasoline, other light refined liquid fuels and chemical feedstocks.
- To ensure technology transfer and improved unit operations to support commercial liquefaction operations based on existing first generation technologies.
- To perform laboratory studies and process development of third generation liquefaction processes.

Mid-Term:
(–2000)

- Beginning in 1985, to assist commercial-scale implementation of second generation liquefaction technologies which may be capable of providing 3.8 quads by the year 2000.
- To develop and demonstrate at near-commercial scale, third-generation liquefaction technology by 1990 and assist its commercial-scale implementation by 2000.

National Energy Technology Goals Supported

Primary

- Efficiently transform fuel resources into more desirable forms.

Secondary

- Increase the efficiency and reliability of the processes used in the energy conversion and delivery systems.

Strategy

The liquid products derived from coal compete in two distinct markets: boiler fuels (low ash, low sulfur), and premium products (gasoline, distillate heating oil, chemical feedstocks and other light refined liquid fuels).

The strategy is to support a number of liquefaction processes in parallel through the pilot plant stage. This approach is based on a number of considerations. The variety of coals to be processed coupled with the requirements for a wide range of fuels, will necessitate commercialization of a number of liquefaction processes.

Programs are supported in four liquefaction areas: solvent extraction, direct catalytic hydrogenation, indirect synthesis, and pyrolysis. In addition to the programs for development of individual liquefaction processes, several problem areas common to most liquefaction processes have become evident. Timely programs have been initiated to solve these problems. From this base, a series of efficient combinations to produce liquid fuel requirements will be synthesized. It is highly unlikely that any single second-generation process will be used exclusively. Two or more single purpose processes may be selected depending on the coal type, the products sought, and the plant site selected. A broad program is being planned involving production of sufficent quantities of specification fuels to test their interchangeability with existing petroleum-derived fuels.

Technical success or failure of the program can be measured in terms of the degree to which economy, throughput, unit operations, and conversion efficiency is improved when compared to state-of-the-art processes.

Federal Role

Federal participation is intended to reduce or eliminate for industry financial and technical risks, large capital requirements, and certain unrecoverable costs associated with the program. Government fundings of new processes through early development (approximately 67 percent federal funding of larger pilot plants projects, and approximately 50 percent federal funding of demonstration plants), is one approach used to reduce the risks and costs of industrial RD&D efforts. It also is intended to accelerate progress in new technologies beyond normal commercial capability and promote utilization of a variety of coal types that constitute the national coal resource base.

International Cooperation

Three areas of significant cooperation currently exist. Specifically, under the jointly funded Special Foreign Currency Program, the Polish Government will conduct coal liquefaction studies. Technical liaison is maintained with SASOL at the Sasolburg, South Africa coal liquefaction plant. Finally, a liquefaction data exchange program exists with the United Kingdom.

Technological Status and Problems

Status:

- First generation technologies such as the Fischer-Tropsch and Bergius processes offer a technically feasible basis for development of commercial liquefaction processes. However, excessive product costs, resulting from high capital costs and low conversion efficiency, limits the commercial viability of first generation technologies. Several second-generation pilot plants are at various stages of development: (1) using the pyrolysis process, a Char-oil Energy Development (COED) pilot plant has completed operation and the product is undergoing further analysis; (2) using solvent extraction, a SRC pilot plant is currently operating; and (3) the design of the hydroliquefaction, H-Coal pilot plant is currently in progress. Several process demonstration units (PDU's) are operational and acquiring data on newer technologies.

Problems:

- State-of-the-art solids/liquids separation is not currently economically feasible.
- There is a lack of reliable components for feeding slurry streams to and from high pressure, high temperature vessels.
- Long-term performance of liquefaction catalysts has not been adequately demonstrated.
- Inadequate engineering basis exists for design of heaters and multiphase heat exchange equipment for coal slurry service.

Institutional Status and Problems

Status:

- Existing structure of federal, state and local regulations; transportation facilites, rail, water and pipeline; industry infrastructure; and social legislation has been developed for a low-growth industry producing 600 million tons of coal per year (and no shale).

Problems:

- Problems will result from a needed doubling in 10 years of coal output and with the start of a shale industry.
- Local population concentrations and amenities will rarely be adequate to support the labor requirements of operating mines and conversion plants. There will be a major influx of skilled and unskilled workers into remote areas creating an instant need for roads, schools, housing, etc.
- Massive capital investment will be needed for mines and conversion facilities. While energy demand and the financial needs to meet it grows exponentially, these new technologies require much higher investments per unit of net energy output; thus, sharply increasing capital needs.

Environmental Status and Problems

Status:

- Existing liquefaction pilot plants comply with all applicable environmental regulations. In addition, environmental monitoring is conducted at all pilot plants.

Problems:

- Full characterization will have to be made of pollutant and safety problems for coal liquefaction processes at all stages of development.
- Water resource requirements and priorities are problems generic to coal conversion.
- Development of control technologies may be required for any newly identified air and water pollutants or potential health hazards.
- While similar to problems associated with oil refining technologies, environmental control problems for liquefaction processes are more

severe because of combustion/disposal problems resulting from higher levels of aromatic compounds, and the occurrence of a wide variety of trace elements in the process residues with possible toxicity problems still to be defined.

Program Implementation

The liquefaction program strategy is being implemented by performing research and development at multiple levels of effort including, laboratory exploratory research, process development units, and pilot plants. In some cases scale-up is being overlapped to expedite the near-term construction of pilot plants.

Estimations of the process economies of conceptual commercial plants will be determined with the outputs of operational data from the pilot plant projects. The major activity in the near-term is in process development units (PDU's) and pilot plants, with attendant process evaluations and lab/bench work on third generation processes.

Highlights of projects which are operational or will have progressed to the PDU or the pilot stage in the near future include:

- Synthetic crude oil, capable of being refined to specification fuels (transportation and residential) and boiler fuels, will be produced in a 600 T/D Ebullated Bed Direct Hydrogenation H-Coal pilot plant scheduled for operation in FY 1978 at Catlettsburg, Kentucky.
- Design will be completed and construction will begin at the Pittsburgh Energy Research Center in FY 1976 of a 10 T/D Fixed Bed Direct Hydrogenation Synthoil PDU.
- In FY 1976, a Clean Coke PDU will operate to convert high-sulfur coal to metallurgical coke, chemical feedstocks, and liquid and gaseous fuels.
- An engineering test site will be operational in Cresap, West Virginia in FY 1976 for testing reliability of components and selected unit processes and operations.

For the near term, the primary effort will be directed towards developing existing candidate second-generation processes from the PDU level through the pilot plant stage. Efforts will be directed toward developing comprehensive data to allow estimation of environmental impacts. When decisions are made on site selection for pilot plants, environmental impact statements will be filed. Technical, economic and environmental assessments will be made.

LIQUEFACTION

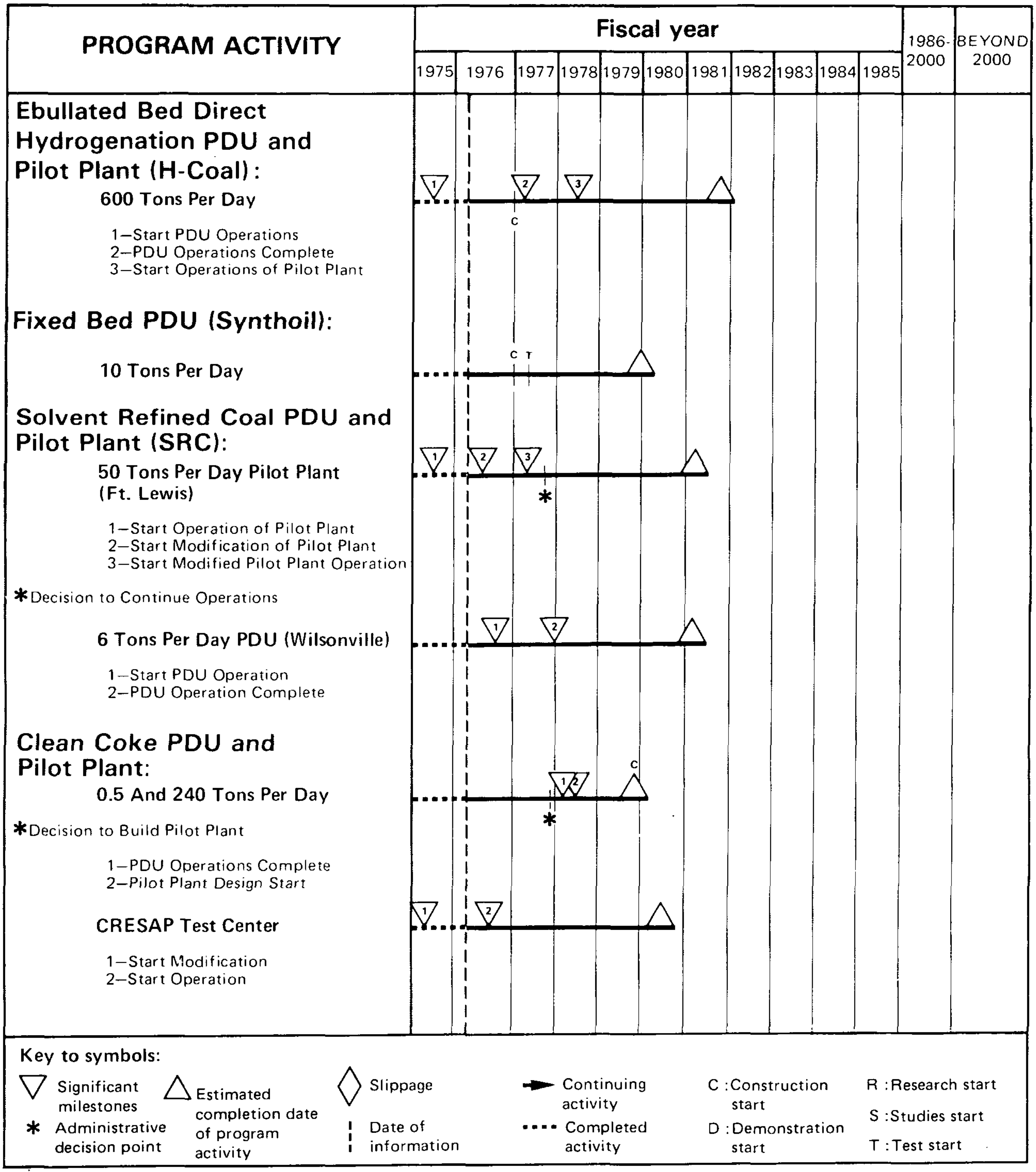
Federal Energy RD&D Budget **($ Millions)**

Agency	FY 1975		FY 1976*		FY 1977	
	BA	BO	BA	BO	BA	BO
ERDA						
Operating Expenses	94.7	35.2	89.9	92.9	73.9	79.5
Plant and Capital Equipment (1)						
Total	94.7	35.2	89.9	92.9	73.9	79.5

(1) Demonstration Projects are funded under the "Coal Demonstration Plants" building block.
* Does not include funds for FY 1976 Transition Quarter.

ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION

LIQUEFACTION



FOSSIL ENERGY

Coal

HIGH BTU GASIFICATION

Objectives

Near-Term:
(–1985)

- To complete the development and demonstration of second generation coal gasification technologies necessary for the construction and operation of commercial scale plants that can convert economically all ranks of coal to substitute natural gas; continue the economic as well as technical evaluation of currently available processes (i.e., first-generation techniques) and assess their applicability to the demands of U.S. markets; ensure that advances in technology achieved in the development of second-generation techniques are used to improve the operational performance of those first-generation techniques now being considered for commercial gasification facilities; initiate laboratory studies and process development of third-generation gasification processes.

Mid-Term:
(–2000)

- To assist private industry in the commercial scale utilization of second-generation coal gasification processes beginning about 1985 with single product plants; continue the development and demonstration of third-generation gasification technologies at commercial scale by 1990; and support private industry on the commercial scale implementation of multiproduct facilities by 2000. The support of these activities may be capable of providing an energy production gain of 6.8 quads per year by 2000, available in substitute natural gas.

National Energy Technology Goals Supported

Primary

- Efficiently transform fuel resources into more desirable forms.

Secondary

- Increase the efficiency and reliability of the processes used in energy conversion and delivery systems.

The high Btu substitute natural gas generated by the gasification of coal will be used by high priority consumers of natural gas. Such use will extend the period over which this high quality energy source will be available to meet consumer demand.

Strategy

The strategy being utilized to achieve program objectives is to proceed as rapidly as possible with the continued concurrent development of a number of second-generation coal gasification processes through the process development unit and the pilot plant stage with the implementation of the technology generated in a demonstration plant stage or on a commercial scale by mid 1980's.

At the same time continued efforts will be made to utilize all technological advances resulting from this work to increase the range of applicability, operational efficiency, and environmental compatibility of first-generation, state-of-the-art processes that are currently available for use. The implementations of both generations of gasification technologies on a demonstration/commercial scale will be supported by data generated in a number of auxilliary studies. As this work on first- and second-generation gasification processes proceeds, further effort will be directed toward the evaluation and continued development of advanced third generation coal gasification techniques, Although many of the gasification processes under development appear to be similar in concept and objective, each is characterized by important differences that warrant concurrent development to a point that the relative merits of these differences can be established.

Technical success or failure of the program can be measured in terms of the degree to which economics, throughput, reliability, and conversion efficiencies are improved when compared to current state-of-the-art processes.

- Transfer and movement of solids between and within multiple fludized beds.
- Equipment and component development.

Federal Role

Federal participation in this program helps to reduce or alleviate the financial risks usually associated with the development of new technologies. In this program, the cost of development through the process development unit stage is borne by the government. Pilot plant costs are shared on a one-third industry (principally the American Gas Association), two thirds government basis while the demonstration plants are cost-shared on a fifty-fifty basis. Federal participation will also serve to accelerate progress in new technologies beyond normal commercial capability.

International Cooperation

A cooperative data exchange program exists with the British Gas Corporation.

Cooperative fixed bed gasification studies at Westfield, Scotland, were supported by combined government/industry funding.

Technological Status and Problems

Status:

- There are state-of-the-art gasification processes available. Second-generation technologies are being developed in pilot plants under construction or in operation and third-generation processes are under investigation at the bench scale level of development.
- A Request for Proposal (RFP) has been issued to support a demonstration plant effort.

Problems:

- Improved heat removal during methanation.
- Methods of prolonging catalyst life.
- Pretreatment of agglomerating coals.
- Erosion and corrosion problems.
- The Synthane pilot plant will complete its shakedown tests in late FY 1976 and begin operation shortly thereafter.
- The Steam Iron pilot plant construction will be completed during FY 1976 and operation and engineering evaluations will then begin and go through FY 1979.
- The Self-Agglomerating PDU construction will be completed during FY 1976 and operation will then begin and continue through the end of FY 1978.
- Support programs for the development of materials of construction, commercial equipment and auxiliary processes such as liquid phase methanation are also being conducted to support the High Btu Program.
- The Hydrane process, a third generation concept, will be evaluated during FY 1976 and a decision made on starting construction of the PDU.

Institutional Status and Problems

Status:

- Existing structure of federal, state and local regulations; transportation facilities, rail, water and pipeline; industry infrastructure; and social legislation has been developed for a low-growth industry producing 600 million tons per year of coal (and no shale).

Problems:

- Problems will result from a needed doubling in 10 years of coal output and with the start of a shale industry.
- Local population concentrations and amenities will rarely be adequate to support the labor requirements of operating mines and conversion plants. There will be a major influx of skilled and unskilled workers into remote areas creating an instant need for roads, schools, housing, etc.
- Massive capital investment will be needed for mines and conversion facilities. While energy demand and the financial needs to meet it grows exponentially these new technologies require much higher investments per unit of net energy output; thus, sharply increasing capital needs.

Environmental Status and Problems

Status:

- The potential environmental impact of large coal gasification facilities is being addressed for both state-of-the-art and second-generation coal gasification processes. Two environmental impact statements have been filed in New Mexico on plants that would employ state-of-the-art processes. One of the major objectives of the pilot plant program is the mitigation of potential adverse environmental impacts. Existing gasification pilot plants comply with all applicable environmental regulations. Environmental monitoring is conducted at all facilities.

Problems:

- Water resource requirements and priorities are problems generic to coal conversion.
- Potential pollutant and safety problems will have to be characterized for both long-range and short-range impacts.
- Magnification of environmental problems due entirely to large size of commercial high Btu coal gasification plants. Effects of current pilot plants are insignificant. Commercial-sized plants, however, will have appreciable effect on land-use, resources, regional economics, wastes, etc.

Program Implementation

Emphasis has been placed on the concurrent development of a number of advanced processes for the gasification of coal. This work, being performed in parallel, will reduce the time required to generate data sufficient for a technical and economic evaluation of competing processes. At the same time, the representative problem areas associated with these technologies will be investigated and the solutions will be available for use in the demonstration plant program or to improve current state-of-the-art processes.

At present the High Btu Gasification Program is conducting the following pilot plants and process development units:

- The HYGAS pilot plant is operational and undergoing engineering evaluations. An administrative decision will be made in FY 1977 to continue or stop its operation.
- The Bi-Gas pilot plant will be completed in FY 1976 and is planned to be in operation through FY 1980. The critical engineering evaluations and mechanical reliability of the process are planned to be completed by FY 1981.
- The CO_2 Acceptor Pilot Plant is currently being operated. The engineering evaluations will begin in FY 1977 as a basis for an administrative decision to continue or stop its operation.

HIGH BTU GASIFICATION

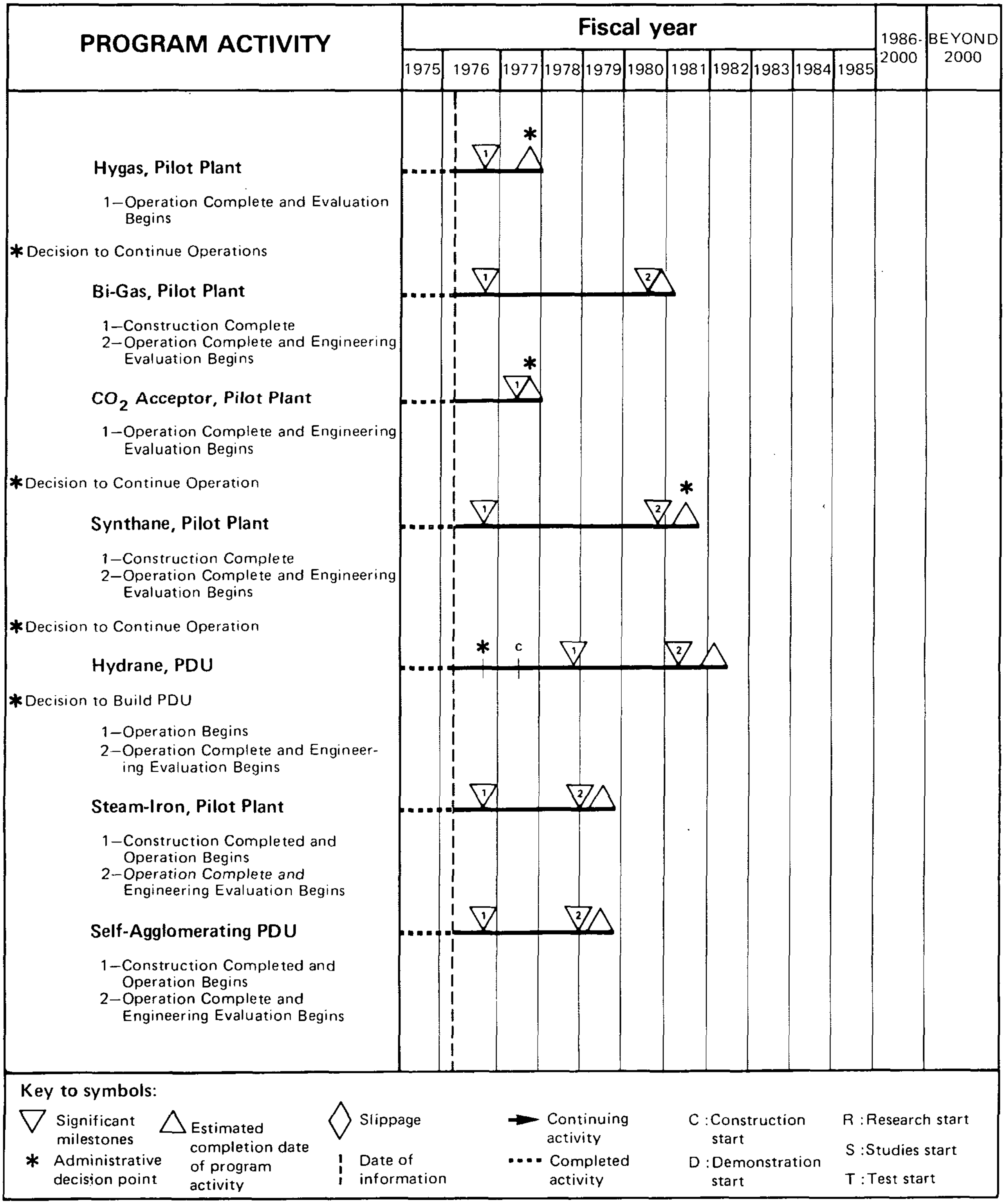
Federal Energy RD&D Budget (\$ Millions)

Agency	FY 1975		FY 1976*		FY 1977	
	BA	BO	BA	BO	BA	BO
ERDA						
Operating Expenses	59.8	36.0	53.4	37.3	45.1	59.3
Plant and Capital Equipment	0	0	0	0	0.1	0
Total	59.8	36.0	53.4	37.3	45.2	59.3

* Does not include funds for FY 1976 Transition Quarter.

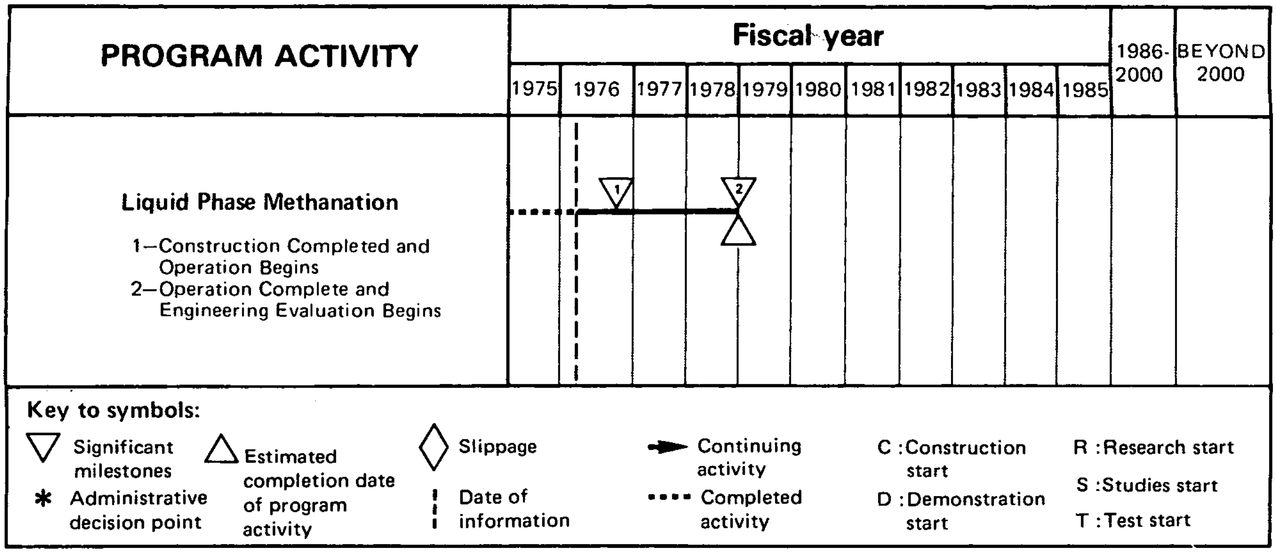
ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION

HIGH BTU GASIFICATION



ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION

HIGH BTU GASIFICATION (Continued)



FOSSIL ENERGY

Coal

LOW BTU GASIFICATION

Objectives

Near-Term:
(–1985)

- To provide the technologies required for the construction of plants to demonstrate the conversion of domestic coal resources to environmentally acceptable low Btu gas for:
  —Electric power generation including combined cycle systems;
  —Industrial and process heat applications; and
  —Chemical feedstocks.
- To provide for the transfer of technology resulting from this program to commercial users of existing gasification systems.

Mid-Term:
(–2000)

- To assist the commercial implementation of second-generation technologies beginning about 1985–86 with single product plants. Develop, make available, and demonstrate third-generation technologies by 1990 in participation with private industry.
- To produce 1.8 quads of low Btu substitute gas by 2000.

National Energy Technology Goals Supported

Primary

- Efficiently transform fuel resources into more desirable forms.

Secondary

- Increase the efficiency and reliability of the processes used in energy conversion and delivery systems.
- Transform consumption patterns to improve energy utilization.

Strategy

The strategy is to develop gasifier and hot gas cleanup systems that operate at atmospheric and elevated pressures to produce electric utility and industrial fuels, and chemical feedstocks. Since the state of development of atmospheric pressure gasification is more advanced than that of pressurized systems, the program pursues the atmospheric development as a primary objective and at the same time continues the development of pressurized systems.

Hot gas cleanup systems provide for high efficiency operation of combined cycle plants, and enhance the availability of such systems at the same time low Btu gasification systems are developed. This will provide industry with a source of a clean low Btu fuel suitable for use in gas turbines.

In order to compress the time required to develop a suitable gasification system for demonstration, several promising concepts (i.e., fixed bed, entrained bed, and molten salt) were selected for concurrent development. The results of these development projects will provide a basis for evaluating and comparing the different concepts. These comparisons, along with economics and fuel supply factors prevailing at thet time of selection, will be used to determine any process selected for the demonstration program.

Federal Role

Federal participation is intended to reduce risk and capital requirements of industry where those factors are of sufficient magnitude to preclude industrial lead.

The current commercial low Btu gas processes are not promising enough to guarantee the availability of low Btu gas in the near-term. The federal government therefore, must supplement industry efforts in order to deliver improved technology in the appropriate time frame.

Federal participation involves total government funding of new processes through early development, approximately 67 percent federal funding of pilot plant projects (100 ton per day units) and approximately 50 percent federal funding of demonstration plants.

International Cooperation

A cooperative data exchange program exists with the British Gas Corporation that encompasses both low Btu gas and hot gas cleanup processes.

Technological Status and Problems

Status:

- Commercial gasification technologies exist. The low Btu program efforts are directed toward the development and improvement of fluid bed, entrained bed, combined cycle, molten salt and fixed bed processes.

Problems:

- The processing and utilization of caking coals which agglomerate in the gasifiers.
- Equipment does not exist to continuously feed coal into a high pressure system.
- Sulfur removal and gas cleanup at high temperatures.
- Materials development of critical components for use at high temperature and pressure and in a corrosive environment.
- Sizing and modification of equipment used in the retrofit of existing boilers to low Btu gas.

Institutional Status and Problems

Status:

- Existing structure of federal, state and local regulations; industry infrastructure; and social legislation has been developed for a low-growth industry producing 600 million tons per year of coal (and no shale).
- Utility interest is currently shown by a jointly funded, commercial size low Btu/combined cycle plant for electrical generation.

Problems:

- Local population concentrations and amenities will rarely be adequate to support the labor requirements of operating mines and conversion plants. There will be a major influx of skilled and unskilled workers into remote areas creating an instant need for roads, schools, housing, etc.
- Massive capital investment will be needed for mines and conversion facilities. While energy demand and the financial needs to meet it grows exponentially these new technologies require much higher investments per unit of net energy output; thus, sharply increasing capital needs.

Environmental Status and Problems

Status:

- Although low Btu gasification promotes environmentally acceptable use of coal, there are environmental impacts associated with the processing of coal.
- Hot gas cleanup and other environmental control systems are being developed simultaneously to mitigate these impacts.

Problems:

- Techniques for the control of trace elements and fine particulate emissions from end usage devices need to be developed.
- Land use, reclamation and water resource requirements are problem areas generic to coal conversion.
- Problems of scale will be encountered when increasing size from small demonstrations to full-scale commercial application.

Program Implementation

The Low Btu Program is being implemented through the sequence of bench scale, PDU, pilot plant, and demonstration plant phases.

The development of an atmospheric pressure gasifier is being pursued in the entrained bed gasification project. This five ton per hour unit will utilize existing components and technology in all areas except the gasification reactor. The project is currently scheduled for operation in FY 1978.

The more sophisticated pressurized units being developed in the program are:

- A three-stage fluid bed gasification one ton per day PDU is currently operational and is being evaluated to obtain process scale up data or future processes.
- A two-stage fluid bed gasification 0.6 ton per hour PDU on which construction has been completed will be operational during 1976 to evaluate the use of dolomite as an internal sorbent

for the removal of hydrogen sulfide and to obtain scale up data for the design of larger units.

- A proposal for the construction of a combined cycle pilot plant which will use state-of-the-art pressurized fixed bed gasifiers, cleanup equipment, and electric power generating equipment is currently being evaluated.
- A five ton per hour Molten Salt PDU is in the design stage and scheduled for operation in FY 1977.

LOW BTU GASIFICATION

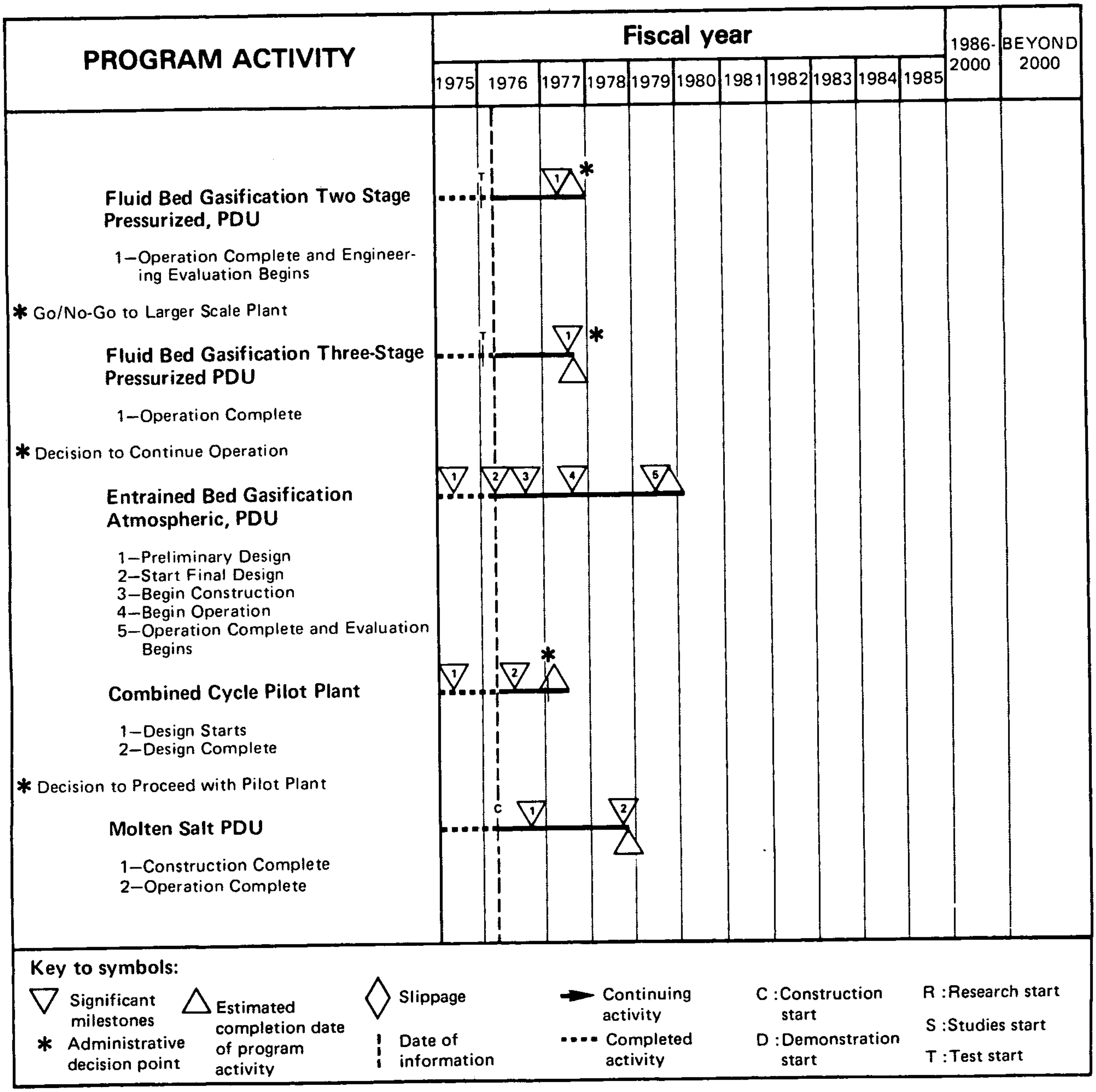
Federal Energy RD&D Budget **($ Millions)**

Agency	FY 1975		FY 1976*		FY 1977	
	BA	BO	BA	BO	BA	BO
ERDA						
Operating Expenses	50.0	23.3	24.6	36.0	33.1	40.0
Plant and Capital Equipment	0	0	0	0	0	0
Total	50.0	23.3	24.6	36.0	33.1	40.0

* Does not include funds for FY 1976 Transition Quarter.

ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION

LOW BTU GASIFICATION



FOSSIL ENERGY

Coal

ADVANCED POWER SYSTEMS

Objectives

Near-Term:
(–1985)

- To establish a technology base that will support development of advanced gas turbine systems (open and/or closed cycle) for use with coal and/or coal derived fuels to meet utility intermediate and baseload power generation requirements.

Mid-Term:
(–2000)

- To develop and encourage commercial implementation of combined cycle power plants using high temperature turbines fueled by coal-derived low Btu gas.
- To develop closed cycle turbine systems with improved economy using coal in an environmentally acceptable manner.
- Advanced systems may be capable of substituting between 2 and 4 quads of coal for oil and natural gas by the year 2000 in new plants.

National Energy Technology Goals Supported

Primary

- Increase the efficiency and reliability of the processes used in energy conversion and delivery systems.

Strategy

The strategy for the open cycle gas turbine program is to achieve technology readiness by development of key components for incorporation into a prototype advanced high temperature gas turbine. Since the closed cycle and alkali metal vapor turbine systems are less mature, the strategy is to proceed with system definition and optimization trade-off studies simultaneously with technology development and testing. Industry participation and cost sharing will be encouraged and are expected.

A manufacturing industry exists to produce full-scale machinery. Little value would exist in the construction of a subscale pilot plant, since the engineering experience gained on subscale turbine systems would have to be repeated in the development of full-scale equipment. Thus, once the cost and risk are known and attractive, industry can proceed with the demonstration of full-scale turbines. This applies to both open and closed cycle gas turbines.

Federal Role

Federal participation will alleviate the financial risk associated with development of new technologies. With government participation, accomplishments in these new technologies can be expected much earlier than solely with industry support. Currently, the federal role is 100 percent funding through the PDU level, although there is some cost sharing. Pilot plants are generally supported with 75% federal funds. Demonstration plants are supported on a 50/50 basis.

By accelerating availability of these advanced technologies, commercialization should be accomplished at a much earlier date. Industry participation will increase as the technology advancement program passes initial performance and cost milestones.

International Cooperation

At the technical level, considerable information exchange exists between domestic and foreign turbine manufacturers and development engineers.

Foreign firms manufacture American products under license and export control, and domestic manufacters to a lesser extent, use foreign licenses.

Technological Status and Problems

Status:

The gas turbine program has as its foundation over 35 years of aircraft propulsion and industrial turbine development experience. An extensive technology base in manufacturing materials, design, testing and operation exists with the following characteristics.

- Technology based on clean fuels.
- Turbine inlet temperatures are currently limited to 2000 degrees F.
- Modest temperature closed cycle systems are operating with limited economic potential.
- Small scale alkali metal vapor turbines have operated as part of the space program.

Problems:

- Efficient and economic hot gas cleanup systems are not yet developed.
- Practical high temperature turbine cooling systems do not exist.
- Closed cycle system heat exchanger components operating at high pressure and high temperature from direct coal combustion are not durable.
- Bearings, seals and auxiliaries of adequate durabiilty for these systems do not exist.

Institutional Status and Problems

Status:

- The advanced power systems being developed will be ready for implementation in—at minimum—5 to 6 years. Regulations, economics, and industrial actions must thus be considered in that time frame.

Problems:

- Problems will result from a needed doubling in ten years of coal output and with the start of a shale industry.
- Massive capital investment will be needed for mines and conversion facilities. While energy demand and the financial needs to meet it grows exponentially these new technologies require much higher investments per unit of net energy output, thus, sharply increasing capital needs.

Environmental Status and Problems

Status:

- New coal-fired facilities are limited to emissions of 1.2 lbs SO_2 and 0.7 lbs nitrogen oxides per million Btu of fuel input.

Problems:

- The techniques for limiting pollutants to comply with existing environmental regulations are not known.

Program Implementation

The Advanced Power System Program for meeting the program goal of "Technology Readiness" followed by commercial demonstration is being implemented by advancing the technology of key components for the open cycle and the closed cycle gas turbine systems and the alkali metal vapor turbine system.

The open cycle turbine program will be implemented by advancing the technology of a 2600 degree F multi-stage turbine subsystem to a "Technology Ready" status. The Program is divided into three phases as follows:

Phase I —Program and System Definition—This phase will generate conceptual designs and perform trade-off analyses of the open cycle turbine system including the gasifiers, gas turbines and steam bottoming systems.

Phase II —Technology Test and Test Support Studies—In this phase the individual components and their support test equipment will be fabricated and evaluated. Also, the high temperature turbine system will be defined.

Phase III—Technology Readiness Verification Tests —In this phase the high temperature turbine system will be tested.

Successful completion of these three phases will provide Technology Readiness and from this development stage, commercial demonstration is expected to follow.

Implementation plans for the closed cycle turbine and alkakli metal vapor turbine systems which are considered to be not as advanced as the open cycle system, are to proceed with system definition and optimization studies concurrently with technology development of key components such as the primary heat exchanger. Upon obtaining technological data that demonstrates the economic and technological attractiveness of these systems, subsequent development phases may be undertaken.

Fluidized Bed Combustors would be used with advanced closed cycle and alkali metal vapor turbine systems as well as the conventional steam systems for which they are currently being developed. The advanced turbine development program would benefit the pressurized fluidized bed program by providing a technology for more durable turbines imploying the direct use of coal.

Combined cycle power systems utilizing advanced open cycle gas turbine systems combined with conventional steam plants, have the potential of producing electrical power in an environmentally acceptable manner at higher generating efficiencies and lower cost from coal derived fuels.

Consequently, with the open cycle gas turbine combined with a gasifier and cleanup system to utilize low Btu coal gas, a means is provided for utilizing coals of all ranks, quality and sulfur content with much lower pollution levels per unit power output. Open cycle gas turbine engine emissions of concern when utilizing low Btu coal gas are CO, NO_x and SO_x. The open cycle turbine program includes development of a low Btu combustor to ensure adequaely low NO_x emissions. Remaining emission problems from sulfur and particulates are addressed in the low Btu gasification program elements.

The closed cycle gas turbine in combination with a bottoming cycle can also produce power at a cycle efficiency superior to existing, commercially-available plants. However, these plants are a mid-term to long-term development.

Other DOD and ARPA developments programs in the area of ceramics are supplying into the ERDA high-temperature materials programs. In addition, a joint inter-agency program with NASA is presently being formulated.

ADVANCED POWER SYSTEMS

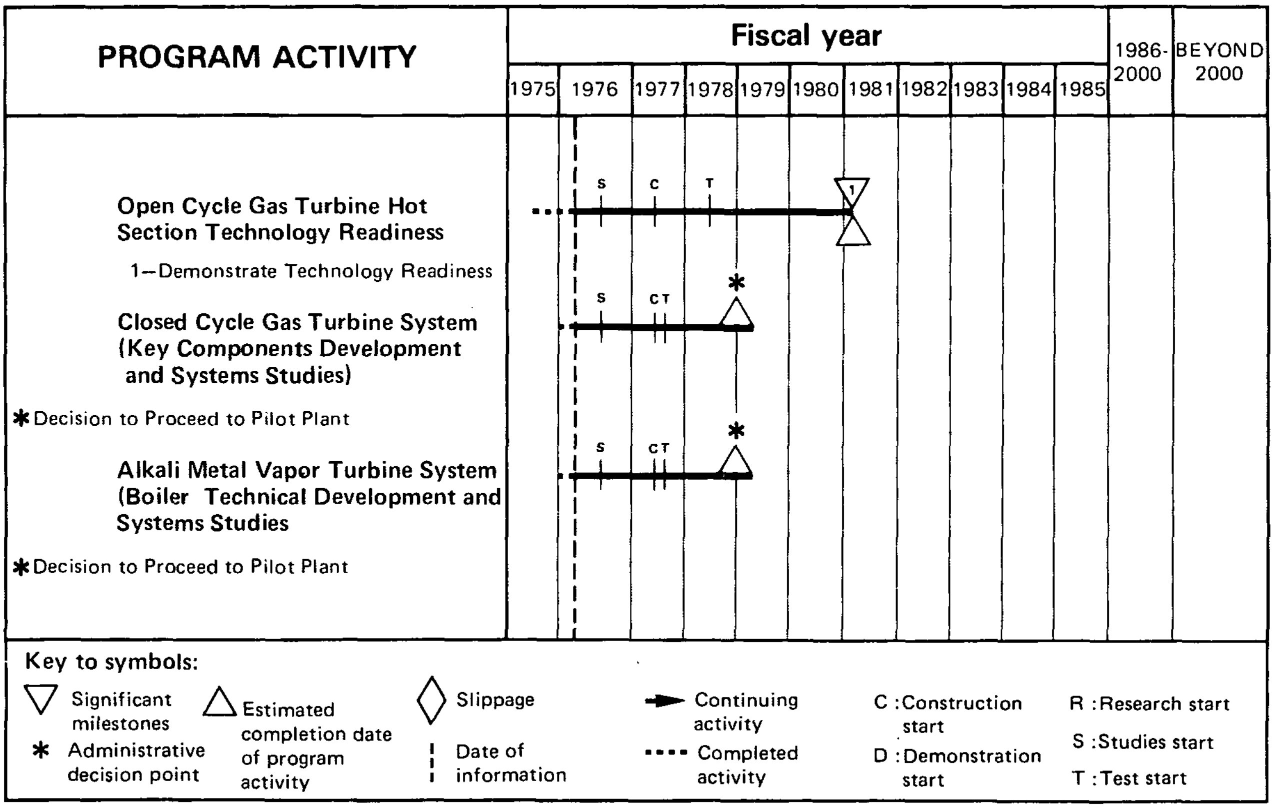
Federal Energy RD&D Budget **($ Millions)**

Agency	FY 1975		FY 1976*		FY 1977	
	BA	BO	BA	BO	BA	BO
ERDA						
Operating Expenses	4.1	1.7	10.0	7.5	22.5	12.8
Plant and Capital Equipment	0	0	0	0	0	0
Total	4.1	1.7	10.0	7.5	22.5	12.8

* Does not include funds for FY 1976 Transition Quarter.

ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION

ADVANCED POWER SYSTEMS



FOSSIL ENERGY

Coal

DIRECT COMBUSTION

Objectives

Near-Term:
(–1985)

- To develop and demonstrate on a commercial scale, the technology for heat and power generation using fluidized bed combustors fueled by high-sulfur coals and coals of all ranks and qualities in an environmentally acceptable and economically attractive manner.
- To develop and demonstrate on a commercial scale, coal-oil slurry firing as a retrofit technique for existing industrial and utility oil fired combustors.
- To improve the reliability and efficiency of present boiler systems.

Mid-Term:
(–2000)

- To encourage industry to implement fluidized bed combustion processes for heat and power generation on a nationwide scale.
- To increase options for environmentally acceptable direct coal utilization at cost and efficiencies superior to present alternatives.
- By the year 2000, direct combustion systems using coal can substitute between 6 and 8 quads of oil and gas annually.

National Energy Technology Goals Supported

Primary

- Expand the domestic supply of economically recoverable energy producing raw materials.

Secondary

- Increase the efficiency and reliability of the processes used in energy conversion and delivery systems.

Strategy

The strategy is to initiate a series of projects that will demonstrate fluidized bed combustion as an economic, practical and environmentally acceptable technique to use coal of all ranks, quality and sulfur content. This permits coal to replace oil and gas firing of utility and major industrial heat and steam plants. Coal-oil slurry and other combustion systems will be developed in conjunction with utilities, industrial and institutional users and equipment manufacturers. Reliability and efficiency data of present boiler systems will be compiled and analyzed so that improvements can be quantitatively assessed and evaluated.

Federal Role

The federal government's role is to develop and demonstrate technologies and processes which are in the public interest and in which private industry is not investing due to the size of investment requirements, the extent of risk, or the length of the commercialization process. Federal participation involves total government funding of new processes through early development; approximately two-thirds funding of pilot plant projects; and about one-half funding of demonstration plants.

International Cooperation

The United States is cooperating in the "Fluidized Bed Combustion Test Facility Project" implemented under an International Energy Agency (IEA) agreement signed in November 1975. The participating nations (United States, United Kingdom, and the Federal Republic of Germany) plan to jointly fund the construction and operation of a pressurized fluidized bed combustor to be located in the United Kingdom. The IEA facility will be used to provide scientific combustion research information on pressurized fluidized bed combustion of world-wide coals and limestones with configuration appropriate for commercial applications.

Technological Status and Problems

Status:

- Preliminary cost studies based on data on SO_x and NO_x emissions from research combustors, have shown that fluidized bed combustion with the capture of SO_x in the bed sorbent can be a less expensive and more efficient cleanup system than stack gas scrubbing.
- Several bench sized fluidized bed combustors are in operation. Experimental sorbent regeneration, pressurized combustion and combustion gas cleanup devices have been built and operated.
- A 30 MW atmospheric, fluidized boiler facility has been fabricated and erected at Rivesville, West Virginia, and is scheduled to be operational by mid-1976.
- A 1 MW pressurized fluidized bed process development unit is in operation to provide design, materials and environmental data.
- Coal-oil slurry firing has been tested several times in the past 60 years. The main concern today pertains to the preparation cost and the handling of the post-combustion products.

Problems:

- Reliability of coal feed, ash disposal and hot gas cleanup must be demonstrated for industrial acceptance.
- The data on erosion/corrosion rates of tubes immersed in fluidized beds must be obtained to support design of commercial equipment.
- Sorbent regeneration systems for eliminating the large quantities of limestone/dolomite required for fluidized bed combustion must be developed.
- Large size multi-bed fluidized bed combustion unit operational stability data must be obtained.
- Coal oil slurry preparation data and firing reliability need to be established.

Institutional Status and Problems

Status:

- Existing structure of federal, state and local regulations; transportation facilities, rail, water and pipeline; industry infrastructure; and social legislation has been developed for a relatively small, low-growth industry.
- As a new technology, feasibility will have to be demonstrated prior to acceptance. Economic feasibility will be difficult to evaluate due to uncertainties of the final market price.

Problems:

- Local population concentrations and amenities will rarely be adequate to support the labor requirements of operating mines and conversion plants. There will be a major influx of skilled workers into remote areas creating an instant need for roads, schools, housing, etc.
- Massive capital investment will be needed for mines and conversion facilities. While energy demand and the financial needs to meet it grows exponentially these new technologies require much higher investments per unit of net energy output; thus sharply increasing capital needs.

Environmental Status and Problems

Status:

- New coal fired facilities are limited to emissions of 1.2 lbs SO_2 and 0.7 lbs nitrogen oxides per million Btu fuel input.
- Data from process development units indicate that fluidized bed combustors can meet environmental standards.
- Carbon containing by-products (char and beneficiation wastes) have been successfully burned in fluidized bed combustors.
- Modeling activities are under way to predict product and by-product distributions based upon coal composition inputs.
- Environment and safety design criteria have been fully incorporated into hardware development activities for coal feed and ash disposal systems, hot gas cleanup systems, and materials development programs for fluidized bed combustion processes.

Problems:

- Extensive, multiple and fragmented permit and approval requirements for environment and safety have significant schedule and cost impacts.
- Site selection procedures are not clearly defined. However, some guidelines are emerging, which will be supplemented to provide a comprehensive plan.
- Procedures are being developed for coordinated actions of the legislative, regulatory and other political, institutional and environmental groups

involved. However, the issues are broad and complex, and considerable work is yet to be done.

Program Implementation

Industrial host sites will be used for pilot demonstration plants to facilitate and encourage industrial participation in the design, fabrication, erection and operation of fluidized bed combustion systems. Industry program involvement will assist in solving institutional and technological problems.

The atmospheric, fluidized bed boiler project has underway the construction of a 30 MW boiler at the Monongahela Power Company plant at Rivesville, West Virginia. It is scheduled to be operational by mid-1976. Testing will continue through 1978.

Operational data obtained from the 30 MW facility will be used in preparing the conceptual design of a 200 MW unit. Concurrently, component development, test and integration work will be conducted.

A study of the feasibility of plant conversion of existing boilers and process heaters will be initiated in FY 1977. A Program Opportunity Notice has been issued to cover a variety of industrial/institutional applications of fluidized bed boilers and steam and process heaters for commercial applications. These small sized fluidized bed development programs are expected to begin in FY 1976. They will be initiated by conceptual design studies and component testing. In subsequent phases, fabrication of prototype equipment and test program definition will be followed by testing in the last phase. Multiple contracts are expected to be awarded since there are four fluidized bed application categories: High pressure steam generation; low pressure boilers; industrial process heaters and direct fired heaters. The timing for these individual projects will vary somewhat; however, the program definition and concept design phase is expected to require approximately one year with completion by the end of FY 1977. The prototype fabrication phase should require 2 to 3 years depending on the specific application with the testing program phase beginning about FY 1980 and continuing throughout FY 1982. At that time, ERDA management will determine whether continued development work is warranted.

The pressurized, fluidized bed program includes a 1 MW process development unit which is providing performance, materials, durability and environmental emissions data. The design, construction and testing of a 13 MW combined cycle pressurized fluidized bed pilot plant will be initiated in FY 1976 with a study of comparative commercial systems and a preliminary design of the pilot plant. This phase is expected to be completed in FY 1977. The next phase is the detailed design of the pilot plant to be completed in early FY 1978. Phase III, construction of the pilot plant, will occur in FY 1978 and FY 1979. In Phase IV, operational testing will be performed in FY 1980 and FY 1981. During the testing phase, preliminary studies of demonstration plants may be initiated so that the program can proceed to prompt commercialization. Fossil Energy will also participate in a pressurized coal combustor research project under the management of the International Energy Agency (IEA). The IEA facility will be used to provide scientific bed combustion research information on pressurized fluidized bed combustion of world-wide coals and limestones. The preliminary design of a Component Test and Integration Unit (CTIU) has been initiated. This facility will be used in programs supporting the pressurized combined cycle plant program.

Coal-oil slurry combustion will be investigated as a retrofit to present oil or gas fired boilers to determine the extent to which this technology can be implemented to substitute coal in industrial and utility combustors. Laboratory studies, other feasibility studies, system analyses, etc., are underway to support the development programs for atmospheric and pressurized bed boilers.

Another project funded by EPA pass through funds to TVA (to be finished in FY 1976) will compare the projected costs of both atmospheric and pressurized fluidized bed power plants to the costs of conventional coal fired steam power plants utilizing flue gas desulfurization.

A concept study for Project MIUS (Modular Integrated Utility System), a cooperative activity involving seven federal agencies, has led to a specific program to develop modular, decentralized, coal fired electric power plants located within a community which uses power plant waste heat for heating, hot water, and air conditioning. MIUS is in the detailed design phase and will proceed to construction in FY 1977. Construction is expected to be completed in FY 1979, at which time testing will commence. A two-year testing period is planned to be completed in FY 1981. Operational data will then be available that may lead to commercialization of the coal fueled total energy system.

DIRECT COMBUSTION

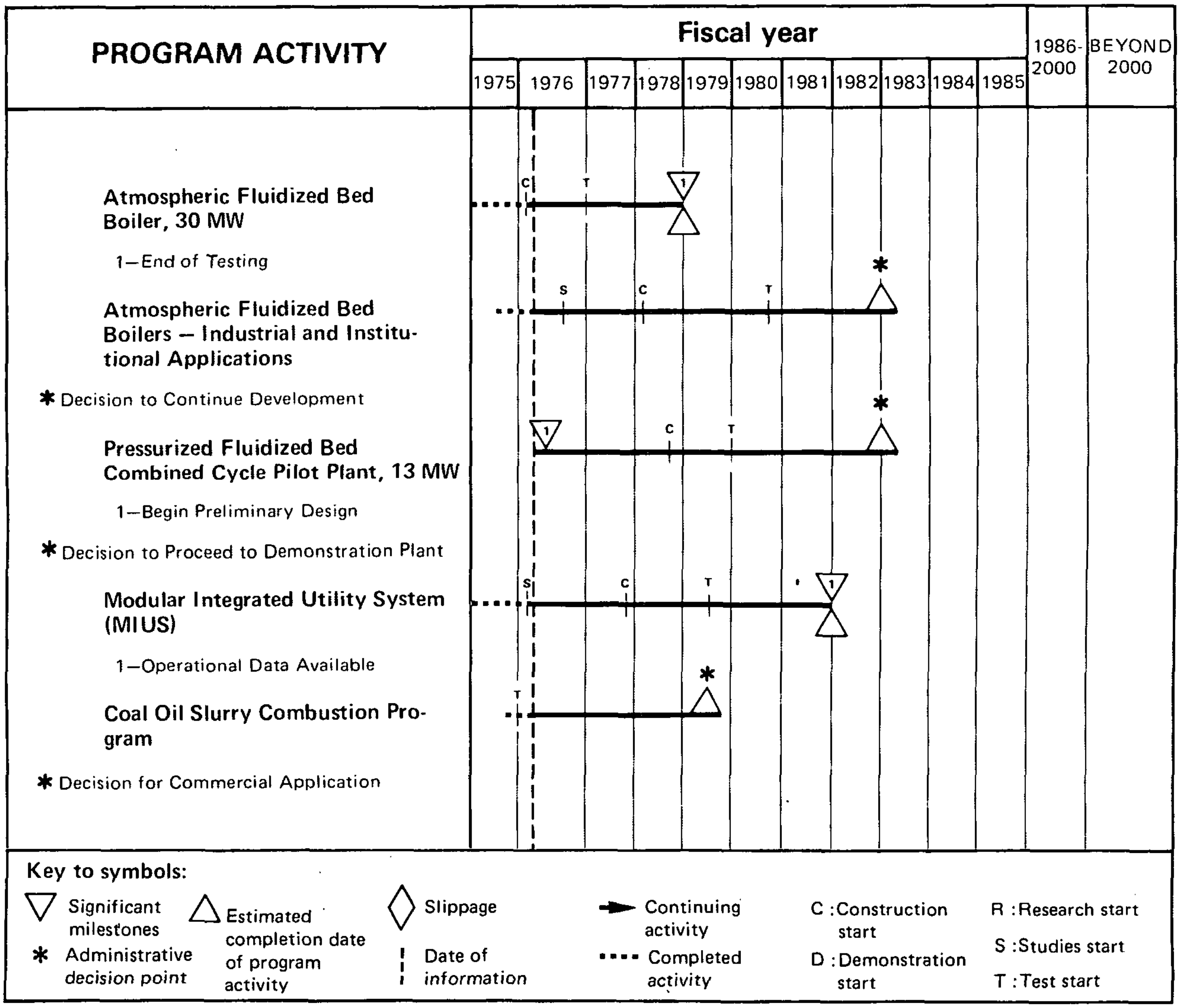
Federal Energy RD&D Budget **($ Millions)**

Agency	FY 1975		FY 1976*		FY 1977	
	BA	BO	BA	BO	BA	BO
ERDA						
Operating Expenses	35.9	10.6	38.1	32.6	52.4	52.1
Plant and Capital Equipment	0	0	0	0	0	0
Total	35.9	10.6	38.1	32.6	52.4	52.1

* Does not include funds for FY 1976 Transition Quarter.

ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION

DIRECT COMBUSTION



FOSSIL ENERGY

Coal

ADVANCED RESEARCH AND SUPPORTING TECHNOLOGY

Objectives

Near-Term:
(–1985)

- To discover and develop the materials and components that ensure reliable, efficient, and environmentally acceptable plants for coal conversion and combustion.
- To discover technologies for improved direct utilization of coal.
- To discover advanced processes for coal conversion to synthetic fuels.
- To conduct systems analyses of processes and technologies to aid in the formulation of planning and policy options.
- To increase the supply of personnel trained in fossil energy technologies from our Nation's university system.

Mid-Term:
(–2000)

- To lay the foundation for technologies leading to improved and innovative advanced coal conversion and combustion processes that could be used by private industry .

National Energy Technology Goals Supported

Primary

- Perform basic and supporting research and technical services related to energy.

Secondary

- Protect and enhance the general health, safety, welfare and environment related to energy.

Strategy

The strategy is to identify those areas where research has the highest potential for technological improvements. The supporting technology will deal with second-generation technology projects five to ten years hence. The advanced research will deal with problems of third-generation technologies.

Federal Role

The major new technologies in coal conversion and utilization are characterized by relatively long lead times and high research risks. Private industry alone cannot meet the task. The federal role is threefold: (1) to conduct a complementary research program in a time frame that satisfies national needs, (2) to undertake the high risk, high potential payoff programs that industry is unable or unwilling to support with corporate funds, and (3) to establish a research climate in fossil energy that is conducive to further action by private industry and universities.

Technological Status and Problems

Status:

- Existing materials, components, processes and technologies are generally not applicable to second- and third-generation development.
- Typical first operation problems are intensified by time, materials and operating parameters.

Problems:

- Costs of coal conversion processes are presently too high.

Program Implementation

This activity serves as the central research point for all elements of coal. Major subtechnology areas include efforts on materials and components, process development, fuel utilization and university relations for coal, as well as shale, petroleum and gas.

Significant near term activities are underway to develop analytical techniques required for the measurement of environment and safety related trace contaminants. Additional data on coal chemistry and the characterization of products and byproducts from coal conversion processes are underway. Significant research activities are underway for stack gas cleanup studies to support expanded direct utilization of coal and low Btu gas from coal.

A broad research program on materials and components develops equipment which will function in an efficient, reliable and environmentally acceptable manner under the conditions required in a variety of coal conversion and utilization processes. These conditions include operation at high temperatures and pressures and under hostile erosive and corrosive conditions. Metallic alloys and ceramic materials will be tested for suitability. This research will lead to more durable heat exchangers, reduce fireside corrosion of boilers, and improved materials for construction of boilers, conversion reactors, gas turbines and magnetohydrodynamics (MHD) equipment.

Improved processes will lead to the development of new improved third-generation processes. This general research is supported by efforts to improve catalysts and analytic instrumentation as well as to develop additional data in coal chemistry on chemical reaction mechanisms, kinetics and coal structure. Early efforts will concentrate on development of novel halide catalysts, very rapid hydroliquefaction of coal to aromatics, coproduction of coke and chemicals, and advanced processes for converting synthetic gas to hydrogen and other chemicals.

The utilization of coal in pressurized bed boilers will be improved by research in desulfurization efficiency. The utilization of low Btu gas will be extended by research on efficient cleanup processes.

The university program will maintain a broad involvement in basic and applied fossil fuels research, primarily in the area of coal. A major function of this research support is ensuring an adequate base of technical manpower trained in fossil fuel science and technology.

Systems Studies project will include the following investigations:

Long Range Strategy:

This area will continue the development of Fossil Energy strategies and rationale to enable a more informed choice of a set of advanced technologies for RD&D. Continuing and planned studies include:

- Development of program strategies and priorities that reflect the future requirements of the real-world market place. To accomplish this, analyses of market requirements and applications potentials will be made, together with analysis of technology readiness and risk assessment.
- Benefit/cost analyses including assessments of: the value of a federal RD&D program in tertiary recovery in terms of increased potential supply and production and decreased costs; products derived from coals for future use in electric utility, gas utility, and industrial applications; the requirements and tradeoffs for coal handling, blending and beneficiation.
- Analysis of the commercialization potential and attendant problems for advanced fossil energy technologies as well as the means to expedite the transfer to these technologies to commercial use.

Planning and Budget:

The objective of this area is to continue the development of integrated fossil energy plans, programs and budgets within the strategic framework established above. Other responsibilities include:

- Planning of fossil energy resource requirements.
- Independent budget review of fossil energy projects and development of guidelines for program objectives and milestones.
- Coordination of Energy Research Center and National Laboratory activities with ERDA Operations Offices.

Review and analysis:

This area will continue to a) independently review and analyze selected fossil energy projects for the purpose of assessing progress toward outlined objectives, and b) evaluate and analyze process technology, process design and process economics as related to fossil energy research, development and demonstration projects. Planned and continuing activities include:

- Intensify process design and economic analyses of fossil energy recovery and conversion technologies, including coal, oil shale, petroleum, natural gas and heavy oils; identify new fossil energy sources and technologies that warrant process design and economic evaluation.
- Review, analyze and evaluate selected fossil energy technologies and process designs; compare competitive processes; and expand the knowledge base for coal conversion technologies through the analysis of foreign technologies.

- Develop criteria for analyzing Fossil Energy program goals and objectives; maintain continuing review of programs to ensure that adequate progress is made; review specific fossil energy projects to determine their technical progress and performance; and assist in preparing the overall ERDA Fossil Energy RD&D program plan.

Environment and Safety:

Work in this area will continue those activities necessary to develop environmental development plans that assure information is available to characterize process effluents, control emissions, assess water availability, promote health and safety, conserve energy and natural resources, ensure sound project siting decisions, and mitigate local impacts associated with fossil energy technologies. Specific efforts include:

- Compliance with National Environmental Policy Act
  - —Development of methodology and planning tools for assessing environmental impacts of Fossil Energy projects and programs.
  - —Completion of draft environmental impact statements and environmental assessments for specific Fossil Energy programs and facilities.
  - —Initiation and performance of environmental analysis on key Fossil Energy projects.
- Compliance with Non-Nuclear Energy RD&D Act
  - —Establish procedures for interfacing with Water Resources Council.
  - —Prepare inventory of data needs and availability for water resources assessments.
  - —Initiate program of water resource assessments for Fossil Energy technologies and demonstration projects.
- Strengthen cooperation with EPA and NIOSH on environmental and occupational health aspects of Fossil Energy.
- Preparation of environmental research strategy for Fossil Energy.

Methods and approaches which will be utilized in implementing the research strategy include the following:

- Sponsorship of industrial and university research projects, including some parallel programs.
- Shared funding with the contractors.
- Coordination of federal research projects supporting ERDA development programs.
- Coordination of federal fossil energy-related research, with the research performed by private and non-profit organizations.
- Evaluate trade-offs among the demands of environment, water rights and local socio-economic stability.

ADVANCED RESEARCH & SUPPORTING TECHNOLOGY

Federal Energy RD&D Budget **($ Millions)**

Agency	FY 1975		FY 1976*		FY 1977	
	BA	BO	BA	BO	BA	BO
ERDA						
Operating Expenses	23.3	7.8	35.4	32.1	37.1	36.6
Plant and Capital Equipment	0	0	0	0	0	0
Total	23.3	7.8	35.4	32.1	37.1	36.6

* Does not include funds for FY 1976 Transition Quarter.

FOSSIL ENERGY

Coal

DEMONSTRATION PLANTS

Objectives

Near-Term:
(–1985)

- To validate the technical, economic, and environmental acceptability of second generation coal processes by designing, building, and operating near-commercial scale modules.
- To accelerate the commercialization of demonstrated technology by stimulating the building of plants with industry funds.
- To accelerate the development of special equipment.

Mid-Term:
(–2000)

- To demonstrate and support the transfer of advanced technologies to the commercial sector.

National Energy Technology Goals Supported

Primary

- Efficiently transform fuel resources into more desirable forms.

Secondary

- Increase the efficiency and reliability of the processes used in energy conversion and delivery systems.

Strategy

The program is directed towards easing the constraints to commercialization of coal conversion technologies. These constraints include risk, low conversion efficiency and very large capital requirements. Together, they tend to impede progress towards the goal of placing less reliance on imports in favor of increased use of domestic energy resources.

The program would reduce the technical risks associated with scale-up from pilot to commercial plant by promoting acceptance by the commercial sector through more precise definition of: (1) process operability and reliability; (2) capital and operating costs; and (3) environmental acceptability.

The program would share part of the capital requirements for plant construction and operation to provide leverage to the industrial partner in meeting his funding requirement. While acknowledging the higher financial risk, the program would encourage the most efficient utilization of capital by promoting earlier construction of full commercial scale demonstration modules, thus avoiding the irrecoverable investment associated with smaller units.

The program would schedule demonstration plants, and best allocation of resources, by considering not only the demands of the various energy sectors, e.g., liquid boiler fuels versus fuel gas, but also the state-of-the-art and availability of particular technologies for demonstration.

Federal Role

The Fossil Demonstration Plants program is designed to promote early commercialization of the national coal resource, ahead of the business-as-usual schedule which would reflect strictly commercial criteria. Federal funding is made necessary by the demands of heavy capital investment coupled with the high risks of new technology.

The federal program is based upon sharing demonstration plant project costs 50/50 with an industrial partner, who has responsibility for selection of the process, plant size, site and coal type, subject to federal concurrence. Cost sharing is a strong signal—a financial commitment—of industry's belief that a technology is at the threshold of commercial development. Cost sharing also provides incentive for cost effectiveness in the conduct of the contractor's effort.

Federal project management includes design approval, design and construction monitoring, and the publication of project data.

Federal participation in each demonstration plant project can be terminated at the completion of any major interim mile-stone; e.g., commercial plant concept design, demonstration plant construction design; and will terminate after a period of plant operation; typically, 36 months.

Technological Status and Problems

Status:

- Several coal conversion processes have been operated successfully at the pilot plant level.

Problems:

- The demonstration must be sized to reflect considerations not only of financial risk, investment costs and plant operating flexibility, but also the validity of economic and process data resulting from plant operation which would be required for successful design scale-up for commercial operation.

Institutional Status and Problems

Status:

- Contracting policies have been improved by the revision of of the proprietary rights/background patent clause.

Problems:

- Capital resources required by demonstration projects limit:
  —the number of potential industrial partners;
  —the size of the process demonstration module that might be chosen from the standpoint of economic efficiency, viz., a full commercial scale module that produces benefits sooner and which might also avoid the irrecoverable investment associated with small units.
- Cooperative federal/industrial participation in the program demands mutual satisfaction of government's and industry's economic criteria, e.g., attitude toward risk, discount rates and program benefits.
- Lead times for environmental and site approvals are a significant uncertainly for would-be commercial development of coal technologies.
- Selection of "correct" processes for demonstration requires judgment regarding their promise of efficiency, flexibility, and applicability for use of major U.S. coal feedstocks.
- Successful integration of federally-encouraged energy resource development projects requires sensitivity to the impacts of industrial development in host communities:
  —Laws, regulations, and public attitudes in different states.
  —Public sector cash flow problems.
  —Changes in employment patterns.
  —Boom-town psychology and attendant social dislocations and land abuse.

Environmental Status and Problems

Status:

- Environmental monitoring is conducted at all pilot plants, which comply with all applicable environmental regulations. However, pilot plants may not exhibit the full range of impacts which could be associated with the operation of larger scale demonstration plants.
- Selection of a process for demonstration gives priority to processes which promise lower uncontrolled emission levels or emission levels that can be controlled by conventional or lower-cost methods. Environmental impact statements will be prepared for all demonstration projects.

Problems:

The problems listed below incorporate the full range of major problems with all processes, but are not equally associated with each process:

- The combustion/disposal problems which may result from a high level or aromatic compounds, and the occurrence of a wide variety of toxic trace elements in the process residues may be environmental control problems associated with liquefaction processes.
- The techniques for detecting and controlling trace emissions and fine particulates are not known or are costly.
- Considerations of water supply and quality control in the Western states may limit the choice of sites for demonstration plants.
- The nature and volume of large plant waste products may require that new waste management techniques be developed.

Program Implementation

Program objectives will be achieved through successful construction and operation of a number of demonstration plants. Several coal demonstration candidates have been chosen.

A contract has been awarded for design, construction and operation of a plant to demonstrate the conversion of coal to clean boiler fuel. Conceptual design of a commercial plant based upon the contractor's proposed hydrocarbonization process has been completed, and a site selected in New Athens, Illinois, for the demonstration plant. Detailed construction design for the demonstration plant is underway. The plant is to be designed to produce 5,000 barrels of liquid fuel and 21 million cubic feet of high Btu pipeline quality gas daily from a coal feed of about 3,000 tons.

A Request for Proposal (RFP) was issued in September, 1975 for demonstrating the conversion of pipeline quality gas from coal. Several processes have been developed, which are of interest to both pipeline and distribution companies. Awards to be made in FY 1976 will provide a basis for several alternate conceptual and plant designs.

A second RFP was issued in February, 1976 for a low Btu gas-from-coal demonstration plant. Low Btu gasifiers can deliver a hot, clean gas to produce central station electric power. In the near term, this gas can be utilized in conventional steam cycle generation; as the technology develops, it promises to be an attractive source of energy for the more efficient combined (gas/steam turbine) cycle. Multiple awards to be made will provide a basis for proceeding with several alternate conceptual plant designs including the coupling of the plant to a central station power operation.

Several conceptual designs of commercial plants are underway in an effort to relate technical data produced by the R&D program to other plant configurations which might merit demonstration.

DEMONSTRATION PLANTS

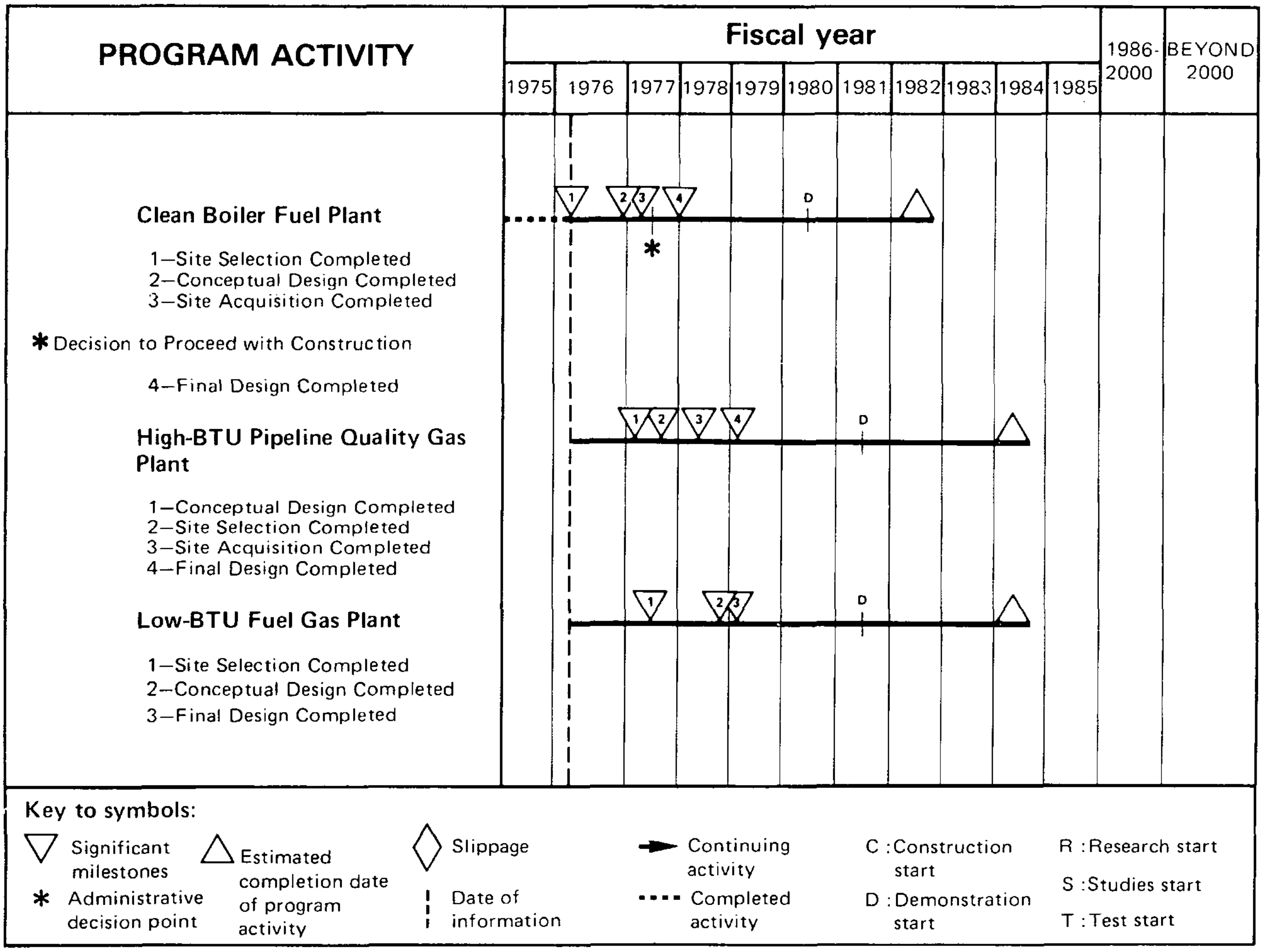
Federal Energy RD&D Budget **($ Millions)**

Agency	FY 1975		FY 1976*		FY 1977	
	BA	BO	BA	BO	BA	BO
ERDA						
Operating Expenses	0	1.3	31.9	14.2	53.0	50.6
Plant and Capital Equipment	13.0	0.6	20.0	9.0	54.2	30.3
Total	13.0	1.9	51.9	23.2	107.2	80.9

* Does not include funds for FY 1976 Transition Quarter.

ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION

DEMONSTRATION PLANTS



FOSSIL ENERGY

Coal

MAGNETOHYDRODYNAMICS

Objectives

Near-Term:
(–1985)

- To design and test magnetohydrodynamic (MHD) components and subsystems, and to integrate these into system tests to be conducted in pilot scale Engineering Test Facilities (ETF)

Mid-Term:
(–2000)

- To develop and operate a commercial scale demonstration MHD electric power plant, fueled by coal, in an environmentally acceptable manner.
- To continue development of the MHD technology to improve the performance, reliability and benefits to expedite the commercialization of MHD. This will ultimately reduce demand for petroleum as commercial plants begin to come on-line.

National Energy Technology Goals Supported

Primary

- Increase the efficiency and reliability of the processes used in the energy conversion and delivery systems.

Secondary

- Efficiently transform fuel resources into more desirable forms.

Strategy

The MHD power system program emphasizes the development of electrical, utility-sized power generation systems, utilizing coal as the primary fuel. When combined with bottoming steam systems, MHD offers greater potential for significant improvements in overall power system thermal efficiencies than any other advanced power cycles. The strategy of the program is to progress through three phases, each focused on specific development requirements for commercial demonstration. Phase I will develop the technology required to design and test individual components and effect their integration, culminating in the completion of a pilot scale Engineering Test Facility (ETF). The second phase will operate this facility and carry MHD into an advanced engineering stage. An advanced ETF will be required in Phase II. The third phase covers the design, construction and operation of a commercial scale demonstration plant.

During the overall development program, interactions and data exchange with other elements of fossil energy technologies are planned. For example, coal devolatilization and slag properties data will be obtained from the gasification efforts.

The development of the open cycle (as opposed to the closed cycle) concept is being pursued as the major effort of MHD because open cycle systems, being at a higher level of development, offer greater potential at an earlier date than closed cycle systems. This emphasis will continue in the future, although laboratory scale closed cycle work will be continued.

Federal Role

A high degree of federal participation is required initially in the MHD program to alleviate financial risk associated with new technologies having long development times. Federal participation also accelerates the progress in new technologies beyond normal commercial capability. During the near-term early development phases, federal funding will predominate. As encouraging results begin to appear, industry participation is expected to increase, particularly in Phase III. There are currently no jointly-funded government/industry efforts.

International Cooperation

The current US/USSR Cooperative Program in MHD program generation involves both the exchange of technical information and joint projects, and is structured to be of substantial benefit to both countries. Materials developed by the U.S. will be tested in the Soviet long-duration test facility, and Soviet materials will be tested in coal combustion environments in the U.S. A U.S. designed and constructed channel will be used for joint high field generator experiments, and Soviet diagnostic equipment will be utilizied in the United States. A cooperative program with Poland is currently being planned.

Technological Status and Problems

Status:

- Component development and testing programs have begun, including construction of subsystem test facilities.
- Preliminary design of an Engineering Test Facility is beginning.
- Supporting science and technology efforts, system and design analysis, and preliminary testing are proceeding.

Problems:

- Necessary simultaneous performance and endurance of large generators, showing at least 15–20% conversion of thermal energy input to the generator as electric power at turbine efficiencies of greater than 60%, have yet to be demonstrated.
- The technology for the design of high temperature corrosion/erosion resistant components such as combustors, channels, boilers, and air preheaters which are exposed to chemical and erosive attack by molten slag, fly ash and alkali salts must be developed.
- Design and construction capabilities must be developed for superconducting magnets required for commercial MHD power.

Institutional Status and Problems

Status:

- There are some existing regulations governing utility operation applicable to MHD.
- Much of the existing structure of federal, state and local regulations has been developed for a low-growth industry. These regulations may eventually require modification.

Problems:

- As a new technological construct, MHD will have to demonstrate economic feasibility prior to the generation of significant interest on the part of industry.
- Demographic problems are likely to arise from the influx of skilled and unskilled workers into remote areas to support the labor—and facilities—requirements of operating plants.

Environmental Status and Problems

Status:

- The basic process of MHD plant operation results in plant exhaust emissions that meet the most stringent air quality standards for sulfur oxides, particulates and oxides of nitrogen. Its higher operating efficiency results in lower thermal pollution levels.

Problem:

- Problems of conventional plants in water use and in solid waste generation and disposal are still present in MHD plants; but because of the higher plant efficiency, are lower per unit of electricity generated.

Program Implementation

The program for meeting the goal of commercial scale MHD demonstration by the late 1980's progresses through three phases, each focused on specific development requirements necessary for commercial scale demonstration. The initial or current phase will develop the technology required to design, develop and test system components. This preliminary engineering phase leads the way to realistic subscale MHD experimental plant in which the major milestone is the construction of a pilot scale Engineering Test Facility.

During Phase II, continued design testing and refinement is pursued to improve performance and endurance to lay the groundwork for the design of a commercial scale demonstration plant. An advanced alternate Engineering Test Facility may be required in this phase.

Phase III commences with the design and construction and ends with the operation of a commercial scale demonstration plant.

Exploratory work is also proceeding on closed cycle systems, concentrating on heat exchanger and generator problems. However, closed cycle development is not as advanced as the open cycle concept, and current work is addressing basic physical issues which must be resolved prior to closed cycle being considered as a potential alternative to open cycle.

MAGNETOHYDRODYNAMICS

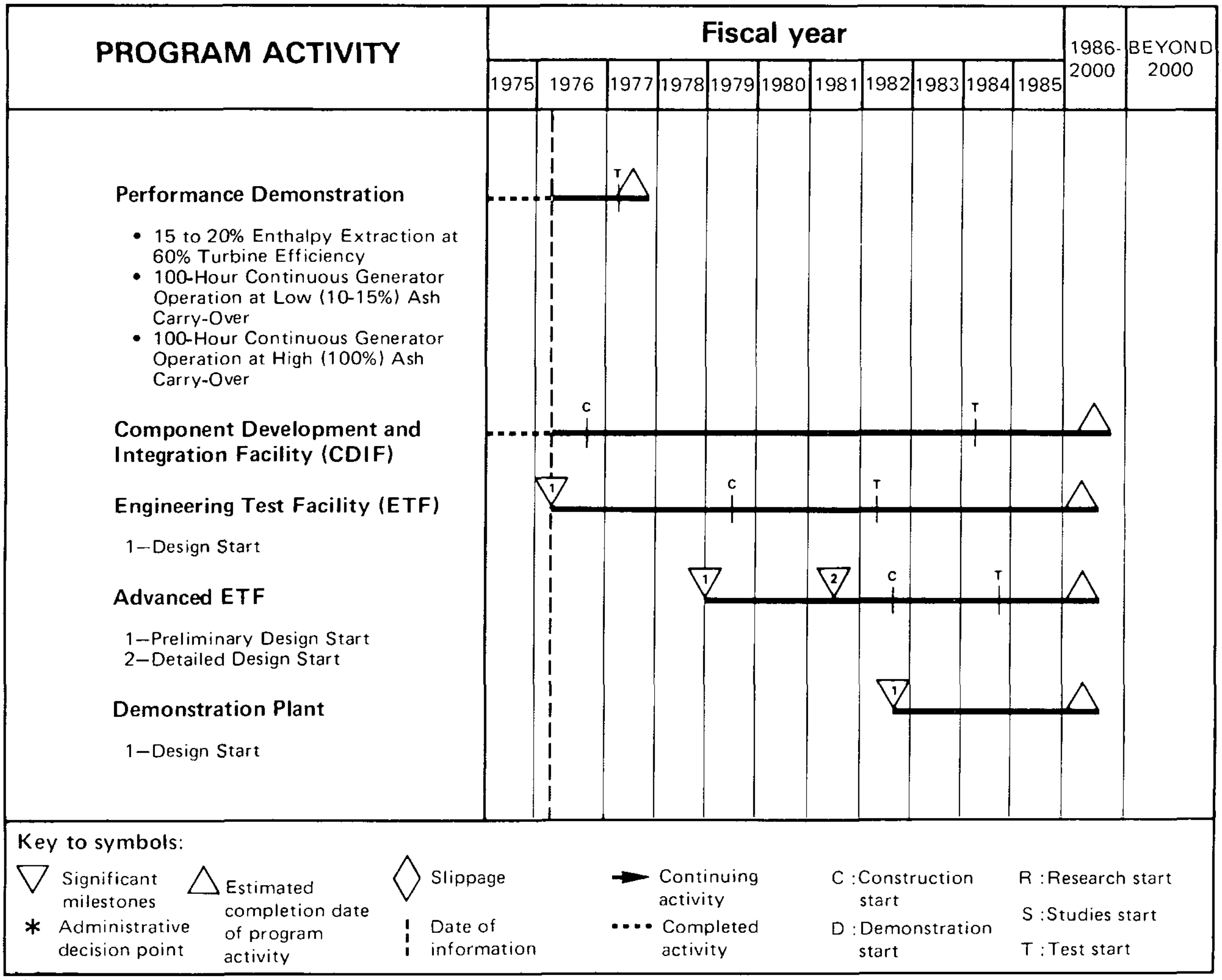
Federal Energy RD&D Budget **($ Millions)**

Agency	FY 1975		FY 1976*		FY 1977	
	BA	BO	BA	BO	BA	BO
ERDA						
Operating Expenses	14.3	4.0	29.6	18.4	37.4	27.3
Plant and Capital Equipment	0	0	0	0	0.2	0.1
Total	14.3	4.0	29.6	18.4	37.6	27.4

* Does not include funds for FY 1976 Transition Quarter.

ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION

MAGNETOHYDRODYNAMICS



FOSSIL ENERGY

Petroleum and Natural Gas

GAS AND OIL EXTRACTION

Objectives

Near-Term:
(–1985)

- To develop and demonstrate, in cooperation with industry, enhanced recovery technologies which may increase production flow rates by 500,000 barrels/day of oil (1.0 quad/year) and three billion cubic feet/day of natural gas (1.0 quad/year), and add two billion barrels of oil and ten trillion cubic feet of natural gas to domestic reserves.

National Energy Technology Goals Supported

Primary

- Expand the domestic supply of economically recoverable energy production raw materials.

Strategy

To achieve the objectives, a program has been designed to increase production of oil and gas from both onsore and offshore areas, including tar sands, through advanced exploration and extraction techniques. Program emphasis is on developing enhanced recovery techniques which could extend the supply of domestically available resources by approximately 10 years, and on developing techniques required in hostile (Arctic and Outer Continental Shelf) environments.

The strategy is to encourage and support industry efforts to develop and demonstrate enhanced oil and gas recovery technology to increase production rates and yields from existing and future oil and gas fields by:

- Cost-sharing demonstrations to accelerate implementation of newly developed technologies.
- Pursuing concurrent projects in fluid injection and formation-fracturing techniques.
- Providing a means for documentation and dissemination of data on enhanced recovery techniques.
- Maintaining an aggressive research program in government and industry laboratories and academic institutions on enhanced oil and gas recovery to provide a scientific basis for present and future recovery methods.

When the cost-sharing program has proven an enhanced recovery technique in a full-scale demonstration, industry is expected to utilize it and to assume all costs associated with commercial development. The government will build an open-file national data base, using its research publications for enhanced recovery as a mechanism to promote sharing of test results among oil and natural gas producers.

Because several different techniques are being pursued, there are alternatives built into the basic program. Should any one technique prove unsuccessful, other techniques may be viable.

Federal Role

Since the development and application of enhanced oil and gas recovery technologies involve high risk and long lead times, the government is providing incentives for industry to accelerate development; the primary responsibility for commercialization however, lies with industry.

The present program provides industry incentives through cost-sharing, and thus risk-sharing R&D contracts with industry. Of eight existing enhanced-oil-recovery (EOR) projects with a total cost of $45.6 million, industry is supporting 64 percent. In seven enhanced-gas-recovery (EGR) projects with a total cost of $12.9 million, industry support is 62 percent. Negotiations are now in progress for several additional EOR and EGR contract procurements; the objective is for industry to support at least 50 percent of the cost.

International Cooperation

The United States and the Soviet Union have an Energy Agreement in several areas, one of which is in oil exploration and production. As a result of exchange visits by U.S. and U.S.S.R. oil experts, areas of cooperation were identified by the U.S. group in September 1975.

Technological Status and Problems

Status:

- Several different technological process for enhanced recovery are being investigated to determine feasibility of oil and gas production from otherwise-marginal resources; these include micellar-polymer, waterflooding, and carbon dioxide injection processes.
- Thermal recovery of oil is being pursued, since decreased viscosity resulting from the process will result in improved flow characteristics.
- Hydraulic and explosive fracturing techniques are being investigated to permit exposure of additional resources for recovery and production.

Problems:

- Reliability of fracturing techniques needs to be improved. Fracture mechanisms, at present, are not sufficiently understood to permit accurate prediction of results.
- Additional information is required to avoid the use of recovery fluids that are not compatible with the local geologic formations. This incompatibility can lead to loss of permeability, and reduced recovery.

Institutional Status and Problems

Status:

- Capital investment will be required for commercial implementation of enhanced recovery processes. At present, it is uncertain whether those resources will be readily available.
- Conflicting regulations create difficulties in unitizing fields for development and production.

Problems:

- The uncertainties of the final market price for oil produced by enhanced recovery methods makes it difficult to evaluate economic feasibility.
- Chemicals and equipment may be in short supply, and may not be available in the quantities required to support some of the enhanced processes being investigated.

Environmental Status and Problems

Status:

- Further enhanced oil recovery is commencing in oil wells that have gone through years of primary and secondary production; consequently the chemistry, geology, and engineering of each well used for enhanced recovery is known.

Problems:

- The actual impact of field injection on deep aquifiers and impacts on the prevailing geological structure (subsidence, movements along fault lines, etc.) are not entirely known.
- Acceptable methods of brine disposal and prevention of damaging runoff or accidental discharge into surface waters of oil-rich chemicals associated with large-scale operations have not been established.
- Environmental and occupational health impact of OCS operations have not been fully assessed. Environmental effects of formation fracturing are not adequately known.
- Oil spills resulting from offshore drilling and transportation.

Program Implementation

The strategy is implemented through a program of development and field tests that are designed to determine economic and technical feasibility. The program is divided into three categories: 1) fluid injection, which deals with oil recovery; 2) nonnuclear fracturing, which deals with gas recovery; and 3) drilling, exploration and offshore technology. The fluid-injection-enhanced oil recovery program consists of projects demonstrating micellar-polymer flooding, carbon dioxide injection, improved waterflooding, thermal recovery, in-situ tar sand recovery, and solvent extraction techniques.

The milestone charts present a typical field test program for each technique. Each technique is evaluated in from two to twelve tests, each of which is a separate contract, but which will have similar milestones. At the completion of each test, a decision will be made to end or expand the project. Basic tests are generally less than 100 acres in size and an expansion may be several hundred acres. As the results of expansion projects become available, further evaluation will be made to allow decisions to be made on increasing and/or continuing programs.

The first technique, micellar-polymer flooding, consists of injecting a micellar fluid to aid in the mixing of oil and water, followed by a polymer solution that forms a slug or mobility control bank in front of the final drive water. Eight to twelve field tests are planned for micellar-polymer flooding. Each test is a multi-phased project consisting of site preparation, pre-flush, micellar-slug injection, polymer injection, and water injection. The first test was initiated in FY 1975 and will run for approximately three years.

With the carbon dioxide injection technique, the resident oil swells and the viscosity is reduced by the addition of the gas, making the oil more easily displaced. The carbon dioxide injection technique is being evaluated in two to six field tests. Each test is a multi-phased project consisting of site preparation and either water injection with CO_2 or CO_2 injection alone. The first test was initiated in FY 1976 and will run for approximately three years.

The improved waterflooding technique consists of injecting fluids into the reservoir to lower the interfacial tension between the oil and water to yield more oil for a given amount of water injected. The improved waterflooding program consists of three to six field tests. Each test is a multi-phased project consisting of site preparation, pre-flush, polymer solution injection, and water injection. The first test was initiated in FY 1975 and will run approximately four years.

The thermal recovery technique uses in-situ combustion to provide high temperature thermal drive to enhance oil recovery. The tests of the two thermal recovery techniques (oil and tar sands) consists of site preparation, combustion initiation, and support of combustion by air injection, either with or without water injection. The first tests were initiated in FY 1975 and will run approximately three years.

The solvent extraction projects—SOLFRAC and cyclic—consists of solvent injection followed by waterflooding (SOLFRAC) or solvent flooding (cyclic), production and data analysis. SOLFRAC is used for recovering oil from shallow consolidated sandstone formations. A SOLFRAC test was begun in Eastern Kansas in FY 1975, utilizing explosive fracturing and solvent displacement. As much solvent is recovered and recycled as possible. Continuation of the tests is planned at least through FY 1977. Cyclic solvent stimulation is used in reservoirs with a cyclic solvent method, which involves injecting solvent into a well, allowing a soak period, and producing back from the same well. This work will continue at least through FY 1977.

Four non-nuclear fracturing techniques are being tested for the enhanced recovery of natural gas. With massive hydraulic fracturing, fluids are injected into the well to overcome natural stresses and cause the medium to fail, thus increasing the formation permeability and increasing gas production. This technique holds most promise for releasing natural gas from massive but intractable formations in the Devonian Shale of the Appalachians and in tight sandstones of the Rocky Mountain areas. For the massive hydraulic fracturing technique, from two to eight field tests are planned that will run for approximately two years each. A typical massive hydraulic fraturing test consists of site preparation, formation fracturing and gas production.

With chemical explosive fracturing, liquid chemical explosives are injected into natural or hydraulically induced fractures. The resulting extensive fractures release the gas. Three to eight chemical explosive fracturing tests will be initiated. The tests, which began in FY 1973, typically consist of site preparation, explosive injection, detonation and gas production.

In the deviated well technique, wells are drilled at an inclination such that they intersect natural fractures, thus connecting the wellbore with a greater volume of gas-bearing structures. Hydraulic fracturing may be applied by these wells to extend the fracture. Two to seven deviated well tests are being initiated. The first began in FY 1976 and is expected to be completed by FY 1978. A typical test consists of site preparation, fracture analysis, deviated drilling, fracturing hydraulically or by chemical explosives or both and production.

The government will initially share the costs of projects that involve technology for demonstrating fluid injection and thermal methods to recover oil as well as hydraulic and/or chemical explosive fracturing of natural gas-containing formations. Other than cost-sharing, the contractor must own, lease, or option the demonstration site, and evaluate and publish the results.

Preliminary analyses are underway to develop the value of alternative federal RD&D programs for encouraging enhanced oil recovery, and develop enhanced oil supply and production curves for different technical and economic scenarios. These studies will also estimate the number and types of projects required to achieve ERDA's objectives. Based on the available information, the management plan will then be developed for implementation at the beginning of FY 1977.

GAS AND OIL EXTRACTION

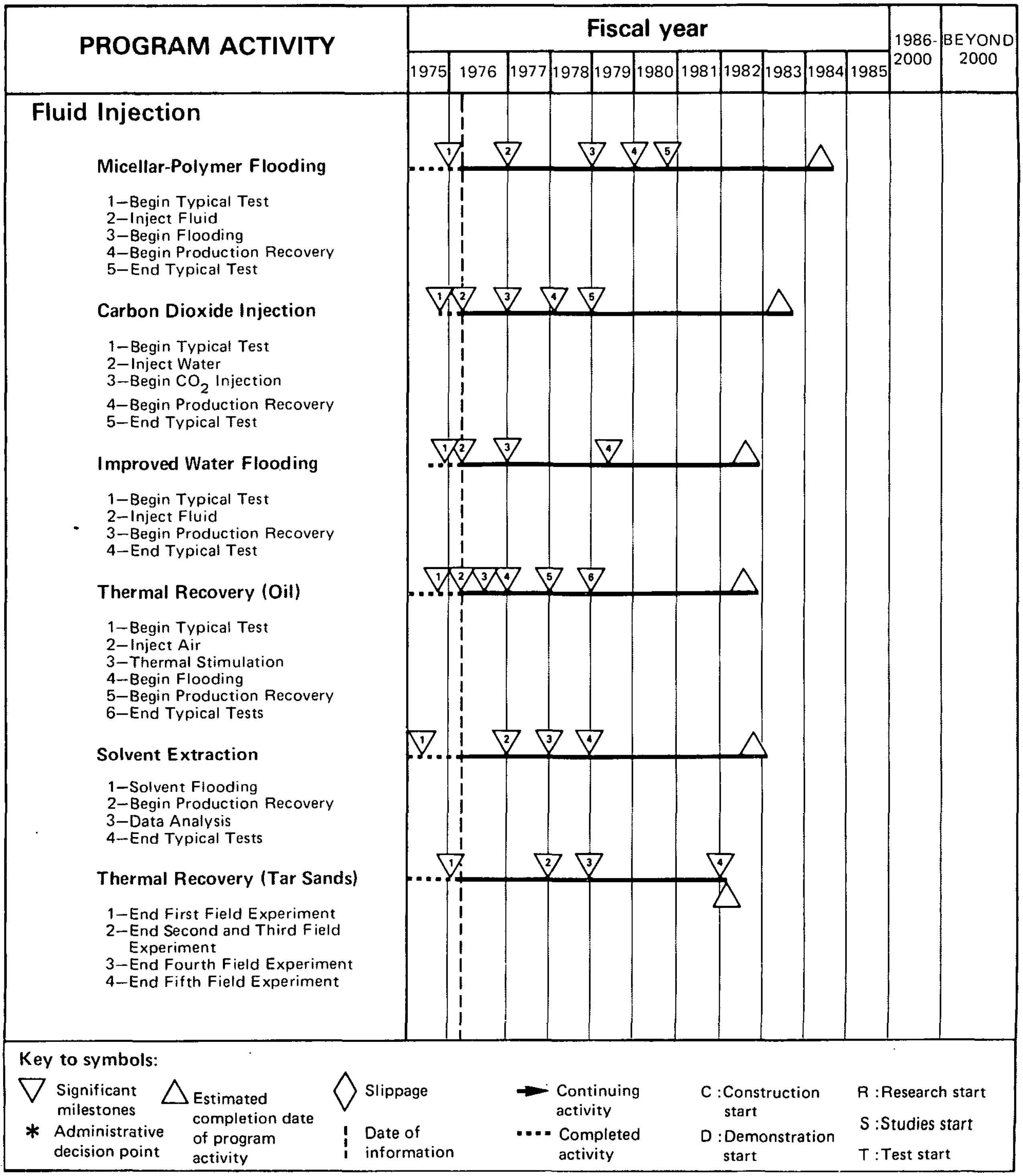
Federal Energy RD&D Budget **($ Millions)**

	FY 1975		FY 1976*		FY 1977	
Agency	**BA**	**BO**	**BA**	**BO**	**BA**	**BO**
ERDA						
Operating Expenses	26.4	8.7	41.4	32.8	35.1	30.4
Plant and Capital Equipment	0	0	0.1	0.1	0.1	0.1
Total	26.4	8.7	41.5	32.9	35.2	30.5

* Does not include funds for FY 1976 Transition Quarter.

ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION

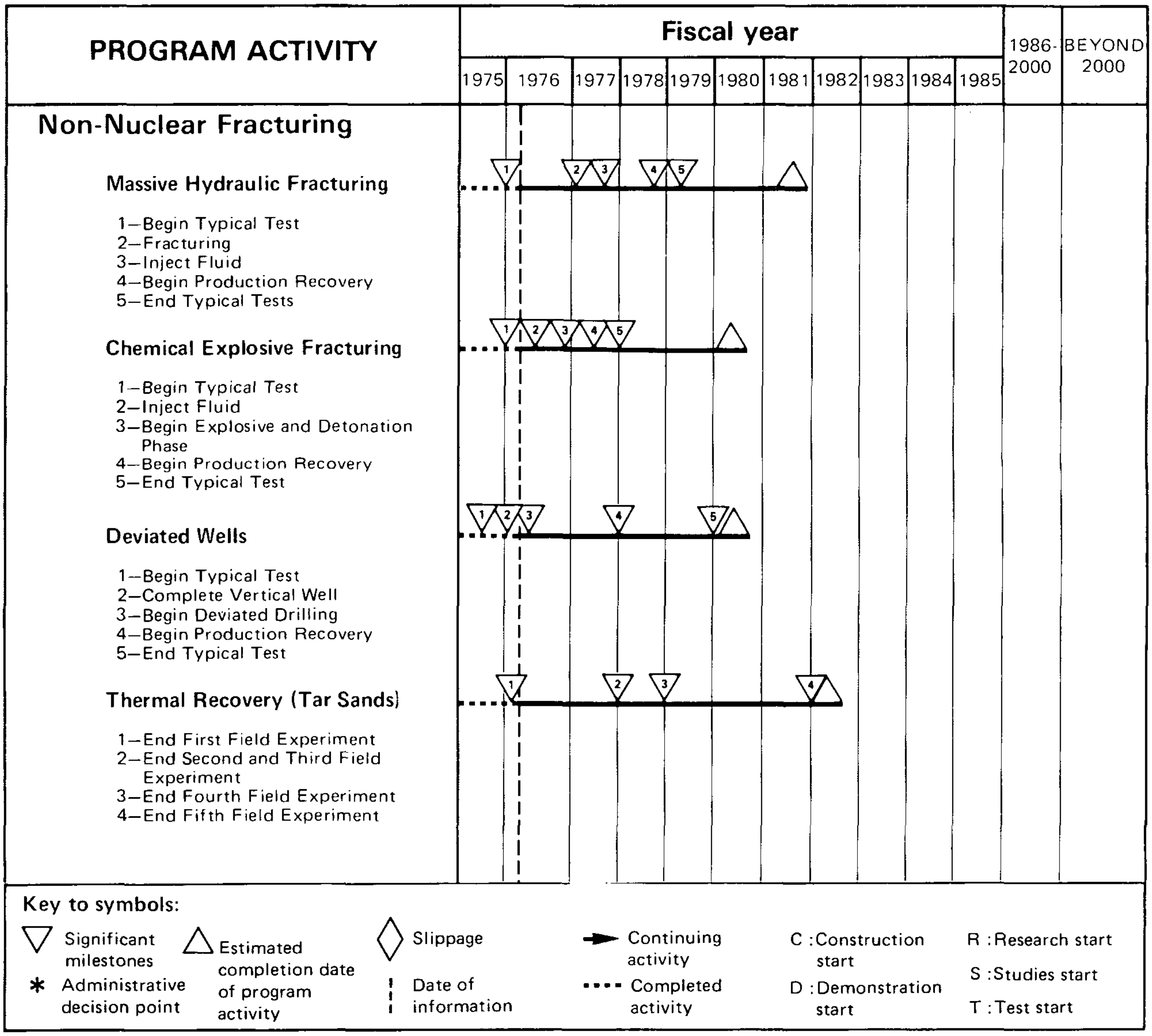
GAS AND OIL EXTRACTION



ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION

GAS AND OIL EXTRACTION

(Continued)



FOSSIL ENERGY

Petroleum and Natural Gas

SUPPORTING RESEARCH

Objectives

Near-Term:
(–2000)

- To develop and maintain a fundamental research technology in support of the gas and oil extraction program.

Mid-Term:
(–1985)

- To maintain supportive research on utilization of energy sources developed using new technologies resulting from oil and gas research.

National Energy Technology Goals Supported

Primary

- Perform basic and supporting research and technical services related to energy.

Secondary

- Increase the efficiency and reliability of the processes used in the energy conversion and delivery systems.
- Expand the domestic supply of economically recoverable energy producing raw materials.
- Protect and enhance the general health, safety, welfare, and environment related to energy.

Strategy

The government will sponsor basic and applied research at various universities, national laboratories, energy research centers and in industry.

Federal Role

The federal role is to increase the development of enhanced recovery technologies and make them available to industry through sponsorship of research projects.

Resource appraisals on public and private lands will also be conducted to provide basic data for the development of national energy policies.

International Cooperation

USGS has a cooperative agreement wih Institute Francais du Petrole for studying petroleum zones in major sedimentary basins of the world. USGS assesses hydrocarbon resources of the Circum-Pacific Region, a study sponsored by the American Association of Petroleum Geologists, the United Nations, and the Pacific Science Association.

Technological Status and Problems

Status:

- Studies are underway to match the chemicals used in enhanced oil recovery projects to reservoir rock and fluid characteristics.
- Heavy petroleum solvent extraction product analysis is in progress. New experimental adsorption columns which should shorten analysis are operational.

Problems:

- Reliable data obtained from test of chemically treated asphalt road surfaces are not available. These data are needed to determine the effects of natural, physical, and chemical changes to the road surface.

Program Implementation:

Energy Research and Development Administration

Gas and Oil Supporting Research in ERDA is directed toward developing more efficient end use of oil, gas and synthetic fuels. The research projects are grouped into the two broad categories of Characterization and Transportation.

Characterization:

Five research projects are currently directed toward the characterization of petroleum and synthetic fossil fuels. Currently, three projects are directly concerned with the characterization of fuels. One project is concerned with refining process technologies, and one project with the qualities of oil and identification of oil to determine the origin of oil spills. The bulk of the research is performed under the direction of the Bartlesville Energy Research Center. One characterization research project is performed under the direction of the Laramie ERC.

Transportation:

Research in the Transportation area is directed towards efficiency in the use of transportation fuels. This can be accomplished by increasing the efficiency of auotmobile engines and by increasing the life of materials such as asphalt, which are made from petroleum. Four projects are currently in progress, three under the direction of the Bartlesville ERC, and one being directed by the Laramie ERC.

Materials properties for primary containers for LNG will be defined during the period 1970–1984. Electromagnetic and transport fluid properties as well as an instrumentation and measurement system for LNG will be developed during the near-term with analogous efforts for SNG and hydrogen following during the mid-term. Other activities include offshore atmospheric studies, tanker design and design of offshore structures and facilities.

SUPPORTING RESEARCH

Federal Energy RD&D Budget **($ Millions)**

Agency	FY 1975		FY 1976*		FY 1977	
	BA	BO	BA	BO	BA	BO
ERDA						
Operating Expenses	1.8	2.0	1.8	1.6	1.8	1.8
Plant and Capital Equipment	0	0	0	0	0	0
Total	1.8	2.0	1.8	1.6	1.8	1.8

* Does not include funds for FY 1976 Transition Quarter.

FOSSIL ENERGY

In-Situ Technology

OIL SHALE

Objectives

Near-Term:
(–1985)

- To provide the technological base to support development of a commercial oil shale and gas industry; and to support oil and gas production research involving both true in-situ and modified in-situ methods.

Mid-Term:
(–2000)

- To provide the technological base to expand the oil shale industry; to support development of technologies capable of improving total resource recovery and lowering environmental impacts and water requirements.

National Energy Technology Goals Supported

Primary

- Expand the domestic supply of economically recoverable energy producing raw materials.

Strategy

In order to develop a technology capable of improving total resource recovery and lowering environmental impacts, in-situ extraction techniques will be studied and developed. These techniques will be developed to exploit leaner and/or deeper deposits, thus offering a means of utilizing those deposits which present technology cannot.

Early commercialization of in-situ technology will require study, testing and evaluation of the various processes. This necessitates an evolutionary process beginning with laboratory research, proceeding through progressively larger field tests and leading to commercial-scale demonstrations. The strategy is to stimulate large industrial projects by first conducting well-instrumented, smaller-scale field tests in cooperation with industry participants, then proceeding up through adequate demonstration levels to establish commercial feasibility.

Several different in-situ recovery techniques are under investigation for application to various resource targets. This is done because no single in-situ process is considered applicable to all major types of oil shale deposits. Successful development of any one of these techniques will materially expand the recoverable resource relative to that available by conventional mining and surface processing.

Successful exploitation of oil shales requires technologies both for surface retorting and in-situ processing. Surface retorting holds the best promise for early commercial development and is, therefore, important to our strategy of natural energy self-sufficiency. Pilot plants have been built and operated by industry to explore different oil shale retorting concepts. At the same time, related mining and materials-moving technologies have evolved through practice and refinement in other commercial endeavors. Indeed, commercial interest in oil shale potential has been actively expressed in the sale of oil shale leases by the federal government in 1974. The proposed synthetic fuels loan guaranty program would provide protection for private industry against the risks of building the first economically viable demonstration plants.

Federal Role

The role of the government is to offset the high risk, long lead time and potentially large implementation costs associated with the in-situ technology.

In implementing this program, the government:

- Encourages and supports innovative approaches to in-situ shale oil production.

- Makes available federal lands for testing concepts on the quality of the deposit, not its size.
- Supports development of a viable prototype technology.
- Provides the data bank and ensures the technology transfer among industry participants.
- Supports industry as necessary by making available the facilities and services of the national laboratories and Energy Research Centers.

Technological Status and Problems

Status:

- Modified in-situ technology has been advanced by private industry through field pilot-size modules at a shallow depth in lean shale. A prototype commercial module is under test. Most data thus far developed are proprietary.
- Small-scale field tests on true in-situ fracturing and shale oil production are currently underway by private industry and the government. Horizontal hydraulic fractures have been achieved at depths approaching 1,000 feet. Sustained shale oil production has been demonstrated at shallow depths using in-situ combustion. Additionally the use of explosives to augment hydraulic fracturing at medium depths shows promise.
- Prototype mathematical models for design and control of in-situ fracturing retorting are being tested.
- A successful process for gasifying residual carbon in Green River, Wyoming oil shale was successfully tested under simulated in-situ conditions giving essentially 100% conversion of carbon to medium Btu gas. The process is under test in a 0.5 ton facility to generate engineering design data for a PDU.
- Limited field tests of in-situ gasification of Eastern shales have been conducted by private industry. Data developed in these tests are proprietary.
- Data were obtained on changes in subsurface water quality from one limited in-situ combustion experiment. Baseline water-quality data are being obtained from several potential experimental sites.
- Small-scale laboratory tests have been performed on limited core samples from oil shale deposits which indicate that the recovery of alumina and soda ash is feasible.

Problems:

- Data from private industry projects are proprietary and not currently available.
- Currently, the technology for true in-situ controlled fracturing is nonexistent.
- Inadequate knowledge of Devonian shale geology and shale characteristics inhibits the development of these resources.

Institutional Status and Problems

Status:

- Accelerating costs in recent years have reduced the relative economic attractiveness of surface processing of oil shale. Industry, after bidding vigorously for public oil shale lands in 1973, has not moved forward to develop the tracts. Some form of governmental incentive is clearly required to stimulate industrial development.

Problems:

- Problems will result from a needed doubling in ten years of coal output and with the start of a shale industry.
- Local population concentrations and amenities will rarely be adequate to support the labor requirements of operating mines and conversion plants. There will be a major influx of skilled and unskiled workers into remote areas creating an instant need for roads, schools, housing, etc.
- Massive capital investment will be needed for mines and conversion facilities. While nergy demand and the financial needs to meet it grows exponentially, these new technologies require much higher investments per unit of net energy output; thus, sharply increasing capital needs.

Environmental Status and Problems

Status:

- First data on in-situ water-quality changes were obtained from fluid-monitoring wells installed as part of the Rock Springs, Wyoming combustion test.
- Studies are underway for controlling environmental changes during in-situ processing. These include in-situ fluid migration, changes in quality of subsurface waters effected by in-situ processing and trace elements potentially leachable from in-situ processed shale.

Problems:

- Modified in-situ processes will still require disposal of up to half as much mined rock or spent shale as conventional room-and-pillar mining and aboveground processing.
- The effects of in-situ fluids and potentially leachable trace elements on water supplies and vegetation are not fully understood.

Program Implementation

The In-Situ Oil Shale program is organized into tests directed at developing oil and gas production methods. The greatest emphasis is placed on oil production because it shows the greatest probability of payoff in the near-term. Most of the project operations are carried out or directed by the Laramie ERC, with support from the Sandia and Los Alamos National Laboratories in the areas of process instrumentation and fracture design. Lawrence Livermore Laboratory provides support in retorting and retort modeling.

Oil Production Field Tests are divided into two categories: True In-Situ and Modified In-Situ. Modified In-Situ techniques, so labeled because a portion of the shale is mined prior to fracturing, are of two types: vertical and horizontal. The thickness and grade of the shale deposit to be processed determines which type should be used. Vertical modified in-situ retorting appears to be the most advanced and is receiving the most industrial interest. Work in FY 1976 will be limited to awarding contracts to begin preparation of field sites for in-situ tests, with the number of contracts and particular technologies to be based on evaluation of proposals received and funds available. Retorting should begin in mid-FY 1977 and operations completed by FY 1980 with evaluations to follow. Tentative commercial design and economic studies will also begin during retorting operations.

The program for developing the True In-Situ technique, which requires no mining, will be continued largely as an ERDA in-house program. It will emphasize the evaluation of different methods of fracturing and rubble-izing the oil shale bed using small field test sites of 1 to 10 acres. Currently, a true in-situ field test is being performed by the Laramie ERC in Rock Springs, Wyoming. The retorting phase will be completed by the end of FY 1976, data evaluation will continue, and post-retorting site evaluation will be conducted by coring and instrumental techniques.

Three additional true in-situ sites are planned. The first two sites will be prepared in FY 1976 and retorting operations will begin in FY 1977. The tests are expected to be at similar depths to the test concluded in FY 1976, but featuring alternative fracturing techniques for bed preparation. The third test will be of a similar scale and bed preparation method as that of the FY 1976 test, but at a considerably greater depth. Site preparation will be iniated in FY 1976. Data will be reported periodically throughout testing. At the completion of the tests, decisions will be made concerning commercial feasibility or scaled-up experiments, and potential for application to deeper shales.

Other in-situ oil production tests are planned. The techniques to be used have not been determined and will depend upon the proposals received from industry. The tests will utilize shale with characteristics different from that in current tests. By increasing the number of shale types tested, industry should gain confidence in the technologies developed.

Instrumentation and special diagnostic studies in support of both true and modified in-situ field testing will be provided by national laboratories and the Laramie ERC. Particular attention is being given to the effect of in-situ processing on water quality and migration.

Gas Production Field Tests are developments prompted by past research which demonstrated that low to medium Btu gas may be obtained from oil shale at low presure by proper selection of control parameters. Because an abundance of low-grade eastern oil shales (a true, illite shale) exists near highly populated areas, significant attention is being given to the development of this resource.

A contract is anticipated to conduct pilot-scale studies on eastern oil shale by the end of FY 1976. If these tests prove succesful, a demonstration scale test is planned to begin in FY 1979.

Bench-scale testing of gasification of western oil shale (actually a dolomitic marlstone) has been on-going since FY 1975. An intermediate scale (0.5 ton batch) gasification retort will be in operation in FY 1976 to verify models developed at bench scale. The design of a large gasification test facility with a 25 to 40 ton retort will be started in FY 1976, but the decision on whether to begin construction will not be made until late FY 1978. Successful tests with this pilot-scale facility should lead to field in-situ demonstration with western shale by the early 1980's.

Industry cost-sharing will be sought for in-situ oil shale field projects. The level of industry cost-sharing is expected to be proportional to the status of the particular technology proposed for further development. If successful, the field projects will establish a technical base for commercial installation.

In the alumina and soda ash recovery from the oil shale program of the Bureau of Mines, laboratory experiments will be performed to confirm the results of earlier research, and to provide the data needed for the design of a mini-plant capable of making approximately 25 pounds of alumina per day.

Construction and operation of the mini-plant by FY 1978 will provide technical and economic data needed for the design and cost-evaluation of the process development unit and the pilot plant to be built in the early 1980's.

OIL SHALE

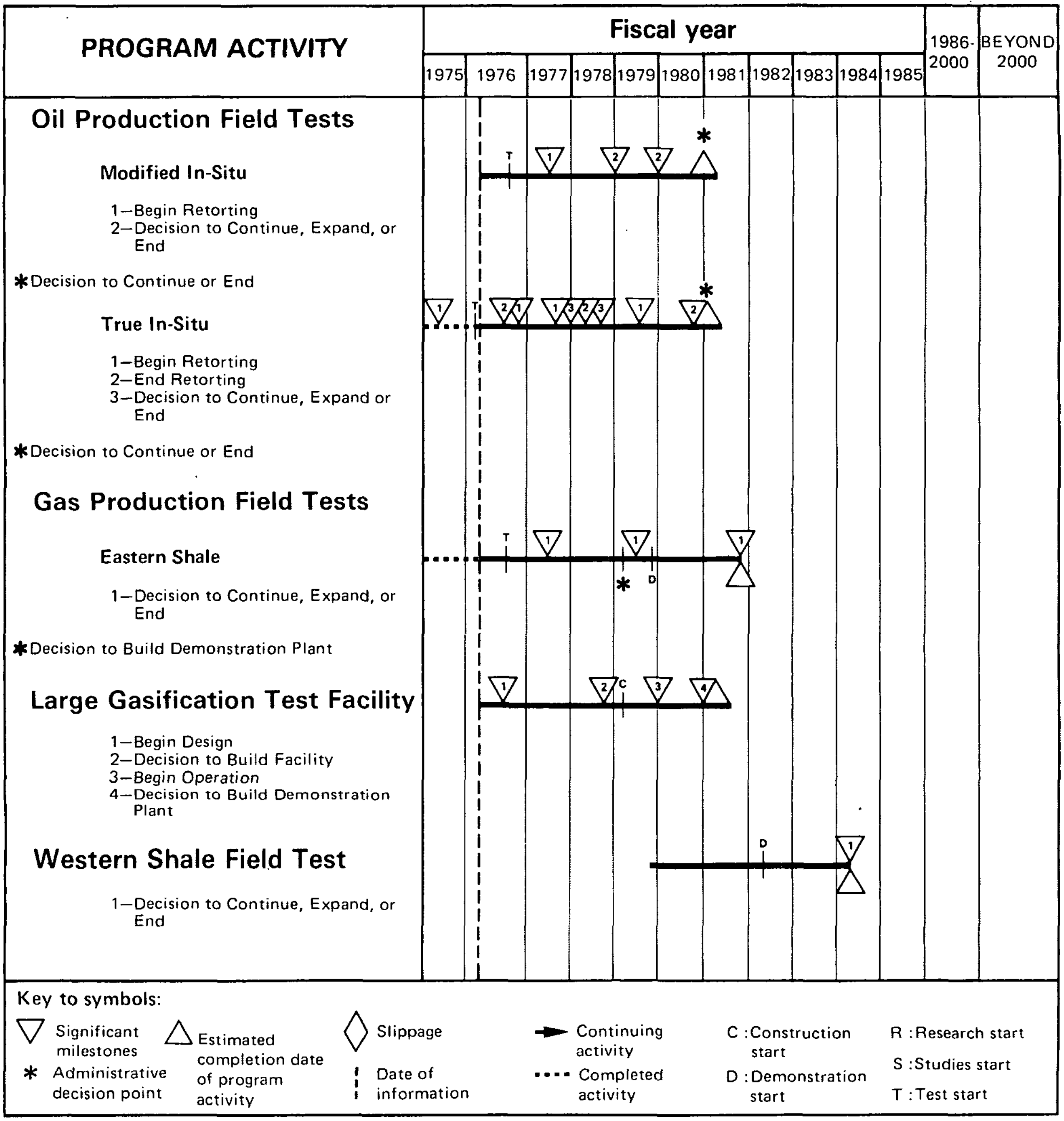
Federal Energy RD&D Budget **($ Millions)**

Agency	FY 1975		FY 1976*		FY 1977	
	BA	BO	BA	BO	BA	BO
ERDA						
Operating Expenses	3.7	3.9	13.7	9.8	21.1	12.1
Plant and Capital Equipment	0.1	0.1	0.3	0.3	0.4	0.4
Total	3.8	4.0	14.0	10.1	21.5	12.5
DOI	0	0	0	0	1.9	1.9
Total	3.8	4.0	14.0	10.1	23.4	14.4

* Does not include funds for FY 1976 Transition Quarter.

ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION

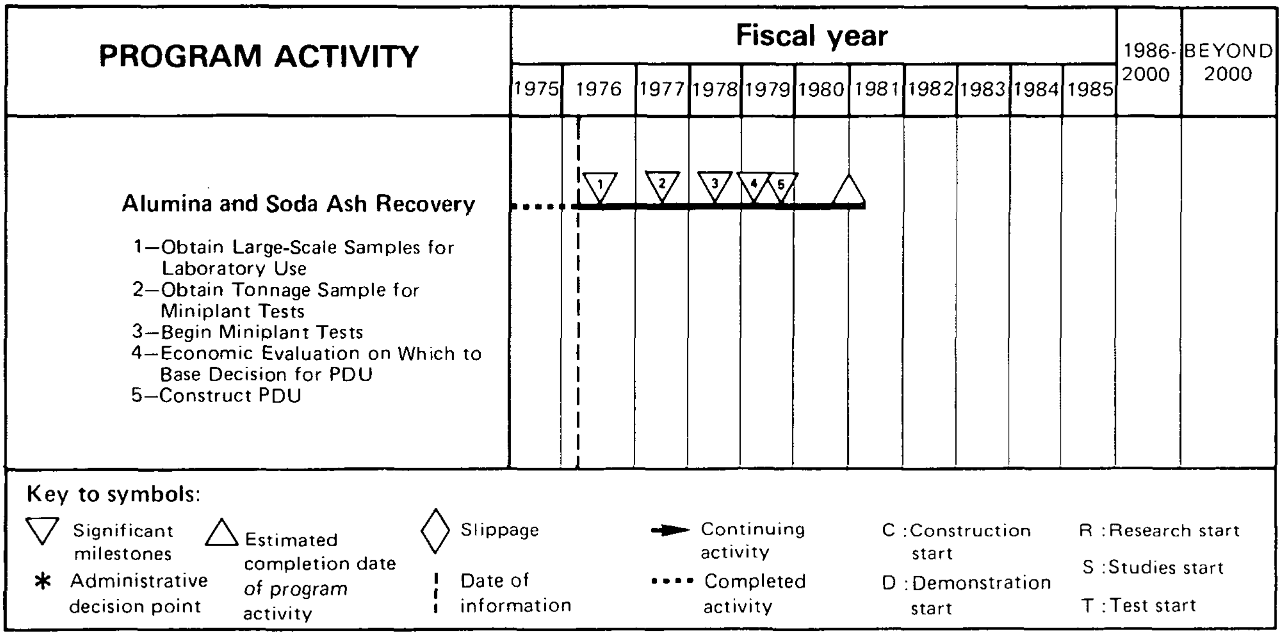
OIL SHALE



DEPARTMENT OF INTERIOR, BUREAU OF MINES

ALUMINA AND SODA ASH RECOVERY

OIL SHALE



FOSSIL ENERGY

In-Situ Technology

IN-SITU COAL GASIFICATION

Objectives

Near-Term:
(–1985)

- To develop and demonstrate a commercial technology for converting coal in place into low and medium Btu gas. To support the transfer of this technology into the commercial industrial sector through cooperative programs with industry. To explore advanced concepts for producing a wider products range from a variety of coal resources.

Mid-Term:
(–2000)

- To develop and demonstrate for industrial utilization advanced concepts, increase resource recovery, reduced water usage and reduced dependency of the process on the nature of the coal formation. To assist in technology transfer to encourage an in-situ coal-conversion industry with a production potential of three to four quads by 2000.

National Energy Technology Goals Supported

Primary

- Expand the domestic supply of economically recoverable energy producing raw materials.

Secondary

- Efficiently transform fuel resources into more desirable forms.
- Increase the efficiency and reliability of the processes used in the energy conversion and delivery systems.

Strategy

The nature of the particular coal resource characteristics strongly influences the strategy being employed to achieve the objectives. An estimated 85% of the U.S. coal resources are presently not economically recoverable by conventional mining; however, much of this coal can be converted in place to other usable energy forms. The program, in order to produce fuel gas in this manner, addresses the following three basic issues:

1) The coal resource and its surroundings vary with location and can be prepared for processing only to a limited extent; 2) the process must be remotely monitored and controlled and 3) the product/market match is controlled by geography.

The strategy is to pursue process development through field tests with the support of laboratory and analytical studies directed towards understanding the process behavior. The program will test a number of process concepts in various geographic areas. From these tests, supporting data and technology will be developed to make adequate process control possible.

Development begins with PDU-scale tests which are single module tests. Scale-up to pilot level will involve multiple modules. If larger plants involve only adding more modules, further scale-up may not be required. Industrial involvement through cost-sharing will be sought in the pilot and subsequent phases. This factor, combined with the reduced capital construction inherent in underground coal processing, may permit more rapid deployment of the processes in the commercial sector.

Systems studies are planned to optimize the process to the best product market. Both the pipeline quality gas and low/intermediate gas markets currently exist.

The highest priority is being given to developing quantitative proof that the basic concept will work as planned. This can usually be determined after executing PDU-scale tests of each concept under development.

Federal Role

The federal government provides financial support to process development especially at the smaller scales and provides R&D ideas and skills to formulate and design field concepts. By fully funding preliminary work and attracting industry to share in pilot-scale work, the federal government expects to develop processes to the degree that they will be attractive to industry for commercialization.

The federal role is to facilitate acquisition of land, surface, mineral, access and water rights and to support the costs associated with long lead time items, high program risks, and uncertain final commercial endeavors.

Technological Status and Problems

Status:

The three major technological processes currently under development are: gasification by combustion linking of vertical wells; gasification of an underground packed bed produced by explosive fracturing; and drilling deviated wells in the coal seam with subsequent gasification.

- Except for the Linked Vertical Wells, these processes are in the early PDU stage. LVW is in the late stage of PDU.
- Good reliability of the processes has not yet been proven; there is still uncertainty as to the underground process and the range of product quality that will result.
- The extent of applicability of these processes to existing resources is not yet known. The limits of usefulness based on resource identification must be defined.

Problems:

- Directional drilling is costly, since accurate monitoring and guidance control and instrumentation is not yet available.
- Water use and subsidence control is not yet adequately understood.
- Good control has not been achieved over the combustion process in the gasification zone. This can cause leakage in the underground process, and result in an inconsistent gas quality and production rate.
- Coal utilization efficiency and underground gas containment adequate to justify commercialization have not been demonstrated.
- Reasonable maintenance of gas production rate and quality in a given field with time is uncertain.
- In-situ steam/oxygen gasification has not yet been proven feasible.
- The permeability caused by explosive fracture for producing underground packed beds is difficult to predict.

Institutional Status and Problems

Status:

- Prior attempts to achieve UCG have met with poor results, due to an inadequate understanding of the technology and process requirements. Nevertheless, prior experience has left a negative predisposition to the technology.
- Industrial firms that would be interested in pursuing the technology generally do not own coal-bearing land. Conversely, coal owners are generally not interested in pursuing the technology.
- There are considerable legal questions concerning multiple ownership rights, and concerning liability for such things as aquifier interruption.

Problems:

- At present, the product price would be high compared to regulated gas prices. A pricing policy for in-situ gas which adequately relates the prices costs to the gas market does not exist.
- Federal and state regulations have increased the time and costs of acquiring field sites.
- The technical feasibility and economic practicability of power generation with low-Btu gas produced from UCG need to be established.
- The logistics of power generation with UCG, low-Btu gas, power distribution, and market demand need intensive study.

Environmental Status and Programs

Status:

Environmental assessments have been made on all active field projects. These projects comply with environmental regulations at the site. Additional environmental impacts are being studied through the following work.

- Effects of local water quality are being analyzed.
- Trace element emissions in product gas will be measured.

- Subsidence modeling is being done to minimize impact.
- Capture of organic water pollutants in the remaining coal is being studied.

Problems:

- No clear method exists to prevent aquifier disruption and water quality reduction.
- Surface subsidence in large-scale processing is not yet predictable.
- Impact on water resources due to process siting in arid regions is unknown.

Program Implementation

To implement the strategy, four process concepts are being developed. PDU-scale tests are being run in the field and are supported by laboratory and analytical applied research programs to verify and improve the technical knowledge and to develop data for preliminary economic estimates.

Since the coal is used in place, concepts to utilize resources of specific characteristics will be developed. The program encompasses three coal thickness ranges for seams of low dip, and one category with steep dip. The current projects, their applicability to coal deposits, and brief descriptions are listed below.

Linked Vertical Wells are used in western sub-bituminous coal with seams of medium thickness (15 to 50 ft.). Gasification has been done with air which produces low Btu fuel for gas utility or boiler use. The work is being done by ERDA's Laramie Energy Research Center at a site near Hanna, Wyoming. This process is in the final stage of development. Vertical wells drilled from the surface are linked by horizontal channels created in the coal by a devolatilization step. This forms a module that is gasified as the linking channels expand through the steam. The first test gave steady production of gas for about six months with an average heating value of 126 Btu/SCF. A second field test is underway to determine the process controllability and percentage of gasified coal in the module. FY 1977 work will concentrate on a field program to support the design of a scale-up of the process.

The Longwall Generator is used in Eastern bituminous coal with thin seams (less than 15 ft.) of low dip. Deviated wells are drilled from the surface and curved to produce long boreholes lying in rows within the coal seam. The coal between the parallel boreholes is gasified using the natural permeability of the coal or along cracks produced by hydraulic fracturing. The deviated wells are now being drilled at a site near Princeton, West Virginia by the Morgantown Energy Research Center. Drilling and flow testing will be done in FY 1976 with a possible first gasification in FY 1977.

The Packed Bed Process is used in thick western sub-bituminous coal seams (greater than 50 ft.). The coal is gasified by steam and oxygen to make intermediate Btu gas which can be upgraded to a synthetic natural gas by further surface processing. The ERDA Lawrence Livermore Laboratory is testing this concept at a site near Gillette, Wyoming in the Powder River Basin. This concept involves fracturing the coal bed with chemical explosives to produce an underground packed bed reactor. The packed bed is consumed from the top center down to the bottom sides in a forward gasification. A preliminary test of a two-shot fracture and gasification is underway in a shallow coal seam. A five-shot test will take place in FY 1977.

The Steeply Dipping Bed Process is applicable to seams which tilt greater than 45 degrees from the horizontal plane. The coal is generally not recoverable by existing mining methods. The in-situ gasification of dipping seams has favorable drilling and subsidence characteristics. Work on this project is starting in FY 1976.

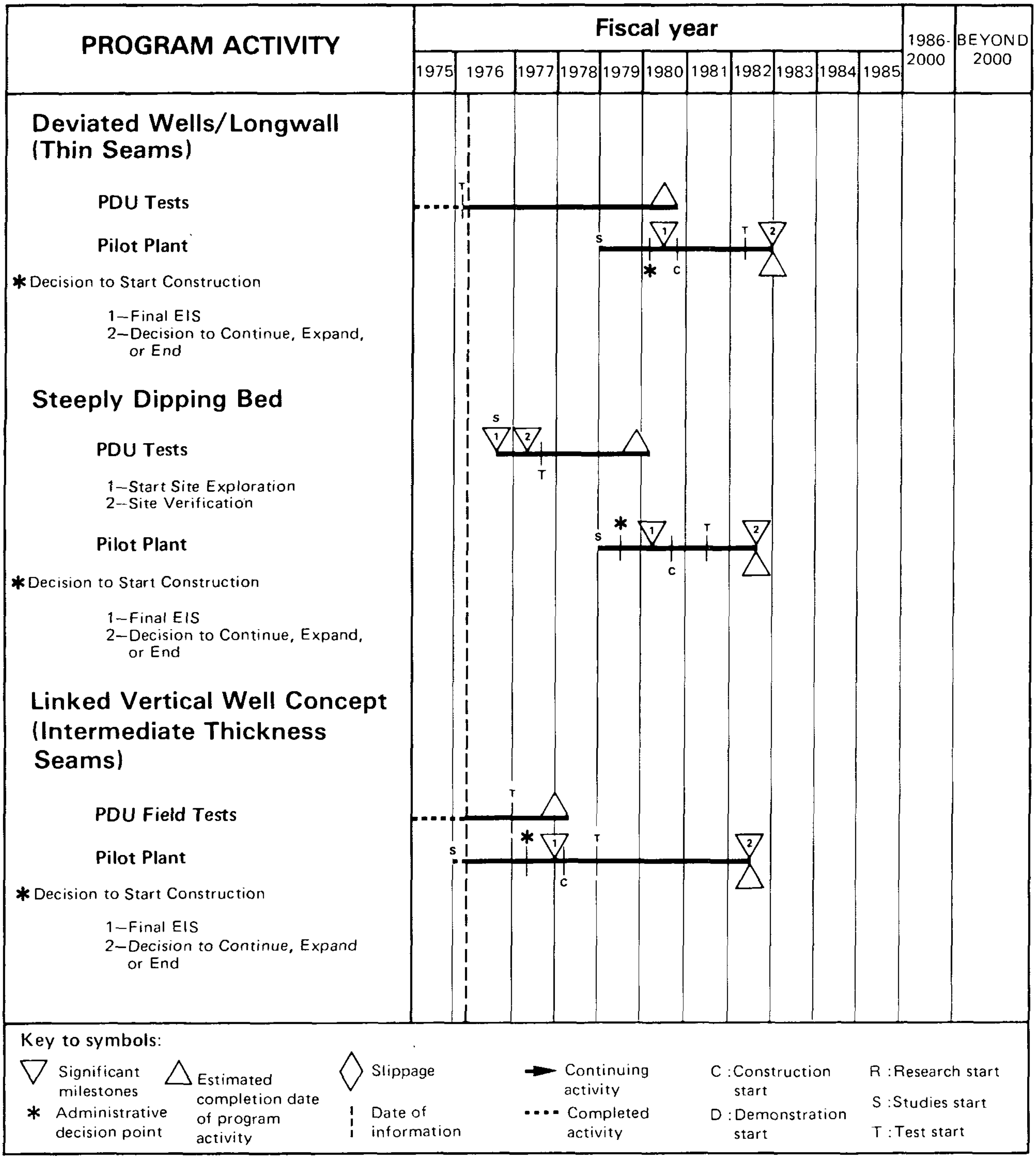
A successful pilot test of the Linked Vertical Well concept could lead to demonstration scale work in the early 1980's. Operating demonstrations for all of these first-generation projects is expected in the mid-1980's.

Industry is participating with in-house performers in providing sites, evaluating process designs, and in supporting research and field testing. The dipping seam project will be carried out primarily by industry. Financial participation will be solicited in process scale-up to pilot and demonstration stages.

Environmental effects on the regions surrounding the field sites is being assessed and minimized, especially those related to surface subsidence, water usage, and possible aquifier disruption.

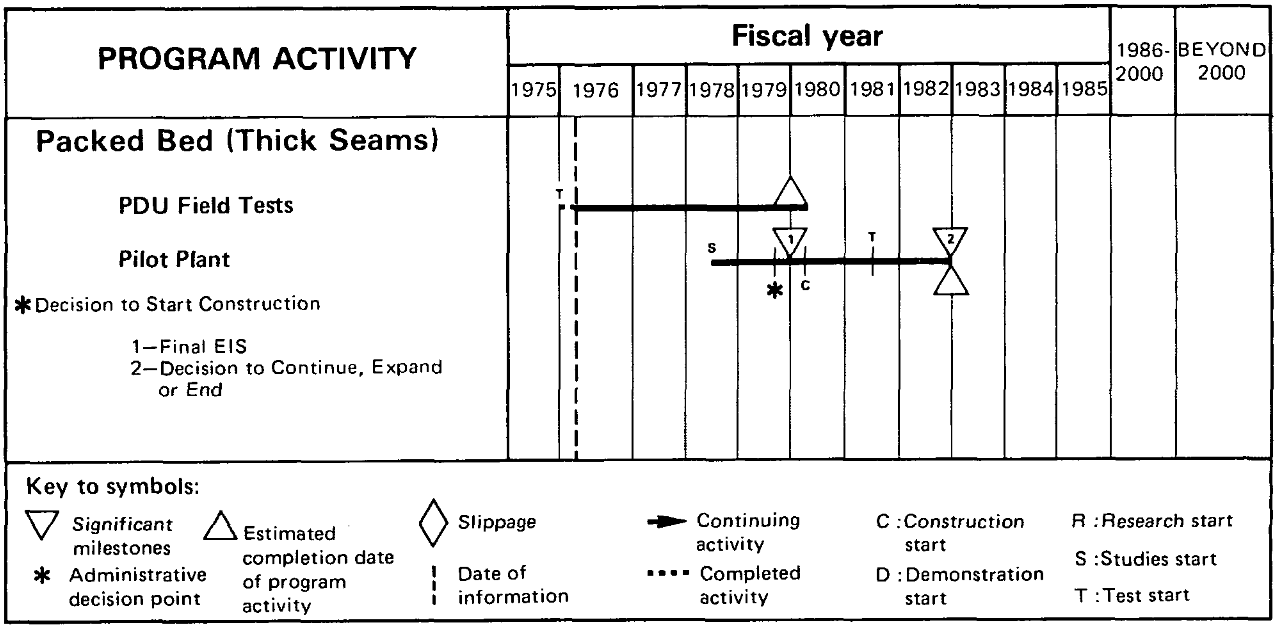
ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION

IN-SITU COAL GASIFICATION



ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION

IN SITU COAL GASIFICATION (Continued)



IN-SITU COAL GASIFICATION

Federal Energy RD&D Budget **($ Millions)**

Agency	FY 1975 BA	FY 1975 BO	FY 1976* BA	FY 1976* BO	FY 1977 BA	FY 1977 BO
ERDA						
Operating Expenses	6.5	2.3	6.1	7.6	8.2	6.7
Plant and Capital Equipment	0.1	0.1	0	0	0	0
Total	6.6	2.4	6.1	7.6	8.2	6.7

* Does not include funds for FY 1976 Transition Quarter.

FOSSIL ENERGY

In-Situ Technology

SUPPORTING RESEARCH

Objectives

Near-Term:
(–1985)

- To provide test support, general support, and basic research necessary to develop and optimize processes and components for both aboveground and in-situ oil shale projects.

Mid-Term:
(–2000)

- To lay the foundation for the development of an innovative technology leading to improved and advanced processes for shale oil recovery by aboveground and in-situ methods.

National Energy Technology Goals Supported

Primary

- Perform basic and supporting research and technical services related to energy.

Strategy

The strategy is to conduct laboratory-scale research on problems relevant to both in-situ and aboveground oil shale processing, and to aid in technology transfer. Supporting technology provides developmental work on new and advanced in-situ processes. The programs are based on the needs of oil shale projects and therefore, the priorities and level of effort are established by the Oil Shale program.

Present strategy in aboveground processing consists of making the Anvil Points facility available for industry-sponsored projects, providing for transfer of the technological results through an observer program, and providing general consultation to industry.

Federal Role

The role of the government is to: (1) support industry needs through the facilities and services of the national laboratories, Energy Research Centers, and other federally-owned facilities; (2) support development of a viable prototype technology, including product testing; and (3) develop the data bank and transfer technology among industry participants.

Technological Status and Problems

Status:

Considerable research has been or is being performed at the pilot or semiworks scale by private industry and the government. Specific work includes the following:

- Samples of oil shales and shale oil products have been acquired and analyzed to determine their characteristics and properties.
- An experimental investigation has been made of a refining plan that involves hydrogenation of separate fractions of in-situ shale oil.

Problems:

- Mechanical and thermal efficiency of aboveground processes are inadequately understood.
- The technology for upgrading crude shale oil to a pipeline-quality product has not been adequately demonstrated.
- Oil shale characteristics of potential project locations are not adequately understood, thus hindering in-situ project design.
- Pioneering research is required to provide a basis for second-generation technologies.

Program Implementation

Oil shale supporting research is conducted by the Laramie ERC with additional work performed by universities. Four primary task areas have been identified to implement the strategy.

The first, Production of Clean Fuels, is concerned with developing improved hydrogen processing and the associated techniques for producing clean liquid gaseous fuels from crude shale oil and its associated functions, especially those produced by, but not limited to, in-situ retorting. FY 1976 work consists of catalytic-hydrogenation experiments with in-situ shale oil to determine the most favorable conditions for hydrogenating the oil to liquid hydrocarbons suitable for preparing liquid fuels including gasoline, jet fuels, diesel fuels, and burner fuels. Laboratory-scale refining studies are being conducted to determine the applicability to shale oil of modern refining techniques, including required modifications for processing shale oils representative of different retorting processes.

In the second task, ERDA personnel observe surface retorting proceedings and tasks at the Anvil Points, Colorado facility. This project, presently being funded by private industry, will eventually publish results to develop a new aboveground retorting process. The results, which will be disseminated in accordance with terms of the lease agreement, will be based on independent government analysis of the raw data.

The New Process Technology task is devoted to new oil shale process technology and is investigating techniques for increasing the solubility of oil shale kerogen, and to develop the basis for economic and technologic assessment of oxidative upgrading of fossil fuels. The research on kerogen solubilization may lead to a second-generation technology for aboveground processing that does not require retorting. Oxidative upgrading of shale oil may improve economics through reducing hydrogenation requirements for removing sulfur and nitrogen compounds.

The fourth task involves the characterization of oil shale, to aid in site selection and to assist process design, control, and evaluation. Oil shale cores are taken for all on-going field projects and analyzed. Approximately 20,000 samples per year are characterized. This task area funds only those cores taken for new site-selection purposes, with other coring charged to specific in-situ field projects. FY 1977 coring under this task is projected at 10 cores taken for new site-selection purposes, with Wyoming and Utah. The cores are then analyzed in the laboratory. The results aid in selecting sites and processes for extracting shale oil or shale gas.

SUPPORTING RESEARCH

Federal Energy RD&D Budget **($ Millions)**

Agency	FY 1975		FY 1976*		FY 1977	
	BA	BO	BA	BO	BA	BO
ERDA						
Operating Expenses	1.0	1.0	1.3	1.1	1.3	1.3
Plant and Capital Equipment	0	0	0	0	0.1	0.1
Total	1.0	1.0	1.3	1.1	1.4	1.4

* Does not include funds for FY 1976 Transition Quarter.

FOSSIL ENERGY

Extraction Technologies

Objectives

Near-Term: (–1985)

- To develop, test, and demonstrate new and improved mining technologies for the economical and environmentally acceptable extraction of coal and oil shale.

Mid-Term: (–2000)

- To continue to develop and extend these new technologies.

National Energy Technology Goals Supported

Primary

- Expand the domestic supply of economically recoverable energy producing new materials.

Strategy

The strategy of the coal program is to improve techniques and equipment which have a high degree of utilization. This requires broad based programs with strong ties to the mining industry, both to identify appropriate targets for R&D and to provide a means of introducing and demonstrating newly developed technologies. Emphasis will also be placed on reducing the environmental consequences of coal mining, reducing the amount of human labor required for each ton of coal mined, increasing the recovery of the coal reserves now being mined, and developing innovative methods to convert presently unmineable resources into reserves to assure continued supplies of coal.

The strategy of the oil shale program comprises two principal thrusts: (1) fact finding through engineering and proof of principle test to, a) assure that government and industry planners have sufficiently well founded information on which to base decisions relating to the problems of mining oil shale and related saline minerals, b) explore the nature and severity of hazards to which the oil shale community might be exposed, and c) develop environmentally acceptable methods of disposing of the spent shale and mine waste; and (2) utilize the results of these studies, together with previous experience, to develop and demonstrate mining methods and disposal procedures that are acceptable from the standpoint of economics, environment, health and safety, and resource recovery. Priority will be given to those projects that (1) develop the facts that government needs upon which to base decisions relating to industry operations on federal land, (2) investigate potential mining methods and waste management methods for the deep saline rich beds, and (3) increase the percent recovery of the oil shale resources.

Federal Role

Federal participation is required becauseof the high costs and risks inherent in applying new technologies. Even with proven methods, mining is a high-risk venture, and industry is reluctant to increase their risk by experimenting on a large-scale with unproven methods. Industry has been, and is expected to continue to be, willing to participate in cooperative, cost-sharing efforts with the government. Federal participation also insures wider dissemination of the developed and demonstrated technology, accelerates progress beyond normal commercial capability, promotes the use of resources which would otherwise be sterilized and wasted, and assures adequate attention to other aspects such as the environment which impact society as a whole.

International Cooperation

The United States is a member of the Coal Mining Technology Clearinghouse established recently under the auspices of the International Energy Agency. The membership in this group includes all of the major coal producing western nations. A bilateral agreement also exists with the National Coal Board of Great Britain. Reciprocal visits of engineers have resulted in the identification of a number of areas of collaboration in mining research. In addition, mining research has been sponsored in Poland and there have been reciprocal visits with mining engineers from the U.S.S.R.

Technological Status and Problems

Status:

Coal:

- Current attempts to leapfrog the conventional technological growth rate by accepting the risk inherent in the development, testing, and demonstration of promising innovative concepts.

Oil Shale:

- Several baseline studies are near completion. They include technical and economic feasibility studies concerning deep underground, integrated open pit, and modified in-situ mining methods.
- Field investigations are underway to determine environmentally acceptable methods for disposing of retorted oil shale waste.
- Core drilling at the proposed Bureau of Mines demonstration mine site in the Piceance Creek Basin, Colorado, is underway.

Problems:

Coal:

- New automated mining techniques are required to increase productivity.

Oil Shale:

- The absence of an oil shale industry limits the spent shale field investigations to one type of waste (PARAHO).
- Lack of operating mines precludes the field testing of new mining methods.
- Competition is strong for available service facilities in the area, especially for drill rigs and supporting services which are in short supply.

Institutional Status and Problems

Status:

Coal:

- Standards need to be evaluated by regulatory agencies on the basis of technological merit, to permit trial and acceptance by industry.

Oil Shale:

- Present inadequate geologic and hydrologic information on the oil shale deposits is hindering development.
- Environmental considerations have delayed somewhat the core drilling and threaten to delay further work at the demonstration mine site.

Problems:

Coal:

- Uncertainty as to the federal, state and local constraints on mining and reclamation.

Oil Shale:

- Lack of capital availability for high risk operations.

Problems:

- Typical mining related environmental problems exist which include subsidence, waste and spoil disposal, mined land reclamation, ground and surface water contamination, aquifer disruption, dust and noise.
- Environmental consideration may delay future work at an oil shale demonstration site.

Program Implementation

Department of Interior

The Bureau of Mines of the Department of Interior has work going on several underground coal mining methods. In the High Speed Mine Development program, demonstrations will be performed in 1976 for improved entry driving systems and shaft/raise boring systems. Demonstrations are also planned before 1980, involving panel (longwall and shortwall) room and pillar; thick, thin with multiple seam mining systems as well as in the area of surface mining and reclamation using area and contour mining. Work is also underway in improving coal preparation, especially in waste coal recovery and coal desulfurization systems.

In the oil shale program, the Bureau of Mines baseline studies consist of technical and economic feasibility investigations of the most promising mining methods for the deep underground mining of oil shale, for an integrated single pass open pit system, and for various modified in-situ mining plans.

The waste management projects to study the stabilization, porosity, dust hazard, and other environmental concerns are being carried out through in-house and field investigations. Expected near-term benefits include the data necessary to design a waste disposal site.

EXTRACTION TECHNOLOGIES

Federal Energy RD&D Budget **($ Millions)**

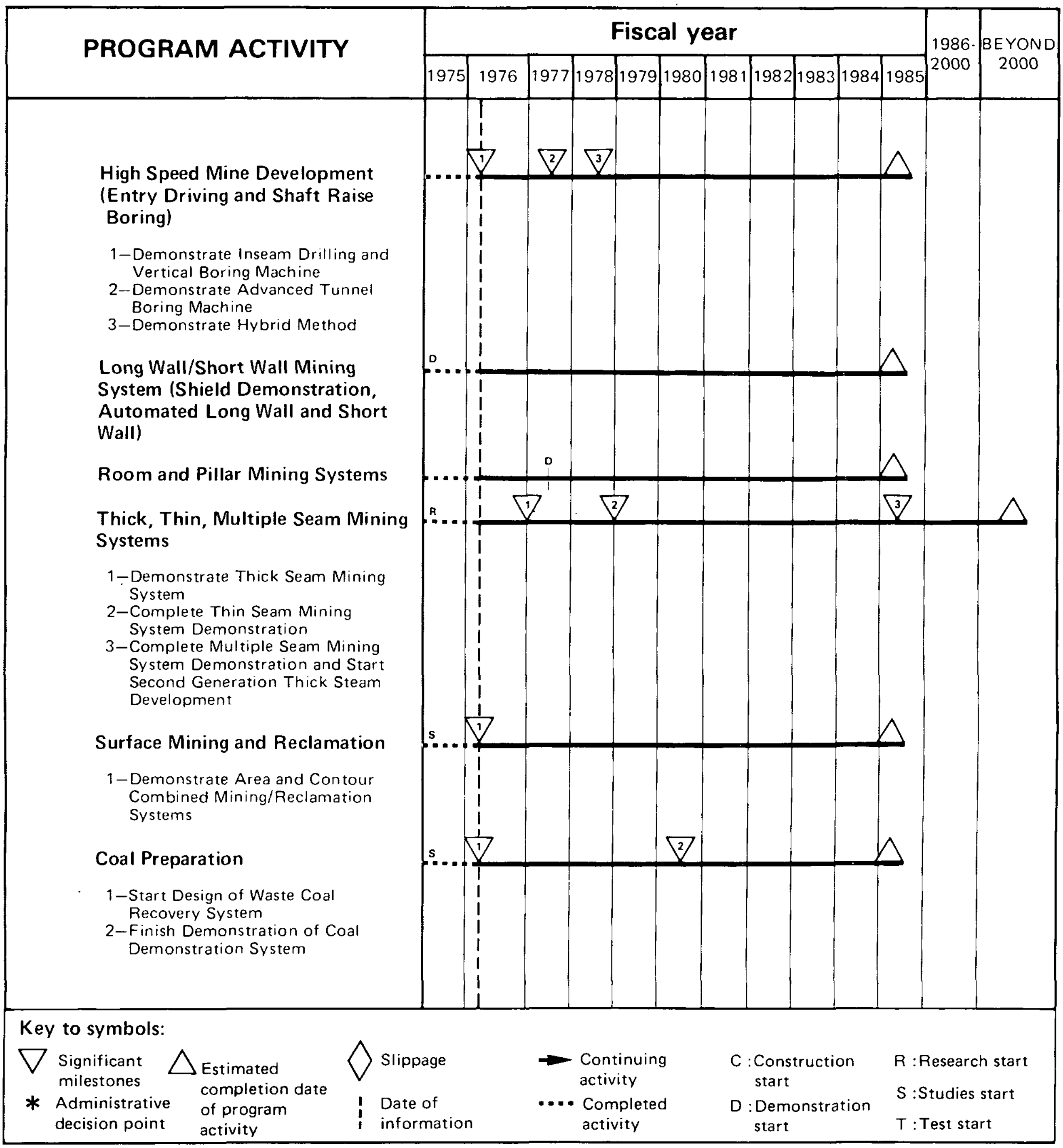
Agency	FY 1975		FY 1976*		FY 1977	
	BA	BO	BA	BO	BA	BO
DOI	52.2	20.1	61.8	52.3	65.6	63.3
Total	52.2	20.1	61.8	52.3	65.6	63.3

* Does not include funds for FY 1976 Transition Quarter.

DEPARTMENT OF INTERIOR, BUREAU OF MINES

COAL EXTRACTION PROGRAM

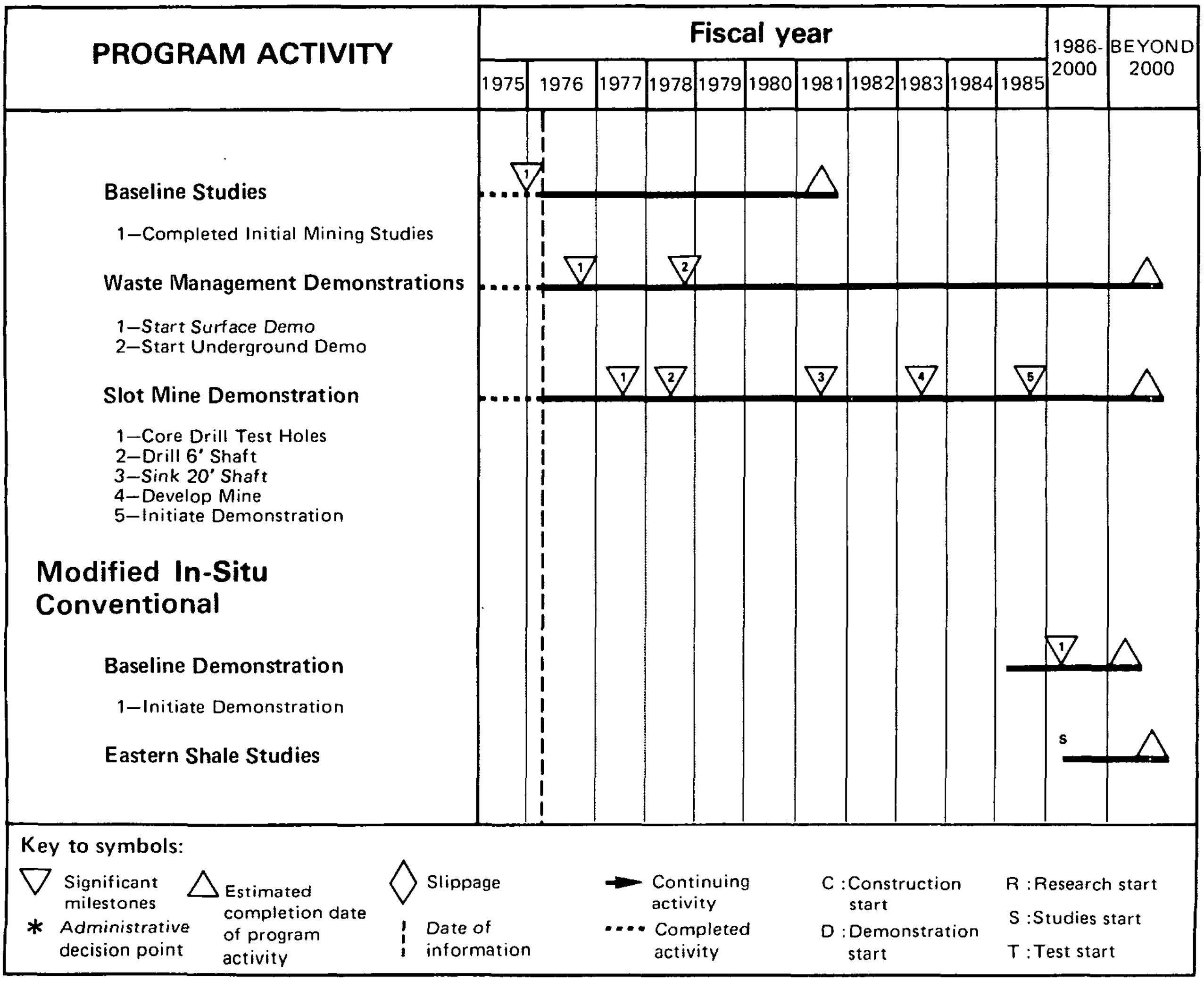
EXTRACTION TECHNOLOGIES



DEPARTMENT OF INTERIOR, BUREAU OF MINES

OIL SHALE EXTRACTION PROGRAM

EXTRACTION TECHNOLOGIES



FOSSIL ENERGY

Resource Appraisal

Objectives

Near-Term:
(–1985)

- To assess the coal, petroleum, natural gas, oil shale and water resources of the United States and to develop methods for the detection, evaluation and recovery, in an environmentally acceptable manner, of existing and potential coal, hydrocarbon and water resources.

Mid-Term:
(–2000)

- To extend the resource assessment, detection and evaluation techniques to less desirable and/or unproductive resource areas and to reassess producing resources incorporating the advanced technologies and capabilities developed in the near-term.

National Energy Technology Goals Supported

Primary

- Expand the domestic supply of economically recoverable energy producing raw materials.

Secondary

- Efficiently transform fuel resources into more desirable forms.
- Protect and enhance the general health, safety, welfare, and environment related to energy.
- Perform basic and supporting research and technical services related to energy.

Strategy

The strategy in coal resource assessment is to (1) locate and measure deposits of coal to the level of inferred reserves and to determine quantitatively the physical and chemical characteristics of the coal, (2) determine the effects of present mining activities, and in potential mining areas, on the environment as mandated by the National Environmental Policy Act, (NEPA) and (3) study the potential of long-term degradation in 8 to 10 major coal-bearing basins that span a broad range of climatic, geomorphic, and geologic provinces.

The strategy in the petroleum and natural gas resources assessment area is to accelerate and refine a multidisciplinary analysis of the 102 productive or prospective petroleum provinces onshore and offshore with priority on the offshore areas and to provide updated information for estimates of undiscovered recoverable oil and gas resources.

The strategy in the oil shale resources assessment area is to undertake nontechnological studies using the combined earth science disciplines to provide, (1) comprehensive assessment of the nation's oil shale resources, and (2) to identify areas most suitable for in-situ retorting, conventional mining, and surface processing with minimal environmental impact.

The strategy in assessing the water needs associated with exploiting coal is to, (1) determine water needs and availability on a regional basis for coal extraction, conversion, transportation, and concurrent reclamation, (2) develop a model of the Madison Aquifer system to permit appraisal of its water supply and (3) appraise water needs, availability, and water-quality problems of major coal slurry systems to evaluate slurry-pipeline potential.

The strategy in assessing the water needs associated with exploiting the nation's oil shale is to, (1) provide the data on the surface and groundwater hydrology needed to predict the amount and quality of groundwater present in the oil shale, its affect on underground mining, open pit mining, and in-situ oil extraction processes, (2) obtain basic hydrogeologic data on aquifer properties and surface-water/groundwater relations by core drilling and aquifer testing, and develop predictive models of the hydrologic system, and (3) obtain regional hydrologic data in the three state oil shale region that cannot be accomplished with the limited data collected on the leases and individual mining properties.

Federal Role

Federal participation in these programs is essential because of government requirements for information about the quantity and quality of the resource and the environmental impact of its development required for planning a national energy policy. Resource assessment studies and investigations of the environmental impact of resource developments are, by their very nature, broadly based programs, both topically and geographically. Federal funding and management of such programs is required to assure their continuity and comprehensiveness.

International Cooperation

A significant agreement between the U.S. Geological Survey and the International Energy Agency, concerning world coal resources data exchange and the development of internationally accepted coal terminology, is progressing. Discussions are in progress with the Geological Institute and Central Mining Institute of Poland for exchange of data and the temporary exchange of scientific personnel. Technical cooperation in the area of environmental analysis is maintained with the Bundensanstalt fur Geowissenschaften und Rohstoffe of the Federal Republic of Germany. Informal liaison continues with the British National Coal Board.

The U.S. Geological Survey has entered into a cooperative agreement with Institute Francais du Petrole for the study, characterization and resource appraisal of petroleum zones in major sedimentary basins of the world.

Technological Status and Problems

Status:

Coal:

- Resource assessment and environmental studies are underway in low-sulphur coal districts in the Central Appalachian basin and in Montana and Wyoming.
- Geological mapping and resource assessment of anthracite in Pennsylvania are more than 50 percent complete.
- Revised estimate of U.S. Coal resources (3,968 billion tons) was recently published as USGS Bulletin 1412.
- Research is being conducted on geophysical methods to rapidly determine depth of burial and thickness of coal beds and their chemical constituents.
- Field and laboratory studies on diagenetic changes in coal and on the origin of sulfur in coal are underway as an aid to predicting coal quality.

Petroleum and Natural Gas:

- Preliminary estimates of undiscovered recoverable oil and gas resources in the United States have been completed for onshore and offshore areas.
- Preliminary estimates of the oil and gas resources have been derived for five of the continental slope areas.
- Special studies to assess the resource potential of significant, major sedimentary basins, such as the North Slope of Alaska and the Appalachian basin, are underway.

Oil Shale:

- Approximately 70 percent of the surface geological mapping has been completed in the Piceance basin, about 10 percent in the Uinta Basin, and about 15 percent in the Washakie Basin.
- Revised appraisal of the shale oil resource of Piceance Creek basin has been completed.

Water for Coal:

Existing water supply monitoring networks in the coal areas of the Rocky Mountain and Northern Plains States have been intensified to supply specific information for coal mining and conversion industry needs.

- A plan of study for the Madison Limestone Aquifer has been completed.

Water for Oil Shale:

- An extensive water monitoring network has been established in the Piceance Creek basin of Colorado.

Problems:

Water for Coal:

- Oil companies have not always been willing to sell well log information for survey use.

Water for Oil Shale:

- Improvements in instrumentation for monitoring water quality and quantity, sediment and biological parameters is needed.

Institutional Status and Problems

Status:

- Numerous federal, state and local regulations exist relative to mineral rights, availability and access.

Problems:

- Proprietary information from deep wells on private lands and unavailability of adequate information from older wells limit hydrocarbon assessments.
- There is lack of resolution as to whether the sodium-aluminum minerals contained in Rocky Mountain oil shale are locatable or leaseable in the interpretation of mining laws.
- Availability of water for an expanded oil shale industry may require acquisition of water rights from agricultural users.

Environmental Status and Problems

Status:

- Study and classification of land in and adjacent to coal-producing areas in the Appalachian basin is underway to determine their suitability as sites for deposits of coal mine wastes.
- Evaluation of regional environmental impact of large-scale surface mining being conducted in eastern Powder River Basin, Black Mesa area, Arizona, and the Four Corners areas, is on-going.
- An evaluation of potential regional environmental impact of large-scale surface mining, processing, and conversion is underway in the Piceance Basin of northwest Colorado.

Problems:

- Long lead times are necessary to collect and analyze geological and geophysical needs for proposed lease sales in the hostile environments of onshore and offshore Alaska because of weather.
- Availability of lands for leasing is limited by natural and man-made environmental constraints.
- Methods to evaluate the reclamation potential of arid or semiarid lands are poorly known.
- Waste materials are volumetrically larger than the original oil shale.
- Disturbances of wide areas of surface land will adversely effect flora, fauna and drainage.

Program Implementation

Department of Interior

To achieve the stated objectives for coal resource appraisal and analysis, the U.S. Geological Survey maintains a coordinated research program, which includes geology, geophysics, geochemistry, and hydrology. This on-going program involves the collection of basic data on coal quality and quantity, geochemistry of minor and trace elements in coal, nature of surficial materials, overburden and floor rocks, ground water and surfacewaters, geochemistry of soil, vegetation and air, and sediment erosion and mass movement. These data are then analyzed and interpreted to prepare maps and reports that describe the nature and extent of coal resources, the potential impact of coal mining on the environment, and the reclamation potential of mined lands. This information also is used to help determine which tracts of federally-owned coal land should be offered for lease.

State governments, public and private universities, and industry participate in coal resource assessment and environmental studies through federal contracts and grants. Cooperative programs between the U.S. Geological Survey and the geological surveys in 16 of the 37 coal-bearing states currently are in effect, and grants to additional state surveys are planned. The state surveys collect coal samples and data for analysis by the USGS, thus expediting the preparation of state and regional coal resource assessment reports. Research grants to universities enable the federal government, through the USGS, to tap a large reservoir of expertise, particularly for topical studies of problems concerning the origin of coal, the distribution of chemical elements in coal and the reclamation of mined lands.

The U.S. Geological Survey implements its petroleum and natural gas resource appraisal objectives by proceeding through a sequence of resource assessments and by exploration research and exploration technology.

Preliminary appraisals of well-known sedimentary basins and initial appraisal of lesser known basins in 1975 provided baseline data for evaluating the nation's oil and gas resources.

These appraisals will continue through 1976 and beyond, and will focus on both onshore and offshore areas. They will be supported by intensive geological and geophysical data collection and analysis in less mature developed basins, particularly in the marine environments.

Geological analysis of sedimentary basins including study of the environment of deposition of source and reservoir rocks; sedimentary processes involved in their deposition; the geometry, extent and physical characteristics of the reservoir rocks and related beds; the nature of sealing rocks; and the types of traps—stratigraphic or structural—has begun. During the study of basins, effort is being made to develop geochemical equipment for the direct detection of oil and gas reservoirs from surface or very near surface accumulations of trace elements of escaping hydrocarbons.

Seismic reflection recording equipment and digital computers for data processing were acquired in FY 1975 and FY 1976 as the first part of basic and applied research on directing detecting of subsurface accumulations of oil and gas. These efforts were supplemented by the use of geophysical service companies.

Applied geological and geophysical research of geologically-related environmental problems in offshore areas, which was accelerated in FY 1975. The early identification of geological hazards in the OCS leasing process and a determination of their potential severity will help to guide the leasing program and protect the marine environment.

The USGS will continue detailed geological mapping the Piceance Creek basin, Colorado, and the Uinta Basin, Utah. Mapping in the Piceance Creek basin has been concentrated thus far on the areas of oil shale outcrop. Mapping in the Uinta Basin is being concentrated in areas of oil shale outcrop and in the areas in which overburden and structural data will be pertinent to resource and environmental analysis.

Eleven holes in the Piceance Creek basin and 6 holes in the Uinta Basin will greatly enlarge information on resources of oil shale and on the associated minerals. The central, deep part of the Piceance Creek basin contains large quantities of sodium and aluminum minerals which are a potential byproduct in production of shale oil. The specific distribution of these associated minerals, however, is poorly known.

The U.S. Geological Survey is continuing detailed studies on oil shales and their associated minerals: (1) To complete knowledge of the distribution, quality, and quantity of oil shale and the associated sodium-aluminum minerals, (2) to enable the Department of the Interior to evaluate potential sites for new lease tracts, (3) to provide information on thickness, grade, and distribution of oil shales which is necessary for conventional mining with surface retorting, open pit mining with surface retortion, or in-situ mining and processing, (4) to provide detailed information on the distribution and quality of the associated sailing minerals, which are potentially large sources for sodium and aluminum, and (5) to facilitate decisions regarding environmental controls that necessarily must be based on a knowledge of the trace element distribution in the oil shales, the associated rocks, and on the quality of the groundwater in these rocks.

Mapping and related studies, in cooperation with other investigations leading to the assembly of basic data maps on the bedrock geology, energy resources, geomorphic features and processes, hydrology, geochemistry, vegetation, and land use of the Piceance oil shale basin are underway. The final effort will be to prepare interpretive and derivative maps and reports to assist in evaluating regional environmental efforts of long-term large-scale, development of oil shale.

The program will involve continued monitoring in the Piceance Creek basin of Colorado with the refinement of models to perrmit prediction of aquifer responses.

Groundwater observation wells will be drilled in the Uinta Basin, Utah, and hydraulically tested; digital models of the groundwater systems will be developed and calibrated.

Water quality models will be developed to aid in managing the disposal of groundwater derived from oil shale mining dewatering operations.

Work in FY 1977 will extend and intensify basic hydrologic data collection activities in the major coal resource areas of the nation with emphasis on the Colorado River Basin and mid-continent areas; water quantity and quality monitoring sites will increase from a total of 955 in FY 1976 to approximately 975 in FY 1977.

Based on data collection in FY 1975 and 1976, preliminary models of coal impacted aquifer systems in the Northern Great Plains and at selected sites in the Southwest will be completed in FY 1977.

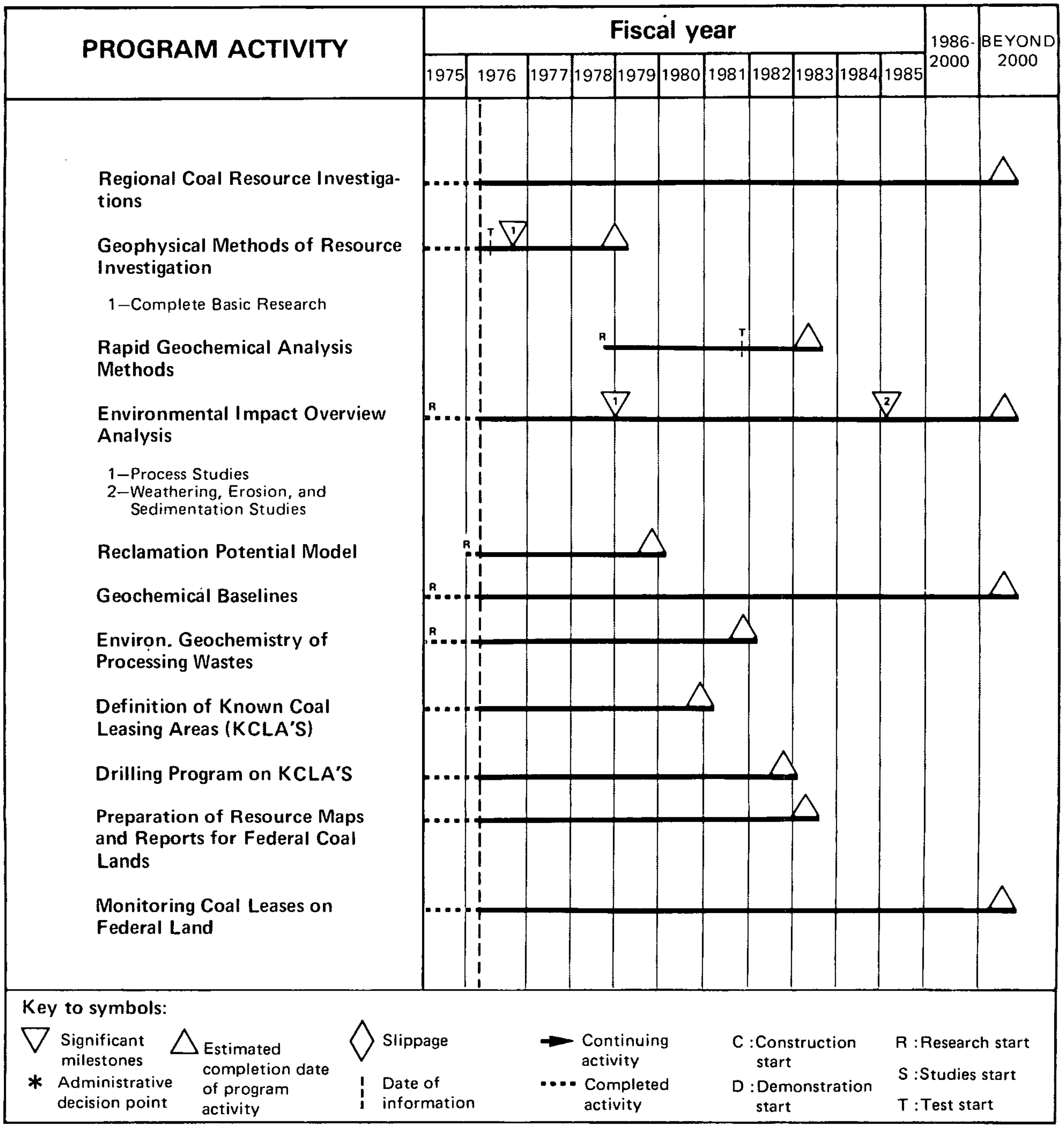
The Madison Limestone program in FY 1976 will largely involve the development of a comprehensive plan of study along with some preliminary geophysical tests and possibly the start of deep well drilling; the program in FY 1977 will emphasize installation and testing of groundwater observation well into the deeper regional aquifers coal deposits.

The study of water supplies and impacts of coal slurry-pipelines will continue in FY 1977.

U.S. GEOLOGICAL SURVEY

COAL

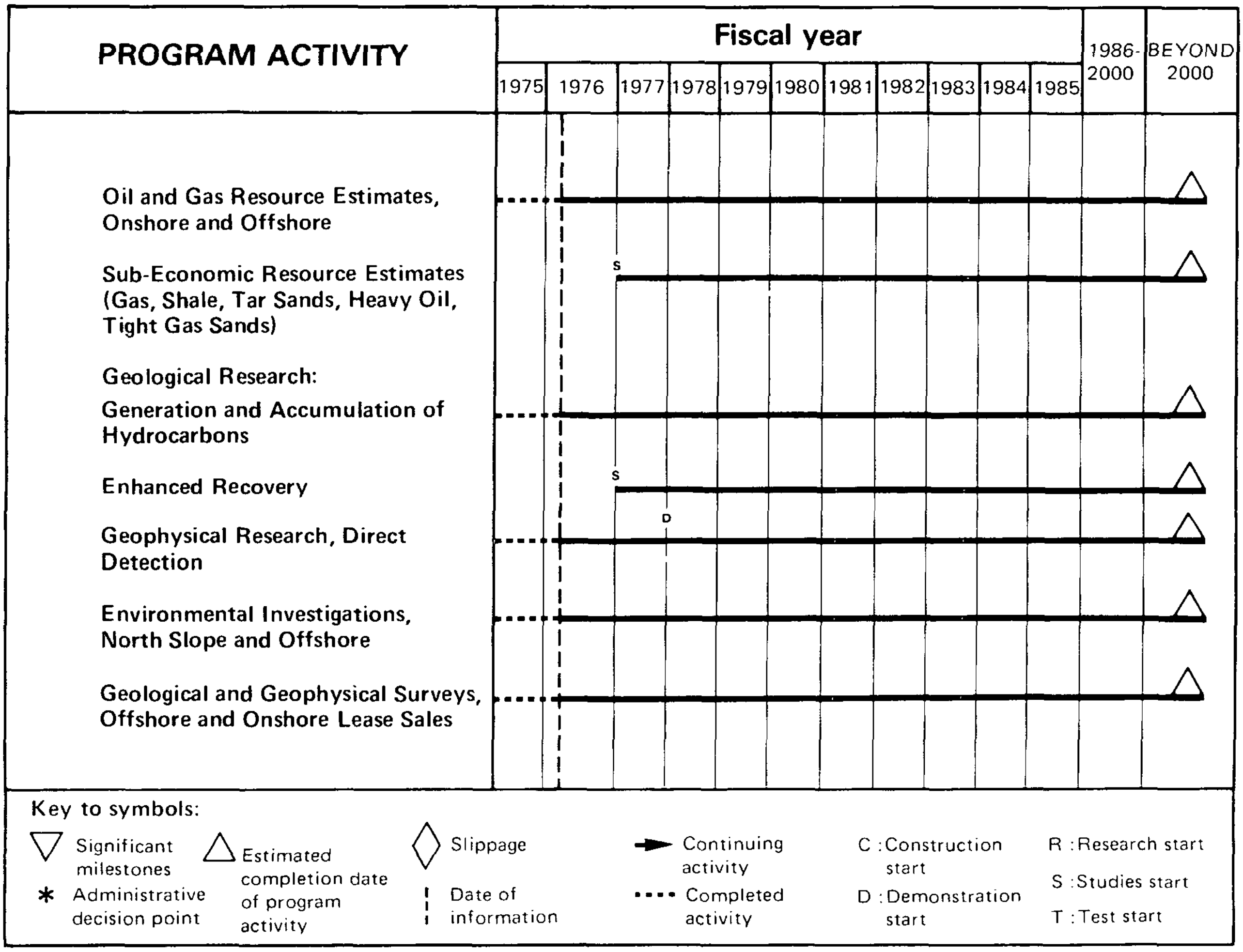
RESOURCE APPRAISAL



U.S. GEOLOGICAL SURVEY

OIL AND GAS

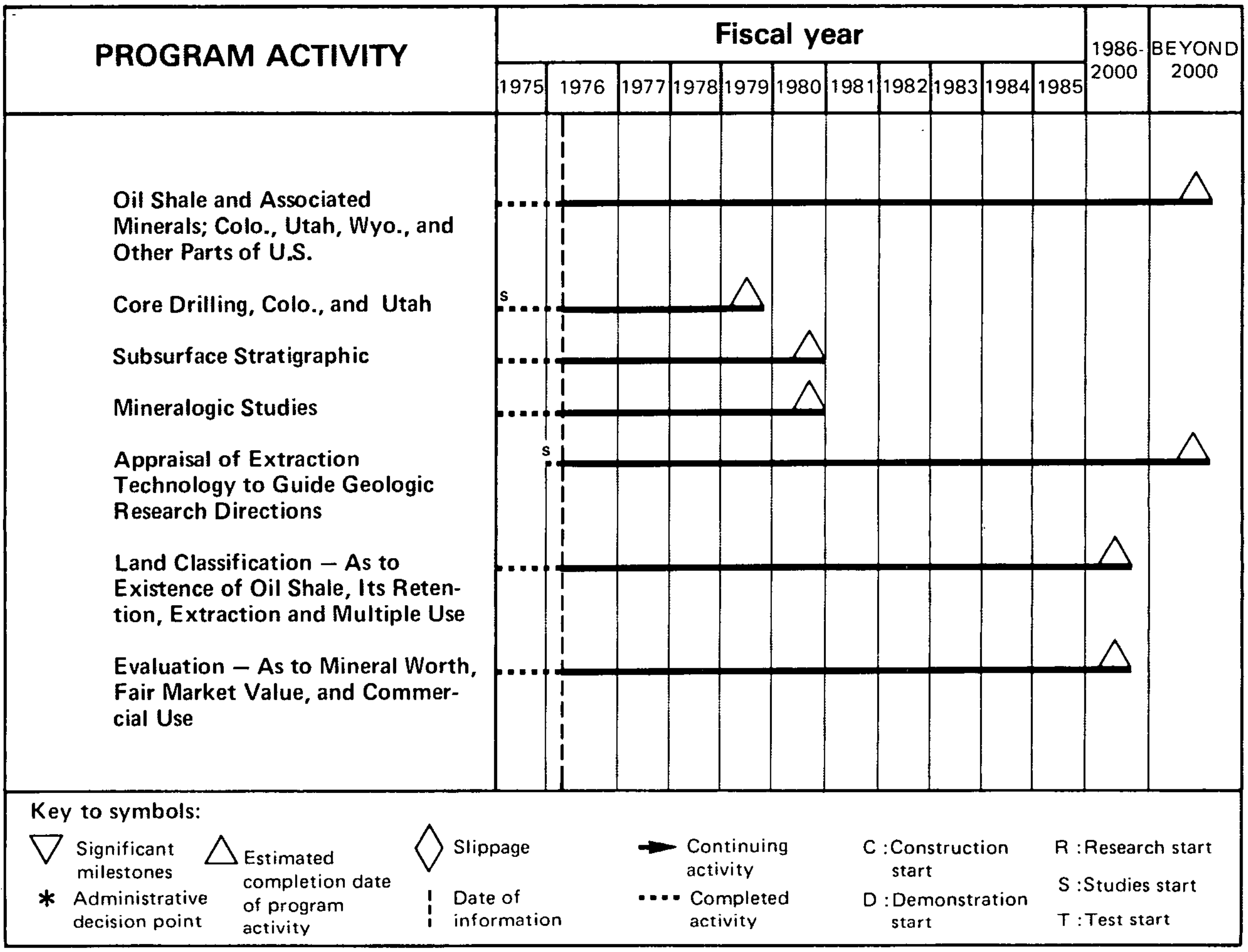
RESOURCE APPRAISAL



U.S. GEOLOGICAL SURVEY

OIL SHALE

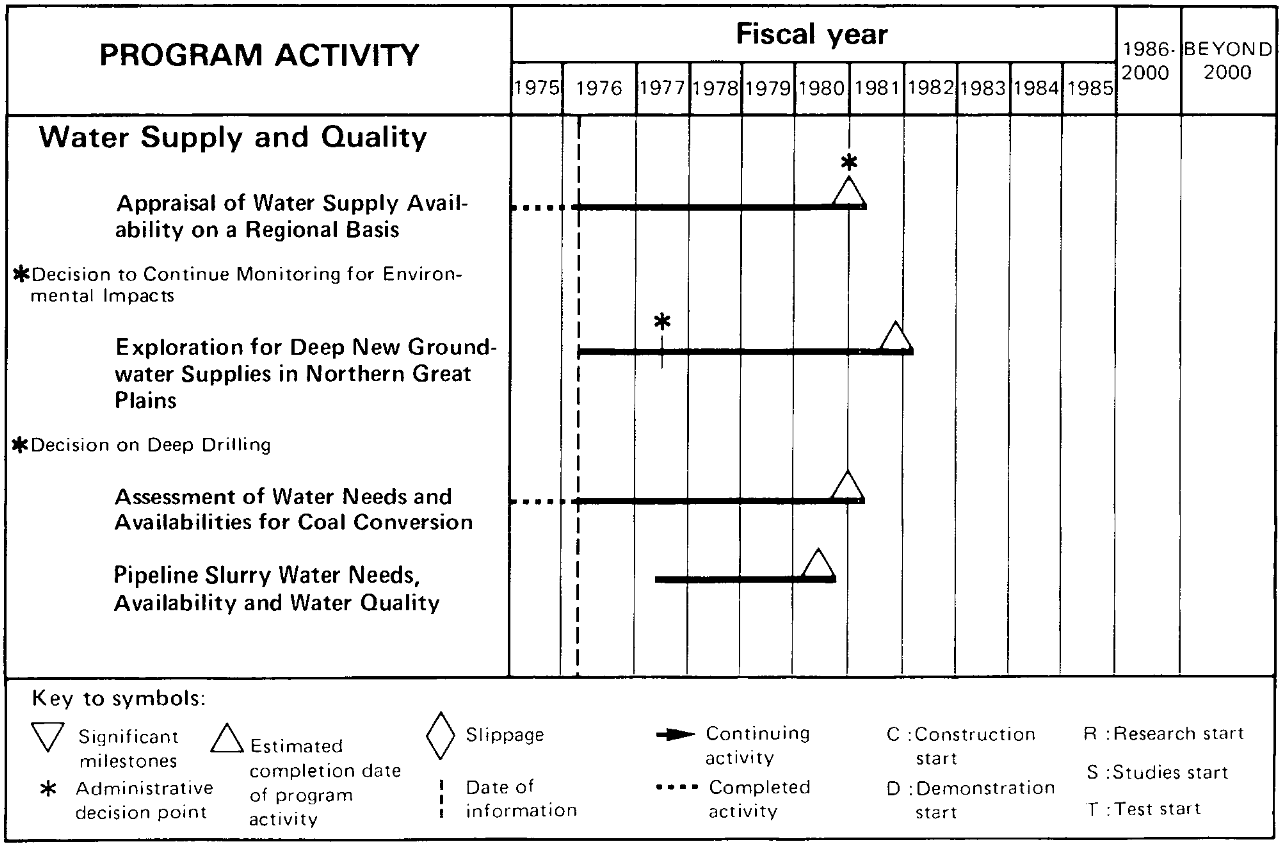
RESOURCE APPRAISAL



U.S. GEOLOGICAL SURVEY, WATER RESOURCES DIVISION

COAL HYDROLOGY PROGRAM

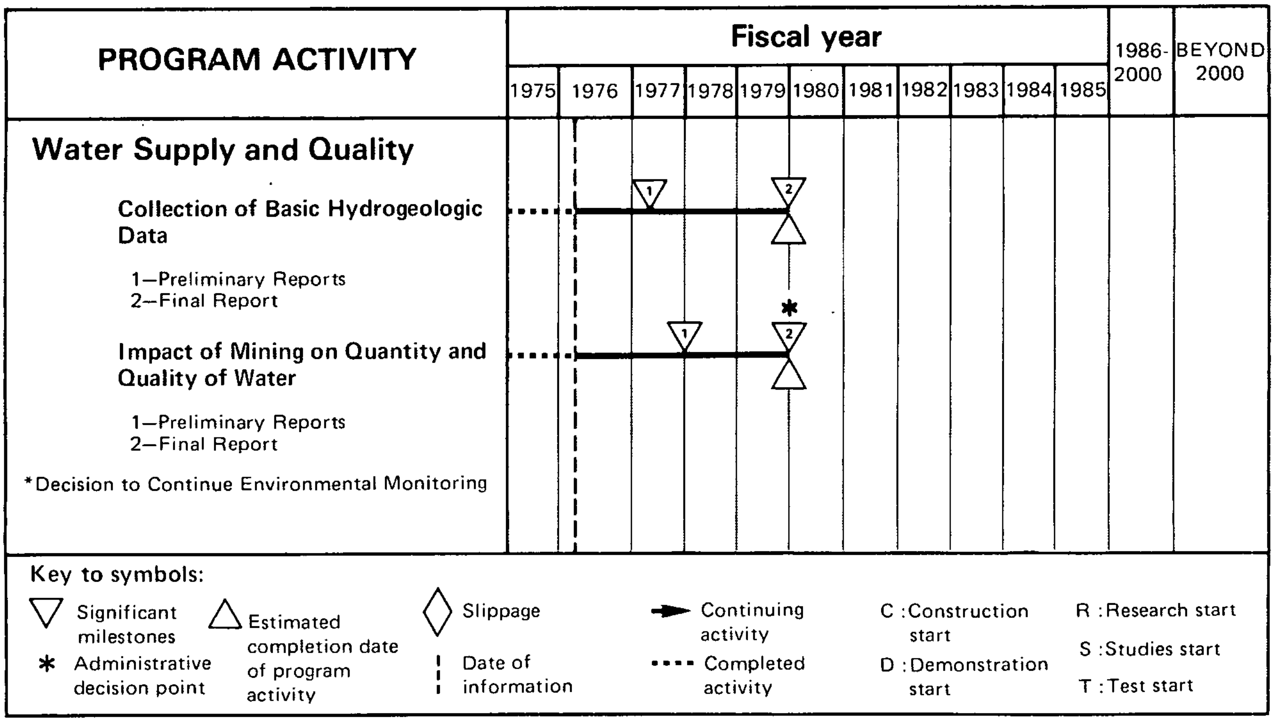
RESOURCE APPRAISAL



U.S. GEOLOGICAL SURVEY, WATER RESOURCES DIVISION

OIL SHALE HYDROLOGY PROGRAM

RESOURCE APPRAISAL



RESOURCE APPRAISAL

Federal Energy RD&D Budget — **($ Millions)**

Agency	FY 1975 BA	FY 1975 BO	FY 1976* BA	FY 1976* BO	FY 1977 BA	FY 1977 BO
DOI	17.4	16.9	18.2	17.9	17.2	17.0
Total	17.4	16.9	18.2	17.9	17.2	17.0

* Does not include funds for FY 1976 Transition Quarter.

SOLAR ENERGY EXECUTIVE SUMMARY

Solar energy represents a huge and virtually inexhaustible supply of energy that is widely available over the United States. It could supply as much as 25 percent of the Nation's future energy needs by 2020 if costs of collecting and using solar energy can be reduced substantially. In support of the national energy RD&D goals, the primary goal of the Federal Solar Energy RD&D Program is to stimulate and work with industry to develop and introduce, at an early date, economically competitive and environmentally acceptable solar energy systems to meet a significant fraction of the national energy requirements, commensurate with its potential.

The solar energy program* is organized into four major areas: 1) Thermal Application, 2) Technology Support and Utilization, 3) Solar Electric Applications, and 4) Fuels from Biomass. The activities in each area are:

- Thermal Applications
  —Solar Heating and Cooling of Buildings
  —Agricultural and Industrial Process Heat
- Technology Support and Utilization
  —Environmental and Resource Assessment
  —Solar Energy Research Institute
  —Information Dissemination and Commercialization
- Solar Electric Applications
  —Solar Thermal Energy
  —Photovoltaic Energy
  —Wind Energy
  —Ocean Thermal Energy
- Fuels from Biomass
  —Terrestrial and Marine Biomass
  —Agricultural and Forestry Residue

The strategy in solar energy RD&D is to lower cost and improve reliability to the point where natural economic forces will achieve expeditious commercialization. The role of industry, including small business, is being emphasized to ensure that results conform to market needs and constraints, thus establishing the foundation for widespread commercialization of solar energy systems.

In pursuing the above strategy, ERDA manages the major part of the Federal Solar Energy Research, Development and Demonstration program and promotes coordination of its activities with those of other federal agencies. In the National Solar Energy RD&D Program, ERDA is the central coordination agency with all activities such as federal, state and local agencies, academic institutions, private industries, societies and associations. ERDA is the national focal point for any international cooperative efforts on solar energy.

The specific details for each solar energy activity are discussed in the individual building blocks that follow.

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* A comprehensive description of the Solar Energy Program is presented in *Definition Report, National Solar Energy Research, Development and Demonstration Program, ERDA-49,* available on written request from the ERDA Technical Information Center, P.O. Box 62, Oak Ridge, Tennessee 37830.

SOLAR ENERGY

Federal Energy RD&D Budget

($ Millions)

Building Block	FY 1975		FY 1976*		FY 1977	
	BA	BO	BA	BO	BA	BO
Solar Heating & Cooling of Buildings	13.1	5.3	35.1	24.8	45.3	34.5
Agricultural & Industrial Process Heat	0.5	0.2	4.8	3.7	3.9	2.5
Environmental & Resource Assessments	0.7	0.5	1.0	0.9	1.5	1.3
Solar Energy Research Institute	0	0	2.2	1.6	1.5	1.0
Information Dissemination & Commercialization	0.7	0.5	2.2	2.1	1.0	0.7
Solar Thermal Energy	13.2	3.7	19.3	15.6	43.4	29.2
Photovoltaic Energy	5.2	2.6	22.4	16.4	32.8	24.3
Wind Energy	5.7	1.0	15.1	11.1	17.1	12.5
Ocean Thermal Energy	1.9	1.0	8.1	6.0	9.2	7.0
Fuels from Biomass	0.9	0.1	4.5	3.8	4.3	3.0
Total	41.9	14.9	114.7	86.0	160.0	116.0

* Does not include funds for FY 1976 Transition Quarter.

SOLAR ENERGY

Thermal Applications

SOLAR HEATING AND COOLING OF BUILDINGS

Objectives

The overall objectives of the federal activities in solar heating and cooling of buildings is to encourage the development of an industrial and commercial capability in economically viable and socially acceptable systems, thus reducing the demand on present fuel supplies through widespread residential and commercial use*

Near-Term:
(–1985)

- To establish through a demonstration program the overall performance of numerous types of solar heating systems by the end of 1977, and of combined heating and cooling systems by the end of 1979, in a wide variety of new and retrofitted buildings in all the climatic regions of the United States.
- To encourage the development of an industry with the capability for product development, production, distribution, installation and servicing of solar heating, cooling and hot water systems, which could develop and serve a growing market. This could lead to projected savings of about 0.2 quad/year of fuel consumption by 1985.
- To develop new technologies that will improve component and system performance, reduce costs, improve component durability and system reliability, and lead to more cost-effective systems for a broader range of applications. Special emphasis will be placed on development of retrofit systems and on new approaches to solar cooling.
- To encourage the private sector in its commercialization efforts through initiation in calendar year 1976 of a data bank and mechanisms for collection and dissemination of information on solar heating and cooling.

Mid-Term:
(–2000)

- To develop innovative systems and components involving high-payoff technologies where the investment of necessary funds by the private sector would involve high-risks. Provide research and development support for special critical problem areas arising from the national solar heating and cooling effort, so that system applications will become economically competitive for a broader range of buildings and climates.
- To continue encouragement of commercialization stemming from the previous demonstration program in conjunction with advances in systems capabilities and economics as a result of mid-term research and development support. This could result in fuel savings of about 2 quads/year by the year 2000.

Long-Term:
(Beyond 2000)

- To phase out federal research, development, demonstration and commercialization activities, as the existing solar heating and cooling industry becomes capable of making a growing contribution to the Nation's needs.

National Energy Technology Goals Supported

Primary

- Increase the use of essentially inexhaustible domestic energy resources.

* This program is described in detail in *National Program For Solar Heating & Cooling (Residential & Commercial Applications), ERDA–23A*, October 1975; available on written request to the ERDA Technical Information Center, P.O. Box 62, Oak Ridge, Tennessee 37830.

Secondary

- Transform consumption patterns to improve energy use.
- Increase end-use efficiency.

Strategy

The fundamental strategy for the solar heating and cooling program is to pursue concurrent efforts in six major areas:

- Residential Demonstrations
- Commercial Demonstrations
- Development in Support of Demonstrations
- Research and Advanced Systems Development
- Collection and Dissemination of Information
- Additional Policy Measures Required to Achieve Rapid and Widespread Utilization

Several cycles of residential and commercial demonstrations will be initiated by the end of FY 1977 in the case of solar heating of water and building space, and by the end of FY 1979 for combined solar heating and cooling. The performance and operation of many of the systems installed during the demonstrations in commercial and residential buildings will be monitored for a period sufficient to determine their technical and operational characteristics. In addition, the processes of design, integration, financing, obtaining of permits, construction, marketing and consumer acceptance will be studied and documented to identify the problems encountered in bringing solar heating and cooling into the marketplace. These results will provide a basis for recommendations for changes in existing procedures and legislation to ensure that the widespread implementation of solar energy in residential and commercial applications can be accomplished effectively. These results and recommendations will be included in documents and other media that will be disseminated widely.

Each cycle will utilize systems and subsystems of solar heating and cooling hardware that are available for delivery in sufficient quantities and with satisfactory characteristics to meet the performance, cost, reliability and schedule requirements of that demonstration cycle. The purchasers of such hardware will ensure that small business is afforded ample opportunity to participate in such procurements.

To expedite early demonstrations and to provide additional early markets for a developing industry, a substantial number of units will be installed on federal or federally administered properties, primarily by the Department of Defense, but including the General Services Administration, the U.S. Postal Service, the Veterans Administration and other agencies.

In close coordination with the demonstrations, the federal program plan includes a development effort that will support the upgrading of near-ready technologies into systems and subsystems available for use in later cycles of the federal demonstration program or in the private sector.

The successful execution of the mid-term national objective of widespread adoption of this technology requires that a vigorous research and development program be supported by the private sector, with some continuing support at the federal level. The R&D program will develop a spectrum of components, subsystems and systems to fill the varying needs of (1) domestic or institutional hot water service, (2) combined space and water heating, and (3) combined space heating/cooling and water heating for the various climatic regions of the United States. Whenever feasible, the R&D program will support a parallel effort involving alternative approaches. System studies combined with system and component performance data will be used for trade-off analyses and key decisions.

Federal Role

The federal role is to stimulate industry and potential users of the equipment, and to encourage the private sector through research, development and demonstration programs that are intended to lead to the early, widespread utilization of solar energy systems.

Federal involvement is justified by the:

- Present uncertainties and financial risks inherent in the commercialization of solar heating and cooling systems.
- Results of major studies projecting that widespread use of solar energy applications may not take place before the end of the century without federal stimulus.
- Need for governmental action (including state and local) to encourage use of solar energy through appropriate legislation and to reduce legal and institutional barriers.

The Federal Solar Energy Program for heating and cooling of buildings is responsive to the following public laws passed by the 93rd Congress:

- Solar Heating and Cooling Demonstration Act of 1974, P.L. 93–409, September 3, 1974.

- Energy Reorganization Act of 1974, P.L. 93–438, October 11, 1974.
- Solar Energy Research, Development, and Demonstration Act of 1974, P.L. 93–473, October 26, 1974.
- Federal Nonnuclear Energy Research and Development Act of 1974, P.L. 93–577, December 31, 1974.

Private investment has been, and may continue to be, limited because the high capital cost of solar systems has thus far restricted market demand. However, federal programs are not intended to be a substitute for private investment, but are designed to act as a catalyst to encourage greater utilization of solar energy systems. Continued primary reliance on the private sector is essential if we are to realize the full potential of solar energy technology. This has restricted development of a substantial industrial base.

International Cooperation

The international cooperation in solar heating and cooling of buildings is centered within the International Energy Agency and the NATO Committee on the Challenges of Modern Society (CCMS). In support of the International Energy Agency, ERDA has participated in the development of a proposed working plan for international cooperation in solar heating and cooling research and development. The project areas within this cooperative program and the lead countries are:

- Solar heating, cooling and hot water supply systems—Denmark.
- Development of components—Japan.
- Thermal performance testing of solar collectors—Federal Republic of Germany.
- Development of insolation instrumentation package—United States.
- Insolation parameters from existing meterological records—Sweden.

The participating countries (Austria, Belgium, Canada, Denmark, F.R. Germany, Ireland, Italy, Japan, New Zealand, Norway, Spain, Sweden, Switzerland, Turkey, United Kingdom, and the United States) have assigned a liaison officer for each of the five project areas. Phase I of the working plan, now complete, provided for dissemination among the participating countries of information relating to the state-of-the-art within each country for each of the project areas. The second Phase, now underway, calls for detailed project plans to be defined as part of an Implementation Agreement.

The objective of the CCMS Solar Energy Pilot Study, initiated in November 1973, is the exchange of information on the solar heating and cooling systems programs and projects of each participating country to encourage the cost-effective and practical application of solar energy to heating and cooling in residential, commercial, industrial, agricultural, and public hearings. A key element in this information exchange is the preparation and distribution of special reports, prepared in an agreed format, on certain projects in the participating country. The United States is the pilot country, responsible for direction and administration, with Denmark and France as co-pilot countries. At present, eight countries (Australia, Belgium, Canada, Denmark, F. R. Germany, Israel, Italy, and the United States) have signed a memorandum of understanding which covers the guidelines for participation in this project.

Technological Status and Problems

Status:

- The basic principles of solar heating and cooling are known and systems utilizing these basic principles have been in use for a number of years.
- Solar energy systems for heating and cooling of buildings are generally expensive at the present time and their durability has not been widely demonstrated.
- Some components (e.g., collectors) are now in limited production. These, as well as modified off-the-shelf items (e.g., absorption air conditioners), are being utilized in complete solar heating and cooling systems, both privately and under the federal program. Much valuable information is being obtained for increasing the cost-effectiveness of such applications.
- There are no solar cooling systems available today that can operate effectively at temperatures easily obtainable with flat plate collectors presently available.
- Water and rocks are the thermal energy storage materials used in most existing solar heating and cooled buildings. The use of phase-change materials has not been adequately developed.

Problems:

- The present cost effectiveness of solar heating and cooling systems is relatively low; therefore, the needs associated with the development of improved systems include:
  1. lower cost designs for all major components,
  2. improved durability of all major components,
  3. low incremental cost (solar costs vs. conventional heating and cooling systems),
  4. improved retrofit designs,
  5. improved passive systems designs.
- Improved collectors using optimized cover systems, improved selective absorbers, concentration, and honeycombs or evacuated spaces as barriers must be developed to meet the high temperature performance requirements for cooling and industrial heat processing. To achieve these higher performance requirements, a greater understanding of optical interactions, materials, and heat transfer, as they pertain to collectors, is needed, as well as additional technological development.
- Aesthetically pleasing collectors that can be integrated easily into the architecture of buildings are needed.
- Advanced concepts such as phase-change, chemical storage, storage in underground aquifers, long-term seasonal storage, and storage integral with building structures should be explored, from measuring basic materials properties to the design and development of effective heat exchangers and containers.
- The potential of solar assisted heat pumps on a regional basis should be evaluated and the associated performance requirements should be established for the low-temperature collectors and heat pumps.
- An effective method must be developed and tested for the optimization of solar heating and cooling systems to be retrofitted into existing buildings.

Institutional Status and Problems

Status:

- Currently, the high initial cost of solar heating and cooling systems overshadows potentially lower life cycle costs, and consequently, life cycle costing often is not considered by building owners.
- Studies of the interaction between the utility industry and the future aggregate of solar heated and cooled buildings have recently been initiated.

Problems:

- Valid economic data for lenders, builders and buyers are not currently available and must be developed.
- Solutions to jurisdictional problems arising out of the use of solar energy for the heating and cooling of buildings are not available and must be developed.
- Policies on sun-rights must be established.
- More extensive design and environmental data must be generated.
- While the future role of utilities is likely to become a very significant factor in the widespread adoption of solar heating and cooling systems, a major assessment of that role has not been made. Innovative techniques will be needed to solve the problems of load management and peak demand. The possibility of utility ownership as a means of overcoming acquisition costs should be investigated.

Environmental Status and Problems

Status:

- While solar heating and cooling systems are believed to be relatively benign environmentally, the total environmental impact of widespread use of these systems has not been evaluated.

Problems:

- Some of the more efficient fluids proposed for use in heat transfer, heat storage, or refrigeration have various degrees of toxicity. The potential for release of such toxic fluids from residential or commercial systems, either by accident or through normal maintenance, must be reduced by utilizing materials, equipment, and operational and maintenance procedures which are essentially fail-safe, or by developing efficient nontoxic fluids.

Program Implementation

To implement the demonstration program, ERDA and HUD will solicit the participation of suppliers of solar heating and cooling equipment. Solar system integration firms, builders, and owners and operators of buildings. The first of an annual cycle of solicitations for demonstrations has been initiated to demonstrate heating applications by 1977 and heating and cooling by 1979. The information obtained from the demonstration projects will be provided in usable forms for widespread dissemination as well as to guide research and development activities. Each additional cycle will bring improved components and systems from the R&D activities into the demonstration program.

R&D objectives are being implemented by funding a broad group of analyses, applied research, technology and engineering development projects. This R&D is being conducted on collectors, storage, cooling cycles, heat pumps, heat exchangers, controls and complete systems. Innovative techniques, such as concepts of passive systems, unique architectural design, and retrofit systems, are also being studied. Supporting projects such as technical workshops are being funded. The R&D results will be widely disseminated to accelerate the rate of technology transfer to the industrial and commercial sectors.

The heating and cooling of buildings program within ERDA is being closely coordinated with a number of other Federal agencies: HUD for residential building demonstrations; NASA for testing and evaluation; DOD for military installations; NBS for standards and test procedures; GSA for Federal buildings; NOAA for resource assessment; and FEA for studies of the costs and benefits or providing incentives for rapid adoption of these technologies. Additional details on the roles of these and other Federal agencies in the solar heating and cooling program may be found in **ERDA 23A,** Chapter 9.

1976–1977

Systems analysis and overall design of the Federal demonstration program are underway to ensure that the projects undertaken will effectively stimulate industry development.

Proposals have been and will be solicited for installing heating systems in new and existing buildings at selected locations using state-of-the-art collection systems. Supporting research and development programs on components, materials, systems and subsystems are also underway. The resulting improved technology will be incorporated into the later demonstration cycles.

1978

Emphasis will shift to demonstrating combined solar heating and cooling systems. Demonstrations will extend to new applications which R&D results indicate may become cost-effective.

1979

A substantial number of residential and commercial buildings equipped with solar heating and cooling systems will have been demonstrated and evaluated. A data base for design of solar heating systems with predictable cost, performance, and reliability will be available. The outputs of the R&D program will be improved devices, processes and concepts to make solar energy systems more competitive with conventional systems.

1980–2000

The demonstration program results will be monitored and appropriate actions taken to follow through with respect to necessary incentives and removal of barriers for widespread use and commercialization of solar heating and cooling of buildings.

SOLAR HEATING AND COOLING OF BUILDINGS

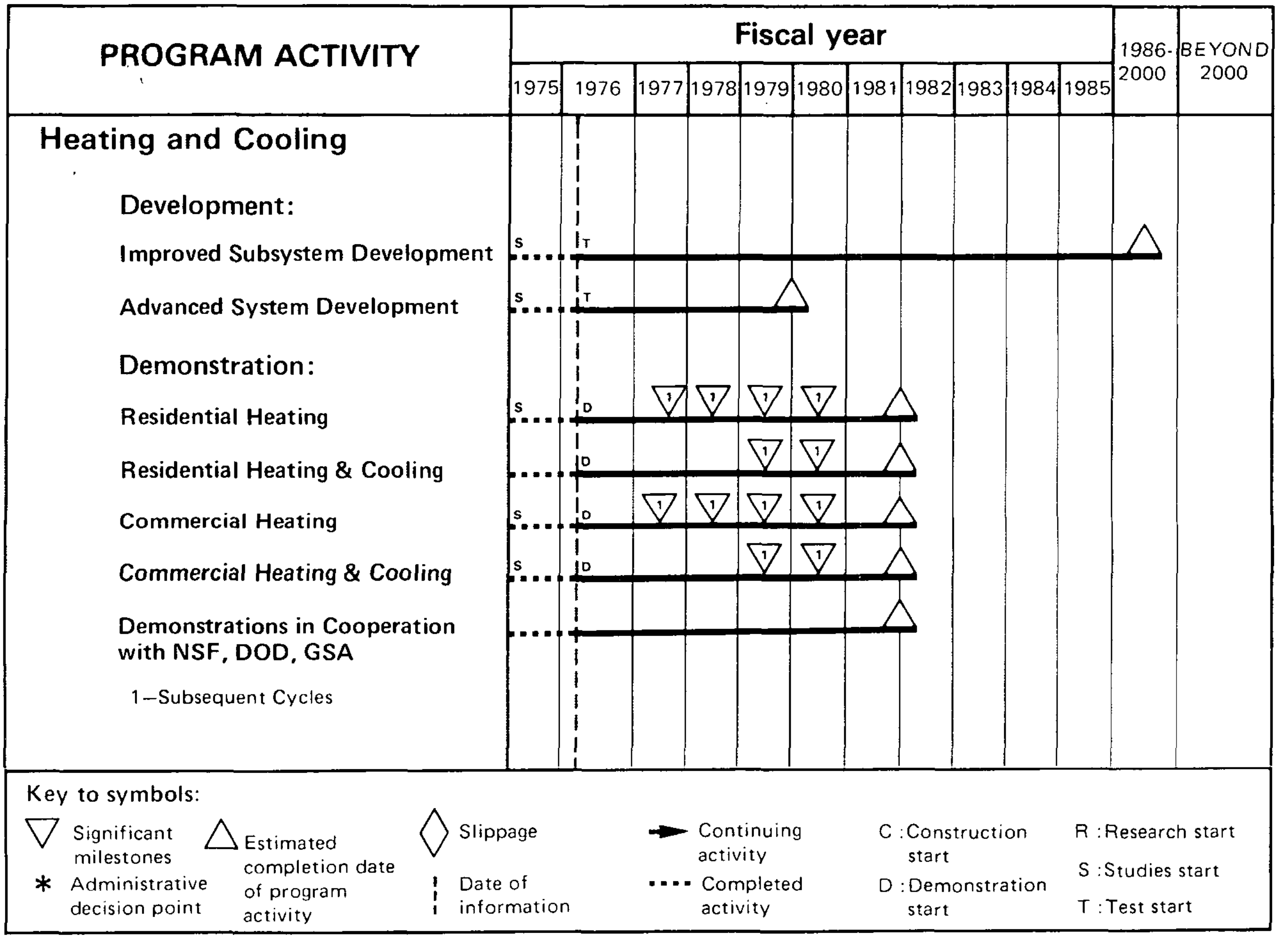
Federal Energy RD&D Budget **($ Millions)**

Agency	FY 1975		FY 1976*		FY 1977	
	BA	BO	BA	BO	BA	BO
ERDA						
Operating Expenses	13.1	5.3	35.1	24.8	45.3	34.5
Plant and Capital Equipment	0	0	0	0	0	0
Total	13.1	5.3	35.1	24.8	45.3	34.5

* Does not include funds for FY 1976 Transition Quarter.

ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION

SOLAR HEATING AND COOLING OF BUILDINGS



SOLAR ENERGY

Thermal Applications

AGRICULTURAL AND INDUSTRIAL PROCESS HEAT

Objectives

Agricultural:

Near-Term:
(–1985)

- To develop and demonstrate a solar energy technology for the drying of grains and crops and the heating of animal shelters and greenhouse structures. The stimulation of commercial development could substantially reduce U.S. consumption of fossil fuels for these purposes. By 1985, it is possible that solar energy could supply about 0.1 quad/year, or about 5 percent, of the demand for energy for agricultural purposes.

Mid-Term (–2000) and Long-Term:
(Beyond 2000)

- To have industry take over and mass produce standard systems for commercial use. The program could make possible, by 2000, 0.7 quads or approximately 25 percent of the expected agricultural demand, and by 2020, 50 percent of the expected demand for agricultural purposes.

Industrial Process Heat:

Near-Term:
(–1985)

- To encourage the application of applying solar state-of-the-art components and technology to industrial processes to reduce U.S. consumption of fossil fuels. To help develop commercially viable industrial process hot water and drying/dehydration systems. By 1985, solar energy systems may supply about 0.1 quad/year or about 0.2 percent of the energy needed for industrial process heat.

Mid-Term:
(–2000)

- To help develop commercially viable, industrial process steam and other drying/dehydration processes up to 350°F. By 2000, this program could make possible a solar energy contribution of about 2.3 quads/year, or about 5 percent of the energy needed for industrial process heat.

Long-Term:
(Beyond 2000)

- To make available the technology for heat for high-temperature industrial processes (greater than 350° F) for high-pressure steam, high-temperature drying and chemical reactions. By 2020, it is estimated that solar energy could be supplying about 20 percent of the energy needed for industrial process heat.

National Energy Technology Goals Supported

Primary

- Increase the use of essentially inexhaustible domestic energy resources.

Secondary

- Transform consumption patterns to improve energy utilization.

Strategy

Agricultural Program

The strategy is to continue support of a range of applications from small-scale field and laboratory studies in grain drying, crop curing and heating of livestock and greenhouse structures through experimental stages of system development. As economical systems are identified and USDA bulletins provide widespread publicity, industry is encouraged to enter the field to manufacture the systems with federal money to support demonstrations.

Independent review and evaluations will be conducted to ensure that new energy conversion techniques and applications are identified and result in optimum efficiency and improved economics. This approach is being used, for example, to combine solar expertise with the agricultural experience of USDA. Technology transfer is both an inherent and a necessary aspect of this program.

Industrial Process Heat Program

The strategy is to support a series of technological programs ranging from system design and analysis, through a pilot development experiment and demonstration programs.

Technical success or failure is measured by: the degree of cost-effectiveness of solar energy system applications over conventional systems; the potential impact on total energy requirements; and the stimulus given to the competitive growth of industry in supplying a significant amount of industrial process heat through the use of solar energy.

Each cycle of design and analysis, experiment and demonstration, will make use of increasingly advanced technology. Demonstration efforts will be aimed at developing advanced systems with improved performance at lower costs and to effect technology transfer and improve applications through user involvement. When cost competitiveness between solar systems and conventional energy source systems are shown in the demonstrations, then the industry will have the incentive to assume the lead role and commercialize the field.

Federal Role

Federal participation will stimulate industry acceptance by alleviating uncertainties and financial risks associated with the introduction of solar energy in agricultural and industrial process heat applications.

The federal role will diminish as success in defined areas of agricultural and industrial process heat applications creates intensified participation by the private sector.

International Cooperation

Some aspects of the International Energy Agency (IEA) cooperative programs described in the Solar Heating & Cooling of Buildings Program, also apply to the Agricultural and Industrial Process Heat Programs.

Technological Status and Problems

Status:

- First-generation agricultural process systems are in design or operation for grain drying, crop drying, and heating of greenhouses and animal shelters.
- Industrial process heat surveys to identify those processes where solar energy can have a major impact are now underway.
- Industrial process heat experiments are being conducted on prototype shallow solar ponds designed to generate water at 140°F (60°C) at Grants, New Mexico, for uranium refinement. Operational data is being acquired to assess performance and system economics.
- A University study is in process to determine the potential of solar heating processes in the textile industry.

Problems:

- Cost-effective solar systems suitable for agricultural and industrial process heat applications are not yet available.
- Agricultural systems must be designed for ease of assembly, maintenance and use by farm personnel, and in such a way that they are useful on a year-round basis.
- Industrial systems must have low initial cost and must be serviceable by plant maintenance personnel on a periodic basis.
- Information and instruction manuals on the erection and servicing of solar systems for agricultural and industrial process heat must be prepared and distributed.

Institutional Status and Problems

Status:

- USDA Information Bulletins are being made available to the users periodically.
- Experiments and demonstrations at Agricultural Research Service (ARS) and State Agricultural Experiment Station (SAES) facilities are being performed at various locations in the U.S.
- The potential market for industrial process heat systems is being determined in current studies.

Problems:

- A new industry must evolve to provide and support an adequate quantity of these systems to significantly impact the National energy needs.
- Application of agricultural and industrial process heat systems may hav a significant impact on utility and rate structures, but the extent is not known.
- There is no precedent by which to decide jurisdictional responsibility of different trades for the installation and operation of solar systems.
- Legislation concerning sun-rights may become necessary to protect large capital investments in solar arrays from becoming shadowed.

Environmental Status and Problems

Status:

- Solar energy systems in agricultural and industrial processes have a relatively benign impact on the environment.

Problems:

- As the use of conventional fuels becomes more costly due to non-availability or environmental control, industry may tend to migrate to regions of high solar flux. Consequently, an increased demand for arid land and scarce water resources may occur, having a moderate to major environmental and social impact.

Program Implementation

In the agricultural solar energy program, close coordination will be maintained with the United States Department of Agriculture (USDA) to assure the maximum use of their expertise. A major USDA-ERDA interagency agreement has been reached covering a period of five years and supporting work in the following areas: Solar Grain Drying, Solar Crop Drying, Solar Greenhouse Heating, Solar Livestock Shelters, and, Solar Agricultural Food Processing.

The economic viability for heating of animal shelters, heating and cooling of greenhouses, food dehydration, agricultural food processing and crop curing will be investigated prior to 1980, followed by commercialization during 1980–1985. The widespread USDA Information Bulletin Service will be used for rapid dissemination of information to the users.

During the 1976 to 1979 period, demonstrations cost-shared with agricultural co-ops and industry are planned so that comparisons may be made between solar systems and conventional installations in full-scale operation.

The industrial process heat program is divided by temperature into three major areas:

1. Under 212°F (under 100°C)
2. 212°F to 350°F (100°C to 176°C)
3. Above 350°F (above 176°C).

Experiments in the area under 212°F in low-temperature liquid and vapor are ready for design and test. Low-pressure steam and intermediate-temperature vapor experiments falling in the 212°F to 350°F range are expected to start within the next two years, while experiments at 350°F, high-pressure steam and high-temperature vapor are expected by 1979. See the milestone charts.

Feasibility and economic viability of solar energy for producing industrial process heat at low-, intermediate-, and high-temperatures could be determined before 1985. Commercialization may begin between 1980–1990. The industry will become involved with experiments, at first supported by government funding and then by full-scale cooperative demonstrations.

Major Milestones:

FY 1976

- Proposals for agricultural and industrial process hot water, drying and dehydration were received.
- Decisions will be made to construct experiments based on these proposals.
- Preliminary designs for solar powered irrigation will begin.

FY 1977–78

- Decisions will be made to construct experimental, solar energy supplemented industrial processes to study performance and economics. The projects will be implemented as quickly as the methodologies for economically viable applications can be supported by the developing technology.

Early FY 1980's

- Decisions will be made to construct full-scale plants for demonstrating agricultural and industrial growth.

FY 1985–1990's

- By 1985, demonstrations and displays of full-scale agricultural and industrial process heat plants may be completed. This could lead to additional plants being constructed by private industry during the late 1980's and early 1990's.

AGRICULTURAL AND INDUSTRIAL PROCESS HEAT

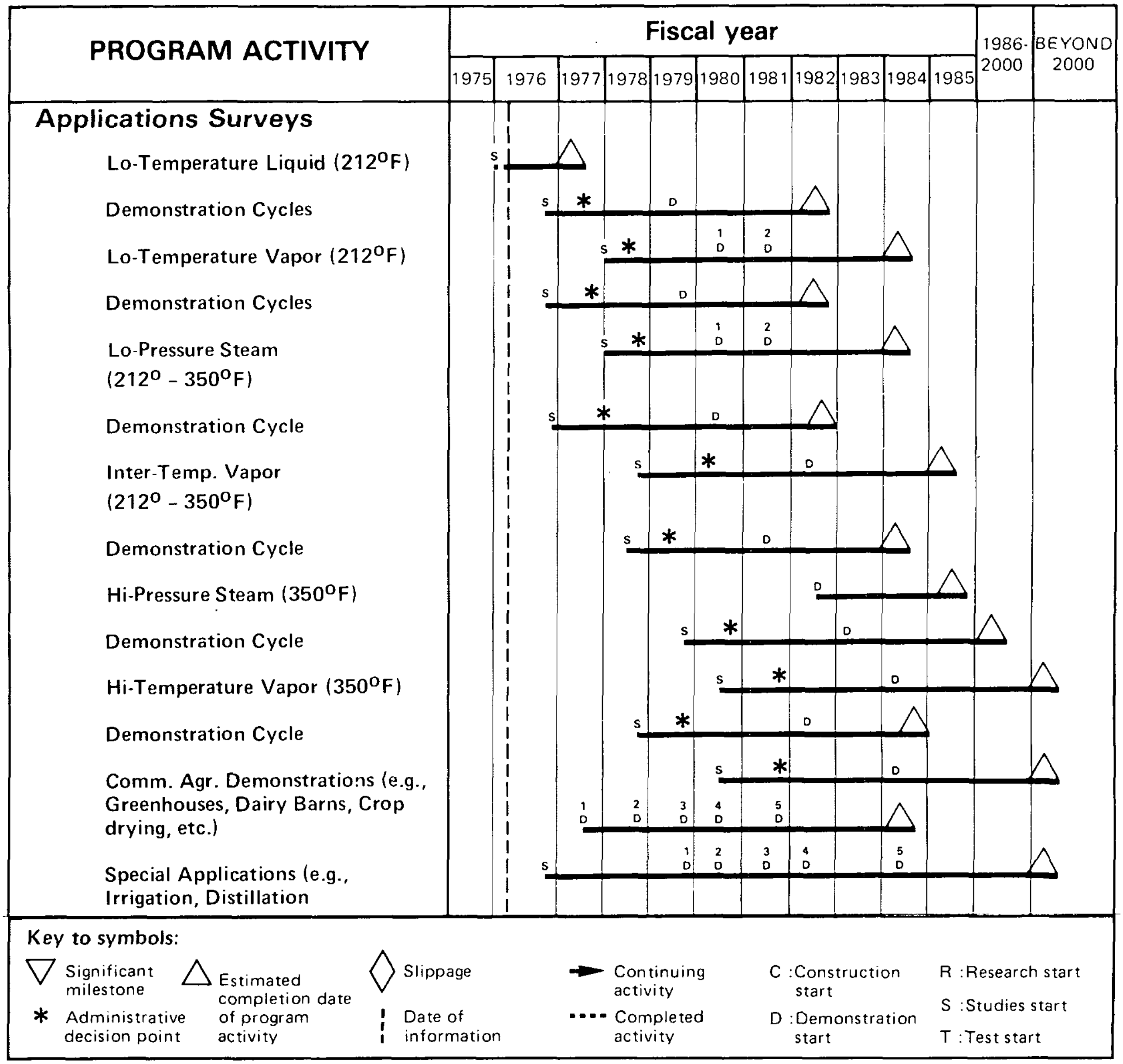
Federal Energy RD&D Budget **($ Millions)**

Agency	FY 1975 BA	FY 1975 BO	FY 1976* BA	FY 1976* BO	FY 1977 BA	FY 1977 BO
ERDA						
Operating Expenses	0.7	0.5	1.0	0.9	1.5	1.3
Plant and Capital Equipment	0	0	0	0	0	0
Total	0.7	0.5	1.0	0.9	1.5	1.3

* Does not include funds for FY 1976 Transition Quarter.

ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION

AGRICULTURAL AND INDUSTRIAL PROCESS HEAT



SOLAR ENERGY

Technology Support and Utilization

ENVIRONMENTAL AND RESOURCE ASSESSMENT

Objectives

Near-Term:
(–1985)

- To collect and standardize existing solar resources (insolation, wind and ocean thermal) data.
- To coordinate collection, preservation and dissemination of data on a nationwide basis.
- To perform environmental and technology assessments of each solar energy technology.
- To identify potential socio-environmental problems early in the technology R&D cycle.

Mid-Term (–2000) and Long-Term:
(Beyond 2000)

- To continue the collection of solar resource data where appropriate.
- To provide new capabilities for resource measurement in response to new requirements.
- To provide continuing support in the areas of environmental and technology assessments.

National Energy Technology Goals Supported

Primary

- Increase the use of essentially inexhaustible domestic energy resources.

Secondary

- Protect and enhance the general health, safety, welfare and environment related to energy.
- Increase the efficiency and reliability of the processes used in energy conversion and delivery systems.
- Perform basic and supporting research and technical services related to energy.

Strategy

To provide the required data on a standardized basis by implementation of a federal network of insolation, wind and ocean thermal measuring stations. Alternative strategy would be to find civilian societies and/or industry to collect the data.

To assess the various types of impacts upon society resulting from widespread implementation of solar energy. To insure that adverse socio-environmental impacts are mitigated and beneficial impacts are exploited to the fullest extent possible.

Federal Role

In some instances, substantial increase in basic resource data is needed to support practical application of the solar technologies, where the high cost and low direct return on resource assessment efforts inhibit the production of these data by industry. In this case a federal role may be effective in developing improved resource data. While extensive use will be made of existing monitoring stations, the addition of new measurements to the current capability will be required, as well as a number of new data gathering points. A central resource data exchange will be fostered through government/private cooperation.

The Federal Government is required by law to conduct environmental assessments for all major actions which may produce significant environmental impacts. This is a responsibility which cannot be delegated to other institutions.

International Cooperation

The International Energy Agency (IEA) program includes worldwide cooperation on weather data and information exchange on research projects using standardized reporting formats. Existing solar programs in other countries (i.e., France, Italy, Israel, Scandinavia) are followed through liaisons with technical program officials. Exchange of technical data is accomplished through the IEA and the NATO CCMS program described in the heating and cooling of buildings section.

Institutional Status and Problems

Status:

- Currently negotiating an inter-agency agreement with whom to facilitate gathering of solar resource data.

Problems:

- Cooperation among various institutions will be required to provide collection and storage and to reduce and eliminate duplication of effort.

Program Implementation

Resource requirements and analyses for each solar technology will be determined. Rehabilitation of historic weather and insolation data will be coordinated with NOAA to establish a basic solar data base. The National Weather Service Insolation Network will be improved to provide better nationwide collection capabiilty. The present wind resource data bank is inadequate for system strategy analysis, and will be appropriately increased beginning with the existing NOAA and DOD data. Acquisition of site-specific wind data for design criteria and system performance evaluation will be completed by 1981

Existing oceanographic data from NOAA, NSF, DOD and others will be correlated by 1977, and a data base for Ocean Thermal Energy Conversion (OTEC) site selection and system application strategy analysis will be established. Acquisition of site-oceanographic data for design criteria and system performance evaluation of OTEC systems will be completed by 1985.

Other federal agencies which support this program include NOAA for weather data for the data bank.

The broad socio-environmental implications of a successful national solar program will be determined. A programmatic environmental plan will be prepared to insure timely examination of each solar technology as the technology becomes a probable contender for commercialization. Technology assessments will be performed as necessary to ensure an orderly acceptance of viable solar technologies with a minimum of social disruptions: socio-environmental opportunities will be stressed and adverse impacts will be mitigated.

ENVIRONMENTAL AND RESOURCE ASSESSMENT

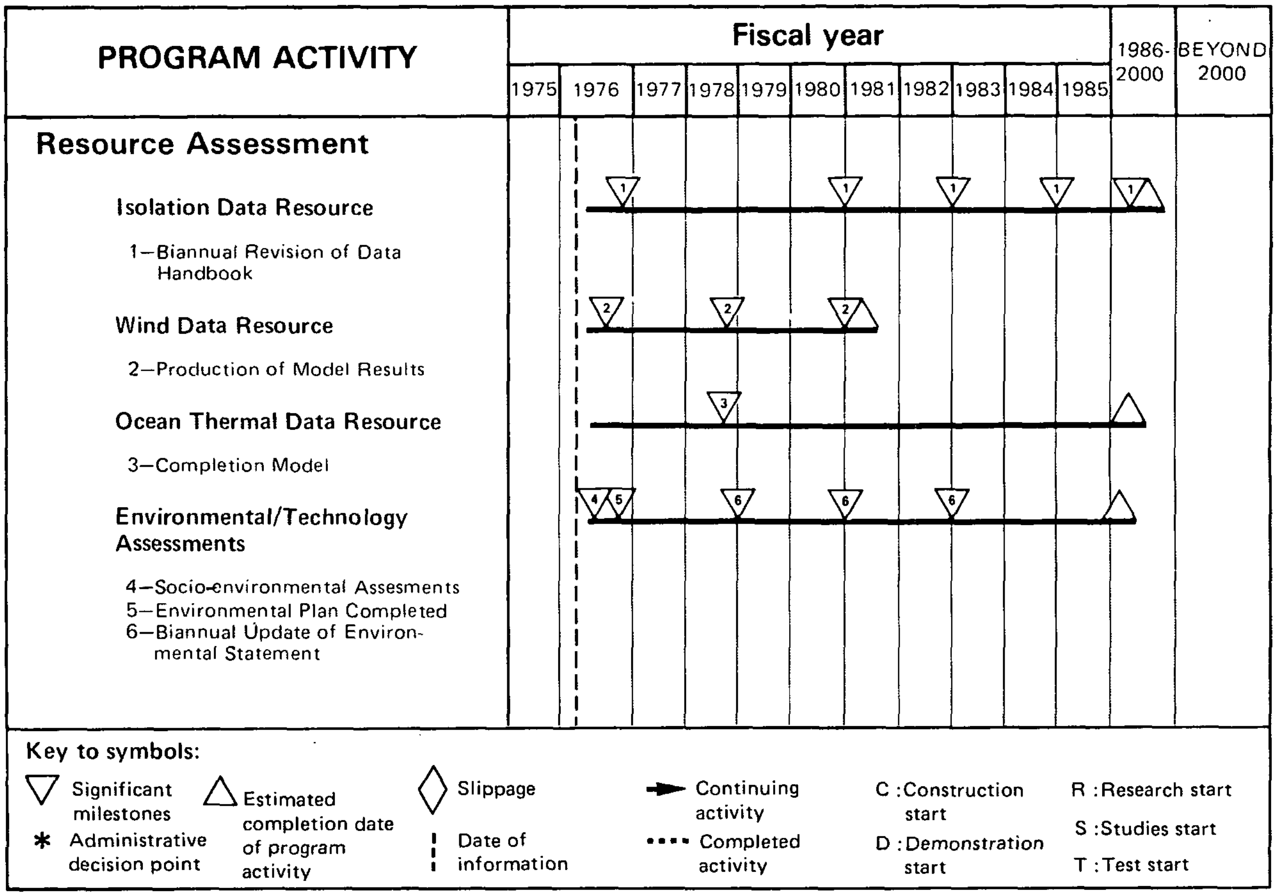
Federal Energy RD&D Budget **($ Millions)**

Agency	FY 1975		FY 1976*		FY 1977	
	BA	BO	BA	BO	BA	BO
ERDA						
Operating Expenses	0.5	0.2	4.8	3.7	3.9	2.5
Plant and Capital Equipment	0	0	0	0	0	0
Total	0.5	0.2	4.8	3.7	3.9	2.5

* Does not include funds for FY 1976 Transition Quarter.

ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION

ENVIRONMENTAL AND RESOURCE ASSESSMENT



SOLAR ENERGY

Technology Support and Utilization

SOLAR ENERGY RESEARCH INSTITUTE (SERI)

Objectives

Near-Term:
(–1985)
Mid-Term (–2000) and Long-Term:
(Beyond 2000)

- To perform such analyses, research, development, and related functions as may be determined necessary or appropriate in support of the National Solar Energy Program.

National Energy Technology Goals Supported

Primary

- Increase the use of essentially inexhaustible domestic energy resources.

Secondary

- Efficiently transform fuel resources into more desirable forms.
- Transform consumption patterns to improve energy utilization.
- Protect and enhance the general health, safety, welfare, and environment related to energy.
- Perform basic and supporting research and technical services related to energy.

Strategy

SERI will support the National Solar Energy Program with analysis and assessment activities and other specific activities to achieve the stated SERI objectives and the National energy goals.

Federal Role

Establishment and operation of SERI is required by P.L. 93–473.

International Cooperation

SERI will support, as required, international collaboration and the collection and exchange of information with respect to solar energy.

Technological Status and Problems

Status:

- SERI will be a Government owned contractor-operated laboratory with programmatic direction from ERDA's Division of Solar Energy.

Problems:

- SERI's relationships with existing organizations and research facilities involved in the National Solar Energy Program will need to be clearly defined.

Environmental Status

- An integral part of the process of establishing SERI will be an evaluation of the impact of any proposed SERI facilities on the environment.

Program Implementation

Energy Research and Development Administration

ERDA's planned implementation of SERI is as follows:

- SERI solicitation was released in March 1976.
- SERI site and management will be selected by January 1977.
- Construction of SERI facilities, if required, will

begin in FY 1977 and be completed in FY 1980.

- The phased start-up of SERI operations will begin during the first quarter of FY 1977, with full operation following in the first quarter of FY 1980.

Within the stated objectives of SERI, its roles will include:

- Analysis and information
- Research (basic and applied)
- Other functions as defined.

SOLAR ENERGY RESEARCH INSTITUTE

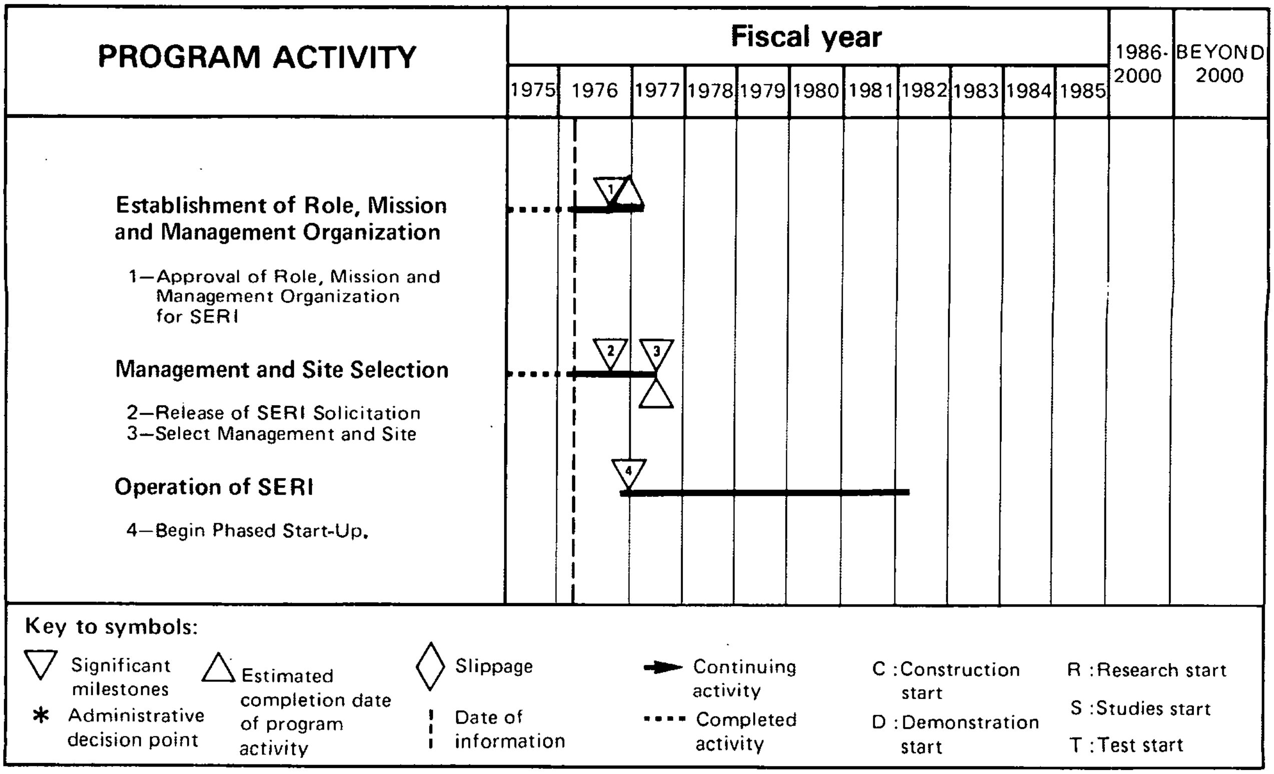
Federal Energy RD&D Budget **($ Millions)**

Agency	FY 1975 BA	FY 1975 BO	FY 1976* BA	FY 1976* BO	FY 1977 BA	FY 1977 BO
ERDA						
Operating Expenses	0	0	2.2	1.6	1.5	1.0
Plant and Capital Equipment	0	0	0	0	0	0
Total	0	0	2.2	1.6	1.5	1.0

* Does not include funds for FY 1976 Transition Quarter.

ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION

SOLAR ENERGY RESEARCH INSTITUTE



SOLAR ENERGY

Technology Support and Utilization

(INFORMATION DISSEMINATION) AND COMMERCIALIZATION

Objectives

Near-Term:
(–1985)

To develop solar energy data in support of all solar energy RD&D areas. To facilitate an effective commercialization program for solar options in coordination with technical program management.

Mid-Term: (–2000) and Long-Term:
(Beyond 2000)

To facilitate commercialization through continued dissemination of results from pilot plants and demonstrations to users, manufacturers and systems designers.

National Energy Technology Goals Supported

Primary

- Increase the use of essentially inexhaustible domestic energy resources.

Secondary

- Increase the efficiency and reliability of the processes used in energy conversion and delivery systems.
- Perform basic and supporting research and technical services related to energy.

Strategy

The strategy is to effect the timely transfer of RD&D results to researchers, users, and industry. All information and transfer activities will focus on the stimulation of solar technology programs toward rapid commercialization. These information and transfer activities will utilize commercial sector avenues (trade associations, manufacturers, professional publications, marketing organizations, media). The program will provide analysis of mechanisms (incentives and barrier removal) to accelerate the growth of a solar energy industry. Active incentive programs will be considered in conjunction with regional development efforts.

Federal Role

The federal role in information dissemination is to transfer scientific and technological results to user groups throughout the United States. Commercialization for this program is the development of information on solar technologies, socio-economic impacts, legal and institutional analyses, and the dissemination of information to accelerate solar industrial growth. The federal goal is to accelerate solar usage and then to withdraw as the solar industry becomes viable.

An additional federal role is to develop a more flexible patent policy for products growing out of federally subsidized RD&D, in order to stimulate industrial involvement.

International Cooperation

The International Energy Agency (IEA) program includes worldwide cooperation on weather data and information exchange on research projects using standardized reporting formats. Existing solar research programs in other countries (i.e. France, Italy, Israel, Scandinavia) are followed through liaisons with technical program officials. Exchange of technical data is accomplished through the IEA and the NATO CCMS program described in the heating and cooling of buildings section.

Institutional Status and Problems

Status:

- An information dissemination program is underway. Studies are being made on incentives, institutional barriers and socio-economic factors. Economic analysis is serving to identify critical design-to-cost goals for technology programs.

Problem:

- Available information does not facilitate practical analysis of the solar technologies, their potential, their cost, and development time frame. Institutional barriers to speed implementation exist in finance, construction, aesthetics, local and state government codes, etc. The demand for answers must await facts from the technical program before definite commercialization can occur.

Program Implementation

A solar energy information data bank with a computerized document referral system is being integrated into the ERDA Technical Information Center in Oak Ridge. A special HUD solar heating and cooling data bank is being established as a subsection of the ERDA solar data bank to provide specific newly generated information products and on heating and cooling applications to elements of the commercial sector such as banks, builders, contractors, insurance companies, and manufacturers. In addition, an engineering data base on solar energy RD&D is being developed for wide dissemination to the technical and manufacturing community.

Implementation of the Information Dissemination technology transfer program has already begun through activities such as solar demonstrations, seminars, workshops, document distribution, seed projects in cooperation with commercial interests (utilities, manufacturers etc.).

The consumer nature of solar heating and cooling technology implementation requires extensive inter-agency liaisons and public feedback mechanisms. The Inter-agency Panel on Terrestrial Applications of Solar Energy (IPTASE) established in 1975, is now a vital tool for multi-agency liaison and cooperation. Establishment of a national solar energy advisory group is underway, to be made up of distinguished professionals and consumer representatives, reporting to ERDA's Solar Division management.

Studies have been initiated to identify constraints to solar energy applications and to develop effective incentive programs (legal, economic, financial and regulatory) to overcome these constraints and accelerate commercialization. A concerted small business emphasis has been established as policy.

Economic studies and industry policies will result in the development of alternative policies and federal roles which will be utilized as the cornerstone of the commercialization program. Immediate emphasis is on solar heating and cooling, agricultural and industrial process heat, and wind energy systems, as these are nearest to commercialization. Program acceleration workshops/seminars are a current strategy for implementation of other technologies.

INFORMATION DISSEMINATION AND COMMERCIALIZATION

Federal Energy RD&D Budget **($ Millions)**

Agency	FY 1975		FY 1976*		FY 1977	
	BA	BO	BA	BO	BA	BO
ERDA						
Operating Expenses	0.7	0.5	2.2	2.1	1.0	0.7
Plant and Capital Equipment	0	0	0	0	0	0
Total	0.7	0.5	2.2	2.1	1.0	0.7

* Does not include funds for FY 1976 Transition Quarter.

SOLAR ENERGY

Solar Electric Applications

SOLAR THERMAL ENERGY

Objectives

Near-Term:
(–1985)

- To assist industry in developing a technology which will allow for implementation by the mid-1980's of commercial solar thermal electric generating plants, and total energy systems which make use of both electric and thermal output.
- To increase the efficiency and reliability of the processes used in solar thermal electric energy conversion and delivery systems.
- To demonstrate the technology for central receiver, distributed collector and other solar concepts through operation of plants such as the 10 MW central receiver pilot plant now in design.

Mid-Term:
(–2000)

- To continue solar thermal conversion technology advancement, further the economic viability of advanced solar thermal systems, and stimulate industry's role in production and use of the systems.
- To conduct additional demonstration of advanced solar thermal conversion technologies where appropriate.

Long-Term:
(Beyond 2000)

- To support as necessary the continued development of a viable commercial solar thermal industry by 2020 through stimulated commercialization of the technology.

National Energy Technology Goals Supported

Primary

- Increase the use of essentially inexhaustible domestic energy resources.

Secondary

- Increase the efficiency and reliability of the processes used in energy conversion and delivery systems.

Strategy

Early demonstration will be undertaken to enhance public and user familiarity with and acceptance of these systems. Industry, including public utilities as well as manufacturers, will be involved in the planning and implementation of the program either by contract or by joint participation. This will facilitate the spread of this technology and also insure that the needs of industry are satisfied.

The federal government will expedite the development and implementation of solar thermal systems by establishing, coordinating, and directing R&D programs using scaled models, large-scale experiments and pilot plants to improve performance-to-cost ratios, reduce technical and economic risks, and verify operating characteristics. The elements of cost will be identified and cost reduction research and development programs will be formulated. Alternative concepts with promise of lower costs will be explored.

In essence the federal government's action is:

- To assist industry to create and perfect the elements of solar thermal technology.
- To assist industry to synthesize and perfect effective and efficient systems.
- In cooperation with industry, to demonstrate these systems in a commercial environment.

- To provide incentives and a conducive environment for the commercial development of the technology.

Federal Role

Federal participation will help reduce the uncertainties associated with this new technology. The participation of the electric utility industry in support of solar electric plants will be encouraged.

International Cooperation

Currently ERDA and the French National Center of Scientific Research (CNRS) are cooperating in a planned test of a 1 MW capacity receiver at the solar furnace at Odeillo, France. In November 1974, representatives of France, Italy, and Japan participated in a seminar on large-scale solar test facilities at Las Cruces, New Mexico. An interchange of visits by technical and program personnel with the U.S.S.R. was made in 1974 to promote cooperation in solar thermal research, and a similar interchange with Japan was completed in 1975. An additional exchange with the USSR is being planned for FY 1976.

Technological Status and Problems

Status:

- One heliostat with mirror surface 3.9 meters × 3.7 meters was tested at the Naval Weapons Center, China Lake, California.
- Four different types of distributed collectors were tested.
- Conceptual design of a 5 MW Solar Thermal Test Facility has been completed and detailed design and construction is being initiated.
- A site selection PON for a 10 MW Central Receiver Pilot Plant will be issued in 1976.
- A total energy test bed with 200 square meters of parabolic collector surface is being operated at Sandia Laboratories, Albuquerque, New Mexico in conjunction with a 40 kW organic rankine turbine-generator.
- Various combinations of reflective metals or glass and a variety of plastic film are being tested.
- Selective coatings resistant to high temperatures have been tested.

Problems:

The technology for solar thermal conversion is at an early stage of development. The technical problems of both components and subsystems include:

- cost
- reliability
- lifetime
- energy storage
- standards
- codes.

Institutional Status and Problems

Status:

- The principles of solar thermal electric and total energy systems have been favorably received by utilities and other industries. One utility is studying the potential interaction of a solar plant within its system.
- Utilities and other industries are being informed of land area requirements as well as technical and cost data.
- The federal government is providing a forum for information exchange with interested local, regional and state energy authorities.

Problems:

The following considerations may limit the utilization of solar thermal electric systems:

- Large land area use
- Competing land use
- High capital cost
- Aesthetics.

The anticipated small size of solar thermal total energy systems virtually eliminates land and aesthetic considerations. Total energy systems will require stand by assistance from utilities. The principal consideration which may limit total energy systems are:

- ability of utilities to recover costs associated with providing stand by capacity
- high capital cost
- high labor cost to operate a small plant.

Environmental Status and Problems

Status:

- French experience with a 1 MW solar furnace has not produced any known environmental effects.
- A recent environmental assessment for a 5 MW solar test facility also did not identify any effect.

- The potential effect of a large solar central electric power plant, on the environment is not known.
- Solar electric and solar total energy systems do not increase net heat to the environment.
- Solar electric and solar total energy systems will reject waste heat locally as do other comparable nuclear and fossil fueled systems.

Problems:

The principal environmental considerations for large solar electric systems are:

- Effect of shielding of large land area
- Local heat rejection
- Aesthetics.

Program Implementation

Energy Research and Development Administration

The general plan for implementation of the solar thermal program is to identify needs and applications; establish the potential market size; identify the relevent technology to utilize for these applications; identify more promising technologies; design, fabricate and test components and subsystems; design, fabricate, and test systems at a user's site, with user participation. In parallel with application-focused efforts, the need for new test facilities will be identified and test facilities will be constructed and utilized to assist in component and subsystem development.

Central Receiver

- Conceptual design of a test facility has been completed; detailed design and construction is being initiated.
- Three parallel contracts with industrial teams were initiated in June 1975. Each team is to investigate design concepts for a 10MW_e pilot plant, and to design, fabricate and test prototype components. After completion of the contracts in FY 1977 one preferred concept is to be selected, and detailed design will be initiated.
- Selection of a site for the 10 MW_e pilot plant is being initiated. This also will involve an arrangement where the site owner participates in virtually all phases of the project, including operation.
- Decisions on pilot plants of advanced concepts are planned at approximately 2 year intervals, assuming resolution of technical problems. The Brayton cycle is a candidate for the next pilot.
- Experience with component tests and pilot plants will form the basis for studies leading to lower unit-cost demonstration plants of about 100 MW_e capacity. These studies will be initiated during the construction phase of the pilot plant. Pilot plant operating experience will be factored into the final design of a demonstration plant. Substantial cost sharing by industry will be solicited.
- Similarly the demonstration plant is to provide the basis for an economical commercial plant. It is anticipated that the Federal role will be minimal.

Total Energy

- A test bed with 200 square meters of parabolic collector area, and with a 40 kWe organic rankine turbine generator, has been completed.
- Other collector concepts were solicited and concepts with economic potential will be selected for construction. The test bed will continually be extended to add new concepts.
- A military application for a barracks complex is being studied for possible initiation in FY 1978.
- Additional federal, industrial, commercial, and residential applications are being studied. A decision to select one of these is planned in FY 79.
- A large total energy system of approximately 20 MW_e/200 MW_t may be completed as early as FY 1983.

Distributed Collector

- Collector experience obtained with the total energy test bed is also applicable to central electric power plants utilizing distributed collectors. The need for a separate facility for distributed collector subsystem and system development will be evaluated in FY 1977 and the facility, if required, could be completed in FY 1980. Modification of the existing test bed to provide the same data, will also be evaluated.
- Systems studies of distributed collector central electric systems will be undertaken in FY 1977–78 utilizing cost data and concepts generated by on-going programs. Preliminary design of a pilot plant with good economic potential is planned for FY 1979. If undertaken, construction of the pilot plant may require about 3 years.

- Demonstration plant studies are planned for FY 1981 and will consider prior technical and cost experience. This plant could be initiated as early as FY 1983.
- Commercial plant studies are planned for FY 84 with selective specific concept scheduled for FY 1986.

Hybrid Power Plants

- Potential application of solar thermal processes to a conventional power plant was studied in FY 1975.
- More specific studies will be initiated in FY 1977 aimed at providing supplementary heat to existing fossil fueled units. This will make possible experimental installation in FY 1978.
- Integrated solar-fossil-fuel hybrids and solar thermal-photovoltaic hybrids will be studied. If possible, a pilot plant may be initiated as early as FY 1979 and a second in FY 1981.

Research and Development

- To date emphasis has been on first generation materials, components and subsystems.
- Advanced materials and processes with promise of lower cost will be emphasized.
- New concepts will be investigated.
- Applications of solar energy to supplying thermal energy and shaft horsepower will be identified.

SOLAR THERMAL ENERGY

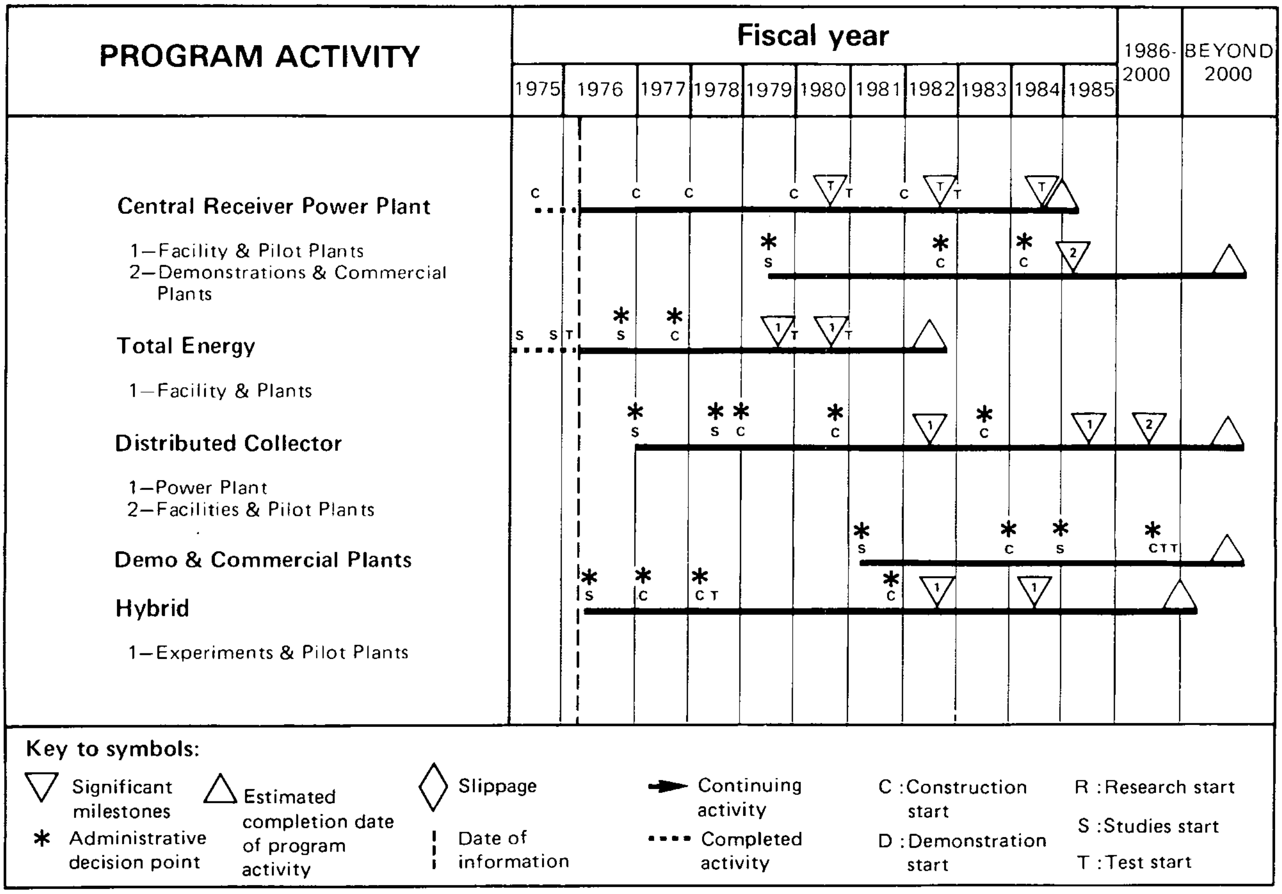
Federal Energy RD&D Budget **($ Millions)**

Agency	FY 1975 BA	FY 1975 BO	FY 1976* BA	FY 1976* BO	FY 1977 BA	FY 1977 BO
ERDA						
Operating Expenses	13.2	3.7	14.3	10.6	30.9	26.5
Plant and Capital Equipment	0	0	5.0	5.0	12.5	2.7
Total	13.2	3.7	19.3	15.6	43.4	29.2

* Does not include funds for FY 1976 Transition Quarter.

ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION

SOLAR THERMAL CONVERSION



SOLAR ENERGY

Solar Electric Applications

PHOTOVOLTAIC ENERGY

Objectives

Near-Term:
(–1985)

- To assist industry in the development of low-cost Solar Photovoltaic Conversion (SPC) systems for future implementation by industry and utilities.
- To test and demonstrate manufacturing processes.
- To encourage application of technologies which could result in commercially generating savings of 0.5 to 1.6 × 10^9 KW_eh annually, or from 1 to 3 million barrels of petroleum per year.
- To continue to test and demonstrate the technical and economic viability of SPC systems as appropriate.

Mid-Term:
(–2000)

- To continue development of second generation solar photovoltaic conversion technologies as appropriate.
- To encourage commercial implementation of solar photovoltaic conversion systems that could supply from 180 to 360 × 10^9 kW_eh annually, saving from 350 to 700 million barrels of petroleum per year.

Long-Term:
(Beyond 2000)

- To promote full maturation of the solar photovoltaic technology in the private sector.
- To make possible a solar photovoltaic capability in the private sector that may approach 50 GW_e peak by 2000 with a market price as low as $100 to $300 per peak kilowatt.

National Energy Technology Goals Supported

Primary

- Increase the use of "essentially inexhaustible" domestic energy resources.

Secondary

- Increase ~~the~~ efficiency in energy production (and reliability of the processes used in the energy conversion and delivery systems.)

Strategy

The central element of the strategy in this program is to lower the cost of collector arrays by a factor of 50 to 100 from present levels. This will be done through R&D on production of low-cost photovoltaic materials, large-area crystal growth, high volume sheet production, materials and techniques for array encapsulation, improved cell and array designs, and high-volume, cost-effective, automated assembly techniques.

The experimental testing and demonstration of SPC systems will be based on applications that promise early cost effectiveness, wide user acceptance and significant market development by the private sector.

Emphasis is initially on the use of single-crystal silicon because of the abundance of silicon and the availability of proven techniques for production of large single crystals. However, alternative techniques and materials such as gallium arsenide and cadmium sulfide, are also being developed.

Assuming the success of the above strategy the following could occur: by FY 1983 pilot plants capable of producing in excess of 5 million m^2/yr. of silicon sheet at a value-added cost of less than $18/$m^2$; the establishment, by FY 1984, of plants capable of producing about 2,000 metric tons of silicon materials at a market price of less than $10/kgm; and the establishment, by FY 1985, of plants capable of producing in excess of 500 MW/year (peak) of encapsulated solar arry modules at a market price of less than $500 per kW (peak).

Federal Role

The federal role is to encourage the advancement of an industry capability for producing and distributing SPC systems, and where appropriate aid in the development of new generations of solar photovoltaic conversion technologies that will result in significant cost reductions.

ERDA, in conjunction with FEA, will study the necessity for incentives to stimulate early, widespread use of SPC systems.

International Cooperation

As a joint cooperative effort in establishing common standards for the measurement and testing of solar cells, Japan, as part of the U.S.-Japan Bilateral Agreement, seems ready to pursue areas of mutual interest in photovoltaics.

The U.S. is discussing with the World Bank its interest in sponsoring photovoltaic projects in several developing countries to provide electricity for educational TV systems in villages lacking conventional electrical power supplies.

Countries such as France, Germany, Canada and Spain within the International Energy Agency (IEA) have active interest in photovoltaic energy conversion. Cooperative arrangements with these countries are under discussion.

Technological Status and Problems

Status:

- Silicon solar cell technology is well established for limited use in terrestrial and space applications.

Problems:

- The present cost of materials and processing for photovoltaic arrays are a factor of 50 to 100 too high to be competitive with conventional systems for almost all but remote site applications.
- Performance standards, reliability, and test data for optimal system design are lacking, and identification of possible applications and environmental impacts is incomplete.
- SPC systems performance suffers from seasonal, geographical and climatic variations and the diffuse nature of the energy source. Large collection areas for arrays and some combination of energy storage, power conditioning, and interties with conventional energy systems are, therefore, necessary.

Institutional Status and Problems

Status:

- The identification and treatment of the institutional problems in this area has just begun.

Problems:

- To substitute SPC systems for existing means of electrical power generation, utilities, industry and home owners will need to be convinced of the technical and economic feasibility and reliability of these systems.
- A systematic effort by the private sector to stimulate and motivate these groups will be required to assure the market penetration required to meet the objectives of this program.
- Possible constraints to rapid system implementation include the availability of investment capital, manpower and material resources, and the long-term assured markets needed to justify private investment.
- Other problems include the ownership and protection of sun-rights and the union jurisdictions in the installation of solar cells on roofs.

Environmental Status and Problems

Status:

- The present silicon arrays present no appreciable environmental problems.

Problems:

- The principal environmental problems foreseen for SPC systems are land requirements and the possible ecological impacts and altered albedo produced by the large arrays needed for required power production. Some future systems may use toxic materials which could be dangerous if released into the environment. Studies of these possible environmental impacts are planned, as are studies of the possible impacts of a major new manufacturing industry.
- As the use of conventional fuels becomes more costly due to non-availability or environmental control, industry may tend to migrate to regions

of high solar flux. Consequently, an increased demand for arid land and scarce water resources may occur, having a moderate to major environmental and social impact.

Program Implementation

ERDA will coordinate activities among other federal agencies such as NSF, DOD, and NASA, as well as state and local governments in establishing industry-wide solar cell performance and measurements standards and studying the feasibility and characteristics of alternative photovoltaic materials and systems. DOD is evaluating advanced concepts in solar cell arrays, and using SPC systems in remote military applications.

Projects are planned to improve design efficiency, reliability, lifetimes and energy payback times of SPC systems through the following:

- Systems analysis and assessment
- Advanced research and technology
- Low-cost silicon solar array project
- Concentration subsystems
- Testing and standards
- Demonstration projects.

The milestone chart lists these elements with major event timing.

The structure and content of the SPC program will be guided by the continuing mission analysis and systems studies aimed at evaluating alternative applications and their major subsystems, identifying and optimizing the most promising ones, and establishing the pertinent cost and performance goals. Studies will also be conducted to determine the environmental, legal, societal and institutional impacts, and to understand how to remove constraints, if any, on public and user acceptability.

The advanced research and technology element is aimed at improving the overall SPC system performance and utility through a variety of studies on second generation materials and devices, including: thin-film silicon, cadmium sulfide, copper sulfide, gallium arsenide and other solar cells.

The principal programmatic emphasis will be placed initially on the development of low-cost, reliable silicon arrays, primarily through contracts to industrial organizations for work on lower cost silicon feed material, production of large array silicon sheets, improved module encapsulants, and the automation of solar array production facilities. These contracts will help to stimulate the growth of an industrial base that will supply components and systems for the photovoltaic market. "Set-Asides" are to be incorporated where appropriate in the near future to enable small business to compete. Work in this area may lead to solar array production capability of 500 MW_e per year with a market price of \$500/peak kW_e by 1985.

A variety of concentrator technologies and systems will also be investigated with a view both to reducing the overall cost of photovoltaic conversion systems and to gaining the additional energy benefit of the heated fluids used to cool the highly-illuminated solar cells.

A series of federally sponsored tests, demonstrations and applications of SPC systems will be initiated by the mid-1980's to establish the technical and economic feasibility and reliability of these systems, thereby stimulating their public acceptance.

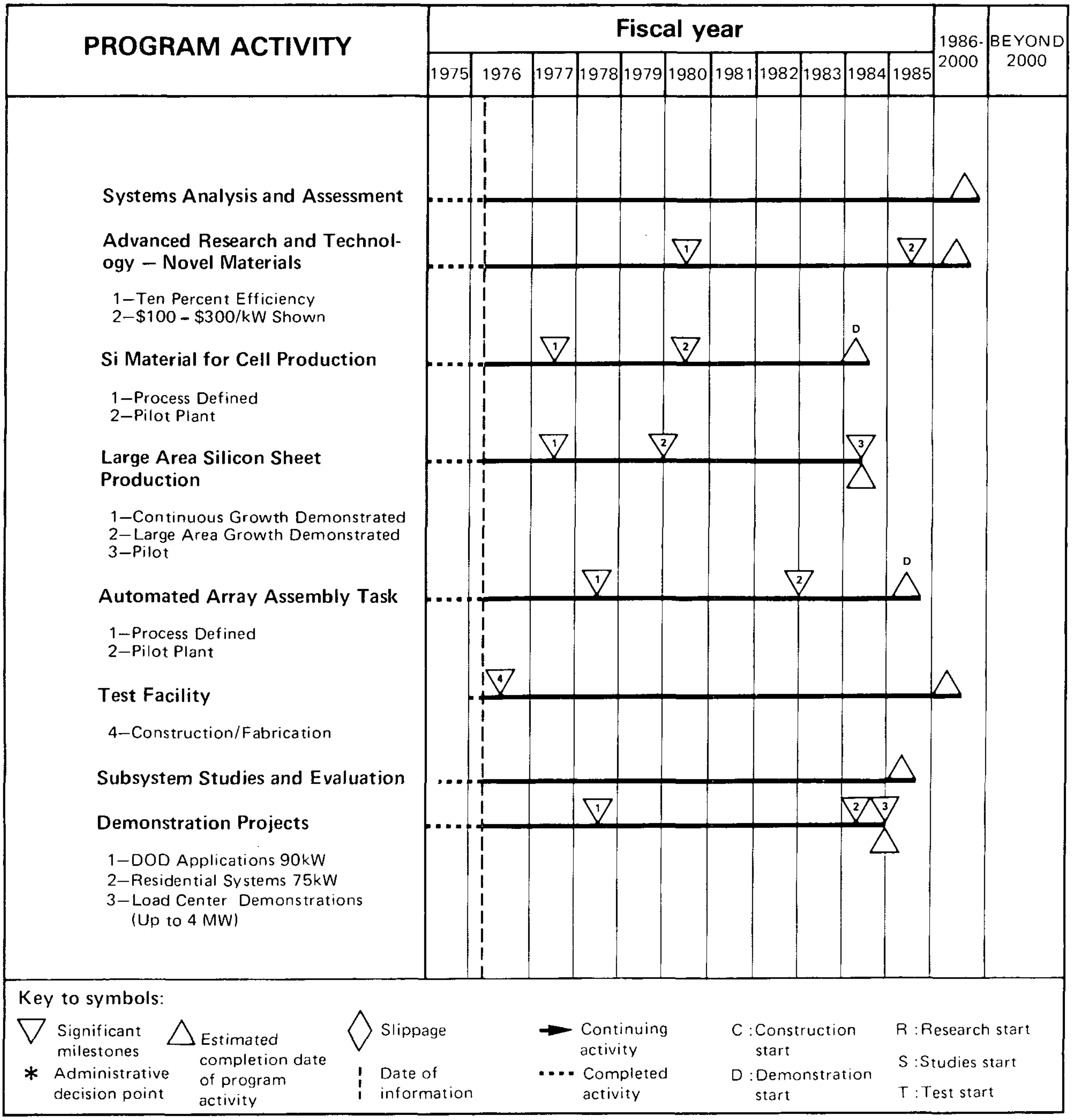
A solar photovoltaic test and standard facility will be established to assess and monitor the progress of the SPC system development. Results from such testing will be widely disseminated in the photovoltaic community and serve as the basis for future industry-wide standards for the production of terrestrial solar arrays and systems.

By late 1978, improvements expected for the various development projects should begin to materialize. Since several approaches are being considered for each technological area, the more successful projects will be expedited and less successful efforts eliminated.

For possible long-range implementation, the approach to providing terrestrial power using solar power systems in earth orbit and transmitting the energy to earth via microwaves is under evaluation. NASA has carried out initial assessments and preliminary systems studies. ERDA, with the support of NASA, will study during FY 1976 and 1977 what further steps, if any, should be carried out.

ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION

PHOTOVOLTAIC ENERGY



PHOTOVOLTAIC ENERGY

Federal Energy RD&D Budget **($ Millions)**

Agency	FY 1975		FY 1976*		FY 1977	
	BA	BO	BA	BO	BA	BO
ERDA						
Operating Expenses	5.2	2.6	21.6	16.0	28.2	22.0
Plant and Capital Equipment	0	0	0.8	0.4	4.6	2.3
Total	5.2	2.6	22.4	16.4	32.8	24.3

* Does not include funds for FY 1976 Transition Quarter.

SOLAR ENERGY

Solar Electric Applications

WIND ENERGY

Objectives

To advance through research, development, tests and demonstrations, the technologies necessary for implementation by the mid-1980's of commercial Wind Energy Conversion (WEC) systems.

Near-Term:
(–1985)

- It is estimated that a successful RD&D program whose results would be implemented at a early date by industry could be capable of supporting commercial energy production of 2.5 to 5 $\times$ 10^9 kW_eh per year, saving from 3 to 6 million barrels of petroleum per year.

Mid-Term:
(–2000)

- Continued commercial implementation of the WEC technology being developed could supply from 120 to 210 $\times$ 10^9 kW_eh of energy annually, saving between 230 and 410 million barrels of petroleum per year. The equivalent power production capacity contributed by WEC systems as normalized to an improved equivalent load factor of 0.7, would be 20 to 35 GW_e.

Long-Term:
(Beyond 2000)

- By 2020, with continued commercial implementation of WEC technology, power capacity from these systems could be further increased, depending upon availability of suitable wind sites.

National Energy Technology Goals Supported

Primary

- Increase the use of essentially inexhaustible domestic energy resources.

Strategy

The general strategy of the WEC program is to advance the development of WEC technology and performance, stimulate industrial efforts to lower the production cost of WEC units through the use of prefabrication and production techniques, and accelerate, through demonstrations, the application and integration of reliable, economically viable wind energy systems capable of rapid commercial implementation. This will require the early involvement of potential manufacturers and users to ensure the definition of proper requirements and facilitate the application of WEC systems. add sent.

Emphasis is initially being placed on developing and testing systems to establish the feasibility of using large unshrouded horizontal-axis wind turbines for generating electricity at prices competitive with conventional generating systems. Alternative WEC technologies also being developed include vertical-axis rotors, ducted systems and vortex generators. Alternative energy applications of WEC systems are being considered, and small-scale systems are also being developed for farms and rural homes. With the exception of small-scale heating and irrigation systems, most applications will likely utilize electricity as an intermediate step, although in some cases unconditioned power may be used leading to lower system costs.

Initial emphasis is on the development of systems for high wind zones with advancements leading toward viable systems in the larger, more moderate wind zones. Key decisions involve selecting the geographical regions for initial applications of WEC by 1976, and possible major farm demonstrations in the early 1980's.

Federal Role

The principal federal role is to assist the private sector in the development of improved WEC technology, and thereby provide a stimulus for private industry to produce such systems and for utilities and others to use them in suitable applications. This role is important because of the uncertainty in market size and user acceptance until such time as sufficient systems have proven their utility, reliability and economic potential through sufficient experience.

International Cooperation

While there is considerable interest in many nations on the use of wind energy, specific cooperative agreements are not yet implemented. This interest is due to the fact that the characteristics of wind energy systems make them particularly applicable to situations of low energy demand per square mile as is the case in many other nations. Cooperative efforts with both developing and developed countries, particularly in the field of "wind prospecting," is anticipated.

Technological Status and Problems

Status:

- Small windmills have been produced for decades for both irrigation and electrical generation and are still available commercially.
- Large wind turbine generators were constructed in the 1930's through the 1950's in the U.S. and Europe.
- A 125 foot diameter, 100 kW wind turbine, the second largest ever constructed, has recently commenced test operations at Sandusky, Ohio.
- The advances and tools developed in recent years in the helicopter industry are only now being applied to this area.
- No fundamental unknowns exist; however, many uncertainties remain in terms of designing for long life, low capital cost.

Problems:

- The intermittent nature of wind and the wide geographical and seasonal variations in the availability of wind energy necessitates either inter-ties of wind energy systems with conventional energy systems or energy storage capabilities. The lack of understanding of the statistical, temporal and spatial variations in the wind as related to energy demand and storage requirements leads to uncertainty in the capacity credit applicable to wind systems.
- The projected high capital costs of the initial large-scale WEC prototypes (i.e., rated at 100 kW or more) need to be reduced by a factor of two to four.
- Structural dynamics of large systems is considered the key development problem in wind energy.
- Estimates of the service life of large-scale WEC units are uncertain because of insufficient data on operational rotor dynamics.
- Capabilities are inadequate to accurately and rapidly predict the wind characteristics of potential WEC sites and to estimate accurately the power output of specific WEC designs located at these sites.
- There is a lack of adequate system design data for larger-scale systems (particularly multi-unit systems).
- There is a lack of sufficient information available on user interface and operational requirements necessary for system optimization and standardization and the determination of viable applications.
- Small-scale systems are very costly, predominantly imported, and in very limited production; cost reduction will require addressing all components as well as seeking a solution through unconventional system concepts.

Institutional Status and Problems

Status:

- There is little recent experience on wind systems other than on very small, home-sized systems.
- Research has recently begun on the broad front addressing institutional issues.

Problems:

- Understanding of possible legal and regulatory questions, such as "wind-rights," is inadequate.
- Uncertainties in the availability of sufficient investment capital and experienced personnel may limit the growth rate of WEC in the near- and mid-terms.
- Public utilities will have limited confidence in large-scale WECS systems due to lack of experience and the systems intermittent operational characteristics until sufficient testing is accomplished.

Environmental Status and Problems

Status:

- There is no recent experience on wind systems other than at the small size.
- Research studies have identified no ecological problems and experiments have been initiated to confirm this finding.

Problems:

- While wind energy is generally considered environmentally benign, insufficient information exists on possible environmental effects of large multi-unit systems, such as possible radio and television interference caused by large rotating blades.
- There are also uncertainties about the public acceptability of large numbers of WEC units, particularly in the heavily populated areas, and about the aesthetics of such units in locations such as scenic shorelines or mountain tops.
- Effects on birds and wildlife is not yet known.

Program Implementation

The wide range of wind energy system sizes and the previous lack of a sustained WEC R&D program has necessitated the adoption of a parallel implementation approach. This consists of the development, test and demonstration of a series of WEC systems of increasing sizes, performance, and power capabilities, supported by a series of technoolgy research and development projects and studies of institutional constraints.

As part of the ERDA directed federal program, NASA is managing the development of large high-performance wind energy systems primarily intended for generating electricity. Similar efforts are being undertaken with the Department of Agriculture on the development and test of systems for farm and other agricultural applications. In coordination with FEA, studies are aimed at the investigation and implementation of an incentives program to stimulate early WEC applications by utilities, farmers, home owners, and other potential users.

ERDA and NASA have recently completed installation and begun tests of the first 100 kW system and have completed the preliminary designs of a Mod–1 MW scale system and follow-on 100 kW-scale systems. These experimental 100 kW and MW systems will be operationally tested in specific applications in 1977–79. Improved systems that incorporate advanced features resulting from the R&D and advanced concepts projects are planned for development and testing.

Methods of improving the performance-to-cost ratios of the types of WEC systems described above are being explored through projects addressing rotor dynamics, aerodynamics, fabrication techniques and systems economics and optimization.

Advanced systems designs using vertical axis rotors, diffusers, or vortex concepts are being examined and may be incorporated into future systems where appropriate.

With the assistance of the Department of Agriculture, projects are being examined that would develop rural home and agricultural applications of smaller-sized wind energy systems, including the use of such systems for on-site fertilizer manufacture by electrolyzing water to produce hydrogen, direct space-heating, crop-drying, and irrigation.

The capability to rapidly locate and assess sites with sufficiently high average wind velocities for WEC are being developed through modeling, studies of boundary-layer flow, wind-tunnel tests, and statistical analyses. Studies of environmental effects, public acceptance, and legal/institutional problems will attempt to quantify these issues and determine their possible impact on the viability of large-scale WEC applications.

The cost-benefit of alternate incentives programs will be investigated in coordination with FEA. Recommendations and decisions on incentives policies would be implemented in the 1978–81 time period.

WIND ENERGY

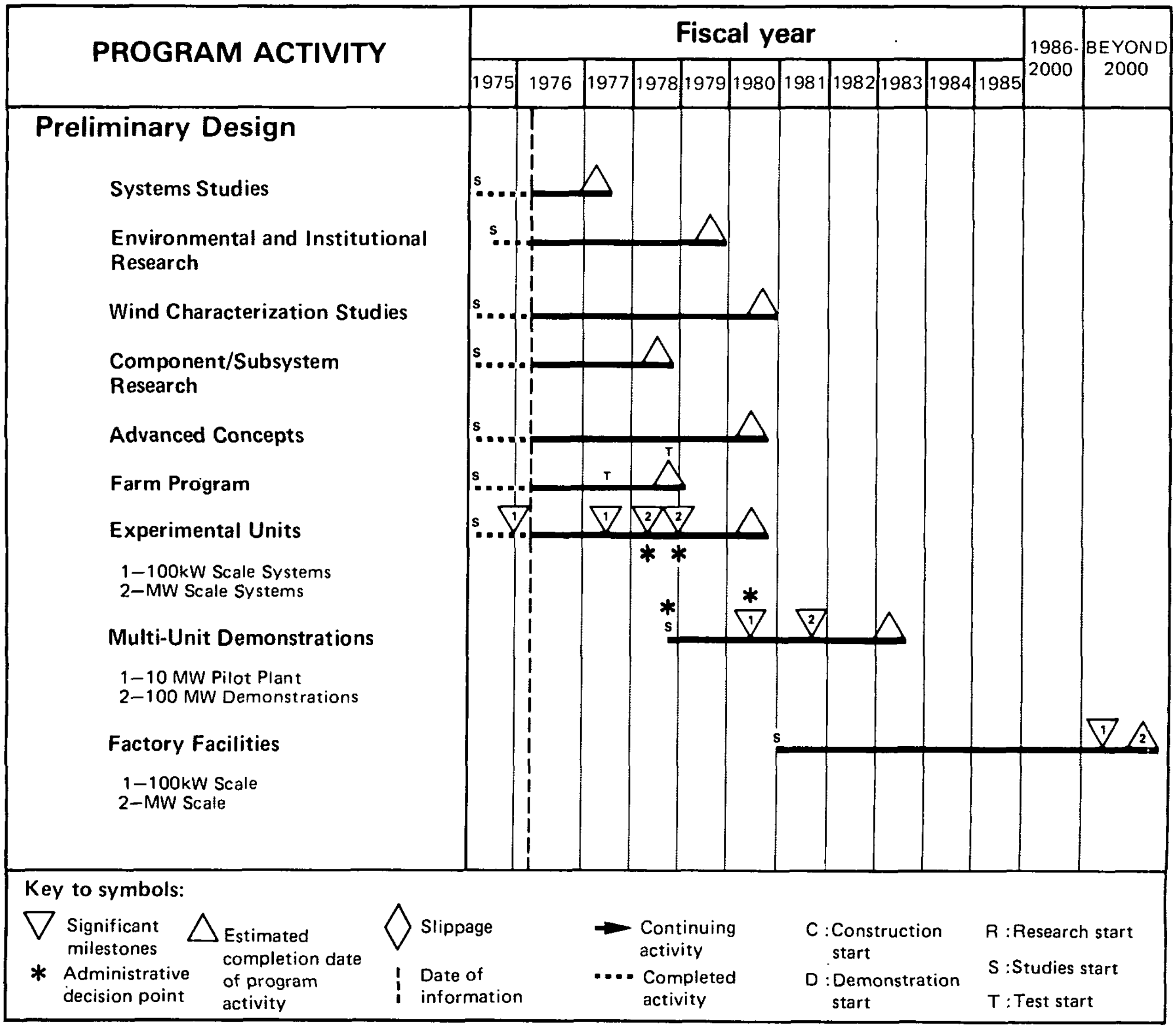
Federal Energy RD&D Budget **($ Millions)**

Agency	FY 1975 BA	FY 1975 BO	FY 1976* BA	FY 1976* BO	FY 1977 BA	FY 1977 BO
ERDA						
Operating Expenses	5.7	1.0	14.9	11.0	16.0	12.0
Plant and Capital Equipment	0	0	0.2	0.1	1.1	0.5
Total	5.7	1.0	15.1	11.1	17.1	12.5

* Does not include funds for FY 1976 Transition Quarter.

ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION

WIND ENERGY



SOLAR ENERGY

Solar Electric Applications

OCEAN THERMAL ENERGY

Objectives

Near-Term:
(–1985)

- To develop a technology for demonstrating the technical and economic feasibility of commercial offshore power plants capable of economically converting ocean thermal energy into substantial quantities of usable electrical energy and/or other energy products such as hydrogen.

Mid-Term:
(–2000)

- To assist the private sector in the development of technology which may lead to commercially competitive off shore OTEC power plants with a total potential power capacity in the range of 10 to 25 GW_e.

Long-Term:
(Beyond 2000)

- To assist the private sector so that with continued commercial implementation of OTEC Technology, power capability from these systems could be further increased to supply over 1500×10^9 kWh annually.

National Energy Technology Goals Supported

Primary

- Increase the use of essentially inexhaustible domestic energy resources.

Secondary

- Efficiently transform fuel resources into more desirable forms.
- Increase the efficiency and reliability of the processes used in energy conversion and delivery systems.

Strategy

Confidence in the potential for extracting energy from ocean thermal gradients in commercially productive quantities has been strengthened by the results of two major OTEC engineering evaluations completed in FY 75. These studies projected technical and economic feasibility and encouraged development of the OTEC option. OTEC program implementation strategy employs overlapping elements, which are represented graphically in the OTEC program schedule and briefly described as follows:

- Subsystem Development—To develop and design the critical components needed for full-scale OTEC utilization.
- Advanced Research & Technology (AR&T)—To refine and improve the scope and effectiveness of OTEC technology and, provide assistance in market stimulation and aggregation to establish the full potential of OTEC utilization.
- Engineering Test Facility—To test and evaluate system hardware and power cycle systems.
- Offshore Pilot Plant—To provide in-situ evaluation and optimization of the OTEC power cycle components and operating techniques.
- Demonstration Power Plant—To operate a full-scale commercial OTEC facility that will provide technical and economic viability data to the private sector and thus, provide commercial operation experience and training. It is anticipated that industry will participate in this phase to the extent of sharing a significant percentage of the design, fabrication and operations costs.

During the period of technology development, an effort will be made to define and resolve jurisdictional, institutional and environmental problems which might hinder effective market growth and adequate technology performance. So that timely and successful transfer of OTEC activity to the private sector can take place, industrial and utility organizations are being encouraged to participate in OTEC program planning and in the development, optimization and demonstration of OTEC systems. This participation will include identification of markets for OTEC electrical energy.

Federal Role

- Improve prospects for technological feasibility and economic viability, reduce operational risks and define energy utilization options, thus encouraging private capital investment in OTEC.
- Initiate an RD&D technology development program that leads to a commercial-scale, offshore OTEC demonstration power plant that will verify technical and economic viability.

International Cooperation

The majority of appropriate OTEC sites are located in tropical and subtropical oceans, thus affording the opportunity for cooperation with other coastal nations. For example, Japan has proposed utilization of OTEC technology on an atoll in Micronesia to support mariculture and industrial operations. There is also a resurgence of French interest in OTEC. U.S. participation with the Association of Southeast Asian Nations (ASEAN) countries in the fields of energy, resources and the environment could be extended to include OTEC power plants.

Technological Status and Problems

Status:

- Since d'Arsonval first published the concept of generating electricity from ocean thermal gradients in 1881, one experimental OTEC plant was constructed in 1928. Systems designs and component studies have since expanded upon the original concepts, and recent engineering evaluations indicate that OTEC is technologically viable on a commercial scale, and that, with engineering improvements and adaptations of existing technologies, it will be commercially viable.

Problems:

- There is a need to demonstrate cost-effectiveness and high level performance of critical components (such as heat exchangers, turbines, and pumps) and of operating OTEC systems.
- There is a need to identify techniques to effectively control biofouling and corrosion common to equipment and hardware installed in and/or exposed to ocean sea water.
- There is a need to continue to assess the potential contribution of OTEC to the mainland U.S.
- There is a need to continue to refine the assessing realistic contribution of OTEC to the mainland U.S.

Institutional Status and Problems

Status:

- The law of the sea as it might apply to OTEC utilization is currently undefined.

Problems:

- There is a need to resolve international law of the sea aspects of OTEC implementation.
- Other institutional problems such as security of the plant, etc., are currently being identified.

Environmental Status and Problems

Status:

- There are possible environmental consequences of redistributing large quantities of warm and cold ocean water by OTEC power plants.

Problems:

- There is a need to predict definitively the possible environmental impacts caused by large-volume warm and cold water mixing on the ocean, biota, and climate. There are indications that the dispersion of the nutrients from the cold water discharge could be beneficial in providing a potential for open-ocean mariculture.
- There is a need to examine possible environmental effects of techniques considered to inhibit biofouling and/or corrosion.
- There is a need to address possible consequences of chemical/industrial processing operations, and of the installation and operation of electrical distribution systems.
- There is a need for an evaluation of possible impacts of coastal zone facilities associated with the operation of offshore OTEC power plants.

Program Implementation

Information already obtained from OTEC studies provides a basis for engineering development of major OTEC components and system tests leading to the design and fabrication of commercial-scale power cycle systems. Initial tests and evaluation of components are being conducted at existing laboratories and facilities.

Large-scale testing requirements and objectives are being defined that may lead to the design and construction of an OTEC engineering test facility onshore and supplemental offshore testing. Such tests will enable the evalaution of critical power cycle components and systems and resolve engineering porblems.

The next major element of the OTEC program will be to design, fabricate, deploy and test an offshore pilot plant capable of generating a net power output in the 25–50 MW_e range. Power cycle components may be interchanged to identify the most efficient and reliable component and system configuration as well as operation and maintenance techniques.

With the achievement of the OTEC program objectives, the offshore pilot plant will be expanded into a full commercial-scale offshore demonstration power plant with a net power output capability of 100–200 MW_e. A demonstration power plant is possible by the mid-1980's.

OTEC commercialization is anticipated by FY 1990. By that time, industry and utilities would be likely to provide capital for constructing commercial OTEC systems to satisfy domestic and international energy demands.

Other activities carried out in the area are studies of the feasibility of utilizing ocean energy from tides, waves and the gradient between differing degrees of salinity. ERDA studies in the area of waves and salinity gradients have been initiated and a tidal energy study will be initiated in FY 1976. The tidal energy study will be coordinated with related studies under way under the direction of the U.S. Army Corps of Engineers and will utilize information provided by the Corps and the Federal Power Commission.

OCEAN THERMAL ENERGY

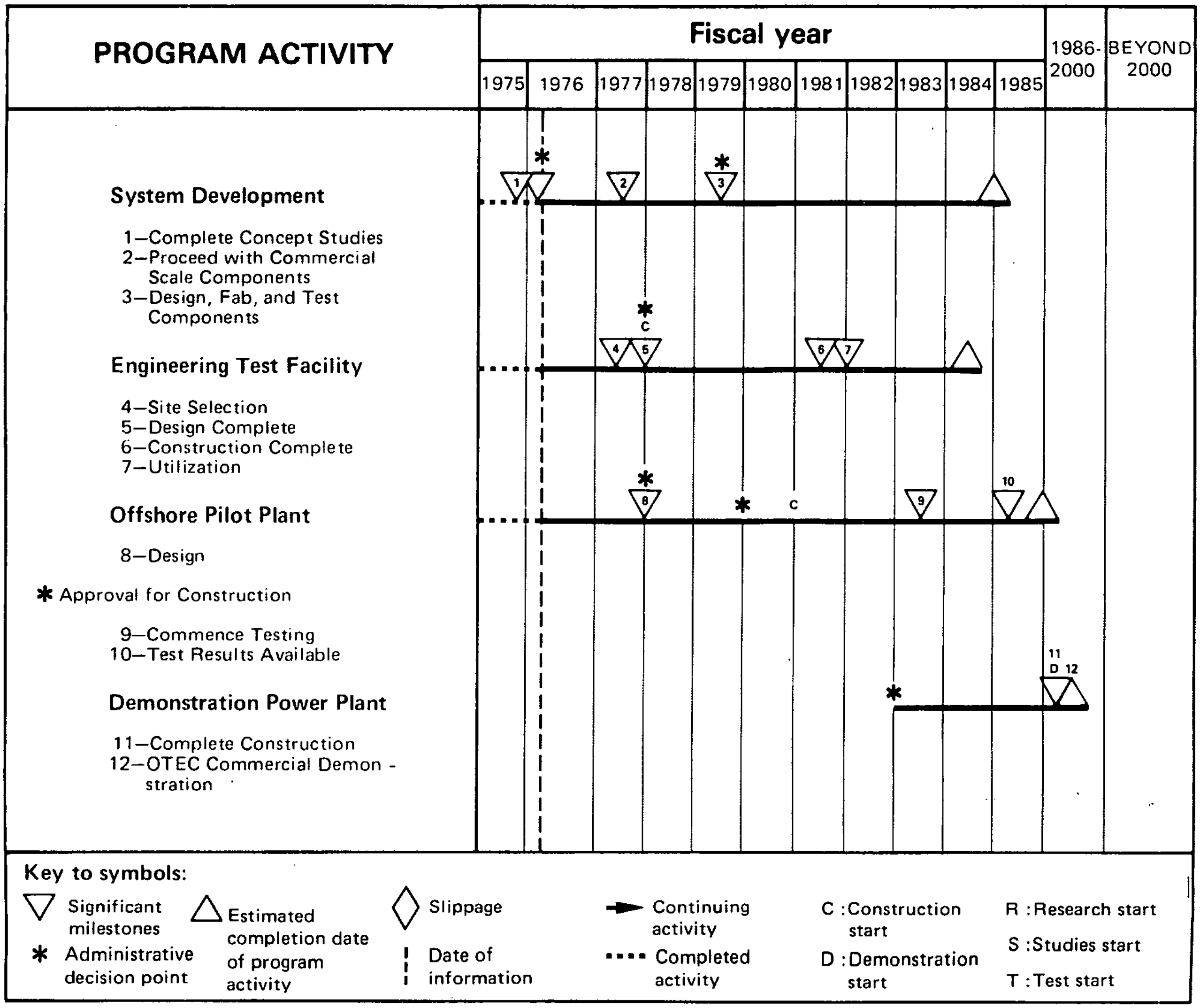
Federal Energy RD&D Budget ($ Millions)

Agency	FY 1975		FY 1976*		FY 1977	
	BA	BO	BA	BO	BA	BO
ERDA						
Operating Expenses	1.9	1.0	8.1	6.0	9.2	7.0
Plant and Capital Equipment	0	0	0	0	0	0
Total	1.9	1.0	8.1	6.0	9.2	7.0

* Does not include funds for FY 1976 Transition Quarter.

ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION

OCEAN THERMAL ENERGY



SOLAR ENERGY

Fuels from Biomass

Objectives

Near-Term
(–1985)

- To investigate and demonstrate the economic and technical feasibility of utilizing agricultural and forestry residues to produce terrestrial plant biomass and converting these organic materials to useful clean fuels. This technology has the potential for producing approximately 0.2 quads per year by 1985.

Mid-Term:
(–2000)

- To investigate and demonstrate the economic and technical feasibility of producing marine biomass and converting organic materials to clean fuels and industrial chemicals. These applications have the potential of producing approximately 2 to 5 quads per year of fuels and industrial chemicals from both terrestrial and marine sources by 2000, with residues comprising the major part of the feedstock.

Long-Term:
(Beyond 2000)

- To assist the private sector with the improvement of biomass yields and conversion efficiencies, and the technological basis for greater commercialization of demonstratable technologies. The resulting potential for production could range from 10 to 30 quads per year of fuels and industrial chemical substitutes from terrestrial and marine sources by 2020.

National Energy Technology Goals Supported

Primary

- Increase the use of essentially inexhaustible domestic energy resources.

Secondary

- Efficiently transform fuel resources into more desirable forms.

Strategy

Near-term emphasis will be placed on the utilization of agricultural and forestry residues so as to take advantage of existing biomass resources and technology in resolving conversion technology problems as soon as possible. Exploratory, advanced and applied research projects in biomass production and conversion processes will be carried out in support of the pilot and demonstration projects.

Depending on the results of the system studies, some of which are currently underway, pilot plant projects in agricultural residue collection and conversion may be undertaken. These studies will address trade-offs resulting from using land for food or fiber production, recreational purposes, or for energy production in addition to surveying pertinent economic, technical, and environmental issues. Agricultural and forest residue demonstration-scale projects will be incorporated as part of the terrestrial biomass production and conversion RD&D element. Similarly, a sequence of system studies, pilot plants and demonstration projects in terrestrial and marine biomass production and conversion to fuels, industrial chemicals and food may be undertaken.

Depending on the results of the preceding studies, decisions will be made to conduct large-scale demonstration projects from the three major energy farming system alternatives (field crops, wood crops and marine biomass).

Federal Role

The emphasis of the Federal RD&D role will be placed in those technology areas where a high-risk is indicated which would preclude an active industrial RD&D effort.

Federal involvement in the Fuels from Biomass program may be needed to establish land use and resource planning policies and to determine the desirability of favorable interstate tariff schedules for biomass feedstocks and products of biomass conversion.

Marine biomass production may call for new international agreements for the use of open ocean waters.

The development of environmental analyses and impact statements must be assured so that potential environmental effects are adequately assessed.

Technological Status and Problems

Status:

- Crop and forest management practices have greatly improved food and fiber yields in the past 50 years. The technologies required to develop a capability for providing fuel from organic matter currently exist. Biological (fermentation, enzymatic hydrolysis), thermochemical (pyrolysis, catalytic gasification) and direct combustion processes have already been proven technologically feasible.

Problems:

- Existing production and conversion efficiencies must be improved if biomass alternatives are to compete on a favorable economic basis with conventional fuel sources.
- Large-scale biomass production within environmentally acceptable bounds, increased acreage yield of biomass, economical collection of agricultural and forestry residues, and conversion processes with improved energy efficiency need to be developed, demonstrated, and proven to be cost competitive.

Institutional Status and Problems

Status:

- Wide-spread usage of biomass for energy has not been practiced in the past.

Problems:

- Present policies and practices do not favor aggregation of land and water resources into economically attractive energy farming units. Large land aggregation and construction of conversion facilities may require significant capital.
- Ocean-based biomass production facilities pose additional legal, political and security problems including disruption to navigation and protection in times of national emergency.

Environmental Status and Problems

Status:

- The products of conversion processes, their possible uses, and the effects of their uses on the environment are being carefully investigated and evaluated. The use of animal and other wastes in the processes will help to alleviate some of the environmental problems derived from wastes.

Problems:

- Near-term problems have been identified in the economic disposal of effluents from conversion processes and in the unsanitary conditions arising from the storage of dairy farm, feedlot, agricultural and forestry residues, as well as terrestrial and marine biomass. Mid-to-long-term problems will have to deal with controlling erosion from large-scale agricultural and silvicultural operations. Large-scale changes in land use may have adverse ecological and socioeconomic effects. Effects of increased levels of nutrients in marine conditions must also be analyzed.

Program Implementation

Within the biomass production supportive R&D element, a project in kelp production is being carried out. Tasks now underway in the conversion technology element include supportive R&D projects in the areas of enzyme hydrolysis, biophotolysis, anaerobic digestion, and small conversion systems for agricultural residues; an experimental facility investigating the Syncrude process is analyzing cellulose/synthesis gas reactions.

Other government agencies involved in the Fuels from Biomass program include the Department of Defense (DOD), and the Department of Agriculture (USDA).

The DOD is studying pre-pilot plant development of cellulose-to-glucose conversion and evaluating the endurance of ocean farm structures in open environments. USDA will support efforts in research for increasing terrestrial crop yields for use in energy and chemical feedstock production. ERDA will take the lead in supporting and coordinating the other RD&D efforts.

Agricultural Residue Projects

The fuel from the agricultural and forest residues element will be guided by several systems studies to be performed in the period from FY 1975 through the FY 1976. At present, five systems studies are underway in the area of agricultural and forestry residues and another is analyzing energy production from dairy farm wastes. An experimental facility is being operated in conjunction with a cattle feedlot, and a pilot project for field crop residues will be strated in FY 77.

Terrestrial Biomass Production and Conversion Project

Demonstration-scale field crop energy production efforts, where needed, would be incorporated in the terrestrial biomass element described below. Decisions on two animal residue energy conversion pilot facilities will be made in FY 77.

The system study and pilot phase of the terrestrial biomass production and conversion element would be carried out over the period FY 1975 to 1984. At present, systems studies are being carried out to analyze the Sucrose Crop Energy Plantation and the Silvicultural Energy Plantation. The demonstration facilities are proposed to be built and operated between FY 1982 and FY 1989. Cost sharing with industry is expected.

Marine Biomass Production and Conversion Projects

The marine biomass production and conversion element, as proposed will include a sequence of systems studies (FY 76–78), a pilot facility of 1,000 acres (FY 79–86), and a demonstration facility of 10,000 acres, commencing in FY 86.

FUELS FROM BIOMASS

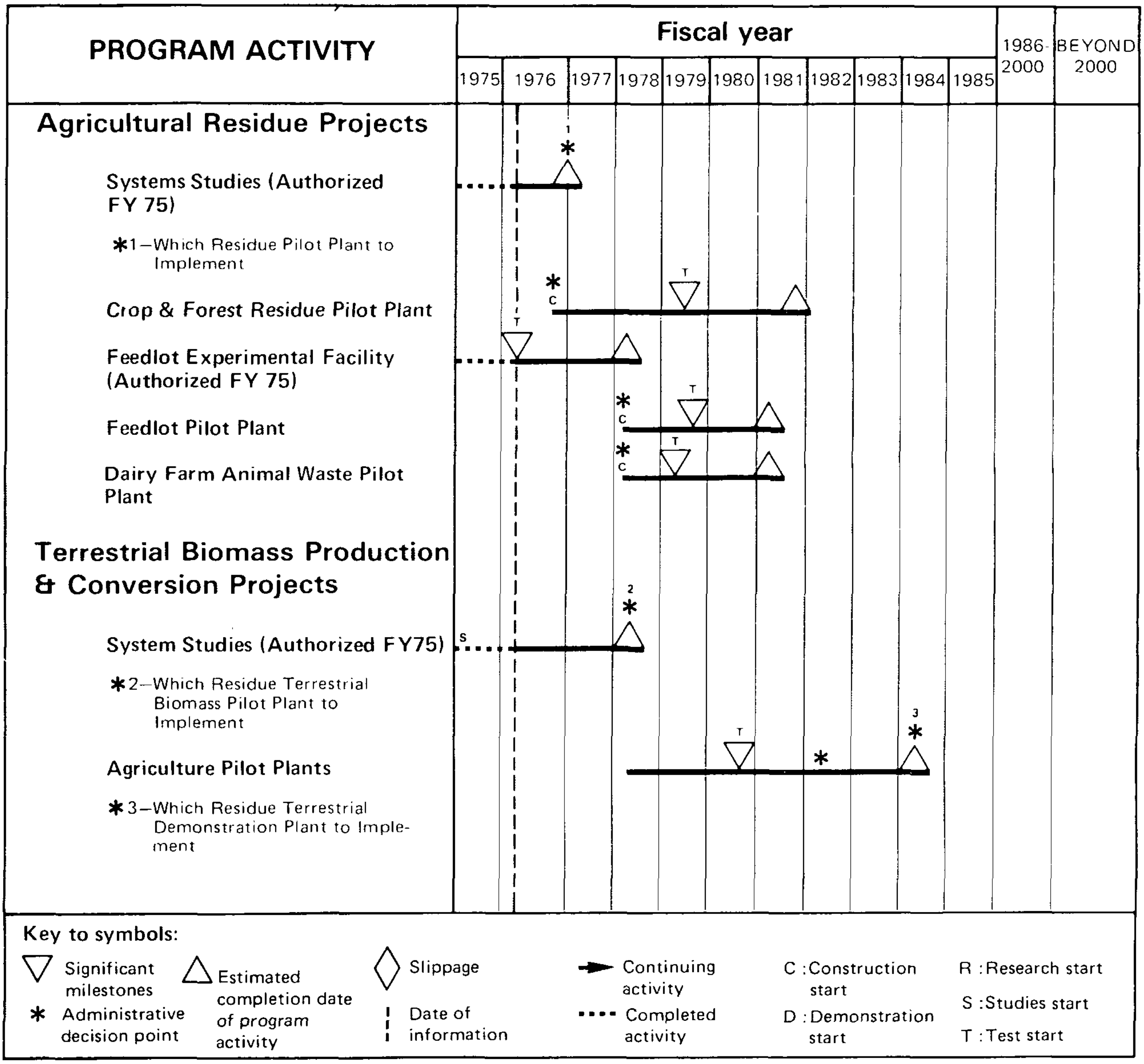
Federal Energy RD&D Budget **($ Millions)**

Agency	FY 1975		FY 1976*		FY 1977	
	BA	BO	BA	BO	BA	BO
ERDA						
Operating Expenses	0.9	0.1	4.5	3.8	4.3	3.0
Plant and Capital Equipment	0	0	0	0	0	0
Total	0.9	0.1	4.5	3.8	4.3	3.0

* Does not include funds for FY 1976 Transition Quarter.

ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION

FUELS FROM BIOMASS



vironmental acceptability has been sufficently demonstrated.

Advanced Technology Applications:

- Continue modeling studies and regional surveys of geopressured resources.
- Conduct flow tests of existing or new exploratory wells to determine reservoir characteristics.
- Improve exploration and assessment methods, and determine the magnitude and other characteristics of hot dry rock resources.
- Develop economically and environmentally acceptable methods for extracting energy from hot dry rock resources.
- In the mid-term, study the feasibility of the extraction and utilization of useful energy from normal gradient, non-associated radiogenic, and other potential geothermal resources.
- Initiate development of the required technology if the results of feasibility studies are favorable.

Engineering Research and Development:

- Develop improved drilling technologies, especially for hard rocks and high temperatures.
- Develop improved geothermal-to-mechanical energy conversion systems, such as helical screw expanders and impulse turbines.
- Develop improved materials and designs for heat-exchangers that are more efficient and less subject to scaling and corrosion, for binary cycle systems.
- Develop geothermal well stimulation methods and down-hole pumps.
- Develop improved, environmentally acceptable methods for extraction of useful minerals from waste brines and for the disposal of the spent brines.

Geothermal Resources Development Fund (Loan Guaranty Program):

- Establish regulations.
- Request borrowing authority as the most appropriate means for creating the Development Fund.

Implementation of all the building blocks of the Federal Geothermal Program will require planning, coordination, and cooperation not only among federal agencies, but also with industry, state and local governments, and the public. ERDA will play an active role in providing the necessary two-way communication channels. ERDA has also established an Advisory Committee on Geothermal Energy, whose membership includes representatives from the industrial, financial, technological, and academic communities, and from the general public.

GEOTHERMAL ENERGY

Federal Energy RD&D Budget

($ Millions)

	FY 1975		FY 1976*		FY 1977	
Building Block	**BA**	**BO**	**BA**	**BO**	**BA**	**BO**
Environmental Control & Institutional Studies	0.5	1.2	3.9	2.5	4.8	4.8
Resource Exploration & Assessment	13.2	13.2	15.3	12.8	15.5	15.0
Hydrothermal Technology Applications	6.6	4.4	5.8	11.9	12.9	10.8
Demonstration Projects (1)	—	—	—	—	—	—
Advanced Technology Applications	4.8	5.8	7.1	4.6	10.6	8.5
Engineering Research & Development	13.8	6.7	11.3	10.0	12.2	12.2
Geothermal Resources Development Fund	0	0	0	0	0	4.4
Total	38.9	31.3	43.4	41.8	56.0	55.7

(1) Studies and projects leading to actual demonstration plants are not funded under this category.

* Does not include funds for FY 1976 Transition Quarter.

GEOTHERMAL ENERGY EXECUTIVE SUMMARY

A comprehensive Federal Energy Geothermal Program* to develop geothermal resources as an economically, environmentally, and socially acceptable energy option has been defined as required by the Geothermal Energy Research, Development, and Demonstration Act of 1974 (Public Law 93–410).

Within the coordinated federal framework, individual agencies are defining and carrying out specified programs each within their respective purviews. Program information obtained from these agencies, identified as to source, has been incorporated into the descriptions of the building blocks, or major program elements that follow.

ERDA, as the lead agency in geothermal energy development, has formed the Interagency Geothermal Advisory Council, as depicted in Figure 1. It is a follow-on to the Geothermal Energy Coordination and Management Project, which was created as an interim measure by PL 93–410. The Council, chaired by ERDA and designed to provide policy and overall coordination and management guidance for the Federal Geothermal Program, is made up of high-level representatives from each of the agencies actively concerned with the Program.

To augment the efforts and coordination capability of the Council, three interagency panels have been established to cover the areas of institutional barriers, research and technology, and resources. Other agencies, besides those on the Council, will participate on these panels as appropriate. In addition, in order to exchange information and advice with the nonfederal sector (which will play a major role in the development of geothermal energy) an Advisory Committee on Geothermal Energy has been established.

* A comprehensive description of the Geothermal Energy Program is presented in the *Definition Report Geothermal Energy Research, Development, and Demonstration Program ERDA–86* October 1975, available on written request from the ERDA Technical Information Center, P.O. Box 62, Oak Ridge, Tennessee 37830.

The seven building blocks of the Federal Geothermal Program are:

- Environmental Control and Institutional Studies
- Resource Exploration and Assessment
- Hydrothermal Technology Applications
- Demonstration Projects
- Advanced Technology Applications
- Engineering Research and Development
- Geothermal Resources Development Fund (Loan Guaranty Program)

The material that follows presents a composite overview of the Geothermal Program and describes information that applies to the entire program. These commonalities will not be repeated in the detailed discussions of each building block.

Objectives

General:

- To provide the nation with an economically and environmentally acceptable energy resource option which could permit the timely exploitation of our nation's geothermal energy resources, primarily by industry or municipal utilities. These resources exist in a variety of forms: dry steam, hot water, geopressured water, hot dry rock, thermal gradients in the earth's crust, and magma. The latest assessment of the nation's geothermal resources (USGS Circular #726, 1975) estimates a total energy content in the first four types in excess of 400,000 quads; the energy content of the latter two is, in theory, almost limitless. Presently, however, they pose too many technical and economic difficulties for exploitation in the immediately foreseeable future.

Near-Term: (–1985)

- To assist and encourage industry or municipal utilities to discover and exploit hydrothermal (steam and hot water) resources. These could provide by 1985 a growth in geothermal useage for electric power generation from the present 500 MW to 6000 MW, and in nonelectric usage from 0.0005 quads/year to 0.1 quad/year.

Mid-Term:
(–2000)

- To assist and encourage industry or municipal utilities to exploit further the hydrothermal resources, and to initiate exploitation of geopressured and hot dry rock resources. This could provide for commercial development of a resource base of some 400,000 quads, with actual utilization per year increasing five- to ten-fold over 1985 figures.

Long-Term:
(Beyond 2000)

- To assist and encourage industry or municipal utilities to increase exploitation of the above listed resources.
- To investigate the energy potential of the normal gradient, radiogenic, and magma resources. This could provide a virtually limitless resource, with actual utilization increasing another five-fold by 2020.

National Energy Technology Goals Supported

Primary:

- Expand the domestic supply of economically recoverable energy producing raw materials.

Secondary:

- Increase the use of essentially inexhaustible domestic energy resources.
- Protect and enhance the general health, safety, welfare and environment related to energy.

Strategy

The accuracy and completeness of assessments of the available resource base, on both national and regional scales, will be improved. In addition, the present industrial development of hydrothermal resources will be facilitated in order to assist industry and municipal utilities in developing the capability of rapid future exploitation of the more extensive geopressured, hot dry rock, normal gradient, and magma resources. Industry and municipal utilities will be assisted in development of the advanced technology needed to exploit geopressured, hot dry rock, normal gradient, and magma resources.

Because commercial-scale development of geothermal resources will be strongly influenced by regional and local factors, the federal government will work closely with state and local governments, industry, municipal authorities, and environmental and other interest groups in identifying appropriate federal initiatives that would most effectively encourage investment in geothermal energy and public acceptance of its development.

Federal Role

- Formulate national energy policies and priorities, and coordinate policy development with state and local agencies.
- Evaluate existing federal policies with regard to taxation, leasing of federal lands, environmental regulation, patent rights, and other policies, and propose alternatives when it is in the general public interest to do so.
- Serve as a catalyst to bring together the various segments of the industrial community and the local and state agencies concerned with geothermal development to determine the course that it should follow.
- Assist state and local agencies in their understanding of the implications of geothermal development and in the conduct of comprehensive regional planning for that development.
- Assist industry and municipal utilities in discovering geothermal resources by a systematic regional assessment of the nation's potential resources.
- Bear part of the initial cost of research, development, and demonstration activities that the private sector is unable to fully support because the capital requirements are too high, the financial risks are too great, or the potentially achievable benefits are too diffuse or too far in the future.
- Assist in making available the capital needed for industrial geothermal development by providing loan guaranties and other incentives.
- Provide for the expeditious leasing of federally-controlled geothermal resources.

International Cooperation

Technical cooperation agreements in geothermal energy have been arranged with Italy and Iceland and with the U.S.S.R. as part of an overall energy exchange program. An agreement is under negotiation with Japan, and informal exchanges of information have taken place with New Zealand. ERDA has also participated in exchanges of information and joint research projects as the lead energy agency for NATO's Committee on the Challenges of Modern Society (CCMS).

Technological Status and Problems

Status:

- Technologies to utilize each of the types of geothermal resources are in varying stages of development. Technologies exist today for generation of electricity from vapor-dominated hydrothermal resouces and, to a more limited extent, from liquid-dominated hydrothermal resources. In addition, hydrothermal resources have been and are being used for a wide variety of non-electric applications.

Problems:

- Utilization of geopressured resources, hot dry rock, magma, radiogenic (i.e., heat from the decay of radioactive materials), and the normal gradient has not yet reached a state of demonstrated technological feasibility. Differing degrees of fundamental and applied research, of field testing and experiments, and of pilot and demonstration projects are required to bring use of such resources to the point of economic viability and environmental acceptability. Of these resource types, geopressured resources appear to be the nearest to commercialization, but the ability of geopressured resources to sustain flow over extended time periods and the economic viability of recovering the methane found in these resources are untested. The technical and economic feasibility of recovering energy from hot dry rock, normal gradient, radiogenic, and magmatic resources is less well known and requires considerable and relatively long lead time basic and applied research. These larger resources, however, offer the greatest potential impact of geothermal energy.

Institutional Status and Problems

Development of geothermal energy may be critically dependent on the resolution of institutional issues arising from the geographic locations of the resource, its incompletely defined legal status, and the special market structure and service industry infrastructure that must be developed to permit its utilization.

Status:

- Much of the known or inferred geothermal resource base is located on federal land. The first competitive leases as provided for in the Geothermal Steam Act of 1970 became effective August 1, 1975. While the processing of leases has been accelerated considerably over the past few months, the industrial response to the leasing program has been somewhat less than anticipated in that no bids have been received on some competitive lands and some applications have been withdrawn on non-competitive lands.
- Because of the many institutional as well as technical uncertainties currently associated with the utilization of geothermal energy, its development is viewed as a relatively high-risk venture. As a result, most industrial investment to date has been limited to dry steam or low-salinity hydrothermal resources.

Problems:

- Commercial development is allegedly being delayed by the lack of economic parity between the development of geothermal energy and the industrial development of other energy resources (e.g., coal, uranium, oil, gas, etc.). This alleged disincentive is the non-parity of geothermal resources versus fossil resources with respect to the write-off of intangible drilling costs and depletion allowances.
- The electric utility industry is closely regulated, and utility-regulating bodies presently perceive geothermal enterprises (with the exception of dry steam facilities) to be too risky to be certified for inclusion in utility rate bases. This policy, combined with somewhat limited utility R&D funds, makes capital formation for geothermal plants difficult.
- Service industries which supply the technology for geothermal exploration, field development, and conversion to electricity, may not see a sufficient market to warrant the large R&D investments required to make geothermal energy more commercially attractive.
- Federal patent policies have, in the past, discouraged service industries from accepting government R&D contracts, thus delaying development of technology and hardware.
- The lack of both environmental data and standards necessarily slows the environmental approval process. Moreover, the approval process is further slowed by the lengthy, complex and

often apparently inconsistent rules, laws, and regulations at federal, state, and local levels of government. The overlay of jurisdiction of the responsible agencies further compounds the process, and has caused much unnecessary duplication of industrial effort in preparation of environmental statements. The uncertainty of ultimate approval and the time involved in obtaining approval have been cited by the industry as major deterrents to geothermal investment.

Environmental Status and Problems

Status:

- Geothermal environmental problems are not new. However, there are few relevant data available on their potential impacts. Adequate, clearly established standards have not been determined for the environmental acceptability of geothermal development.

Problems:

- Utilization of geothermal energy may involve a number of potential environmental effects, including noxious gas emission, land subsidence, stimulation of seismicity, groundwater contamination, waste brine disposal, surface water contamination from spills, cooling water discharge, and condensate discharge. These technological uncertainties exacerbate the related institutional problems noted above.
- The nature and magnitude of the expected environmental impacts, some apparently minimal and some potentially serious, differ from one type of geothermal resource to another, and even within a single type of resource or within a single Known Geothermal Resource Area. For example, the dissolved gas and mineral content of hydrothermal fluids varies considerably. Thus the technology or magnitude of any remedial measures required will vary from one site to another, as well as from one type of resource to another.

Program Implementation

The implementation of the Federal Geothermal Program is a coordinated multiagency and private sector effort composed of the seven interrelated program elements, or building blocks, listed in the Introduction. In the sections that follow, the role and time-phased plans of each agency in the implementation of the federal program are described. Major elements of the overall implementation plan include the following:

Environmental Control and Institutional Studies:

- Research to support the setting of appropriate environmental and safety standards and criteria, including characterization of effluents and studies of toxic levels.
- Recommend appropriate standards and criteria, and conduct technological research on and development of necessary control measures.
- Policy studies on the effects of taxation, land and water use, and regulatory functions at the local, state and federal levels.
- Socio-economic studies on micro- and macroscales, to determine costs, benefits, and other impacts on regional and National scales.
- Cooperation and support for community and regional planning.

Resource Exploration and Assessment:

- National and regional geological assessments of the resource base.
- Development of improved technology for exploration and assessment of geothermal reservoirs.
- Maintain interaction with resource information data banks such as TIC at Oak Ridge and GRID at Lawrence Berkeley.
- Improvement of geothermal lands leasing program to reduce delays and other difficulties.
- Develop better fundamental geological, geophysical, and geochemical models of geothermal reservoirs.

Hydrothermal Technology Applications:

- Establish facilities for testing components and subsystems required for extraction and utilization of hydrothermal and other forms of geothermal energy for use by both government and industry.
- Conduct pilot-scale studies of water-desalting by use of hydrothermal energy, eventually in combination with power production.

Demonstration Projects:

- Construct and operate one or two commercial-scale geothermal electric power plants, in cooperation with industry, if appropriately justified and authorized.
- Dispose of the federal interest in demonstration plants as soon as technical, economic, and en-

vironmental acceptability has been sufficently demonstrated.

Advanced Technology Applications:

- Continue modeling studies and regional surveys of geopressured resources.
- Conduct flow tests of existing or new exploratory wells to determine reservoir characteristics.
- Improve exploration and assessment methods, and determine the magnitude and other characteristics of hot dry rock resources.
- Develop economically and environmentally acceptable methods for extracting energy from hot dry rock resources.
- In the mid-term, study the feasibility of the extraction and utilization of useful energy from normal gradient, non-associated radiogenic, and other potential geothermal resources.
- Initiate development of the required technology if the results of feasibility studies are favorable.

Engineering Research and Development:

- Develop improved drilling technologies, especially for hard rocks and high temperatures.
- Develop improved geothermal-to-mechanical energy conversion systems, such as helical screw expanders and impulse turbines.
- Develop improved materials and designs for heat-exchangers that are more efficient and less subject to scaling and corrosion, for binary cycle systems.
- Develop geothermal well stimulation methods and down-hole pumps.
- Develop improved, environmentally acceptable methods for extraction of useful minerals from waste brines and for the disposal of the spent brines.

Geothermal Resources Development Fund (Loan Guaranty Program):

- Establish regulations.
- Request borrowing authority as the most appropriate means for creating the Development Fund.

Implementation of all the building blocks of the Federal Geothermal Program will require planning, coordination, and cooperation not only among federal agencies, but also with industry, state and local governments, and the public. ERDA will play an active role in providing the necessary two-way communication channels. ERDA has also established an Advisory Committee on Geothermal Energy, whose membership includes representatives from the industrial, financial, technological, and academic communities, and from the general public.

GEOTHERMAL ENERGY

Federal Energy RD&D Budget

($ Millions)

	FY 1975		FY 1976*		FY 1977	
Building Block	**BA**	**BO**	**BA**	**BO**	**BA**	**BO**
Environmental Control & Institutional Studies	0.5	1.2	3.9	2.5	4.8	4.8
Resource Exploration & Assessment	13.2	13.2	15.3	12.8	15.5	15.0
Hydrothermal Technology Applications	6.6	4.4	5.8	11.9	12.9	10.8
Demonstration Projects (1)	—	—	—	—	—	—
Advanced Technology Applications	4.8	5.8	7.1	4.6	10.6	8.5
Engineering Research & Development	13.8	6.7	11.3	10.0	12.2	12.2
Geothermal Resources Development Fund	0	0	0	0	0	4.4
Total	38.9	31.3	43.4	41.8	56.0	55.7

(1) Studies and projects leading to actual demonstration plants are not funded under this category.

* Does not include funds for FY 1976 Transition Quarter.

FEDERAL GEOTHERMAL PROGRAM

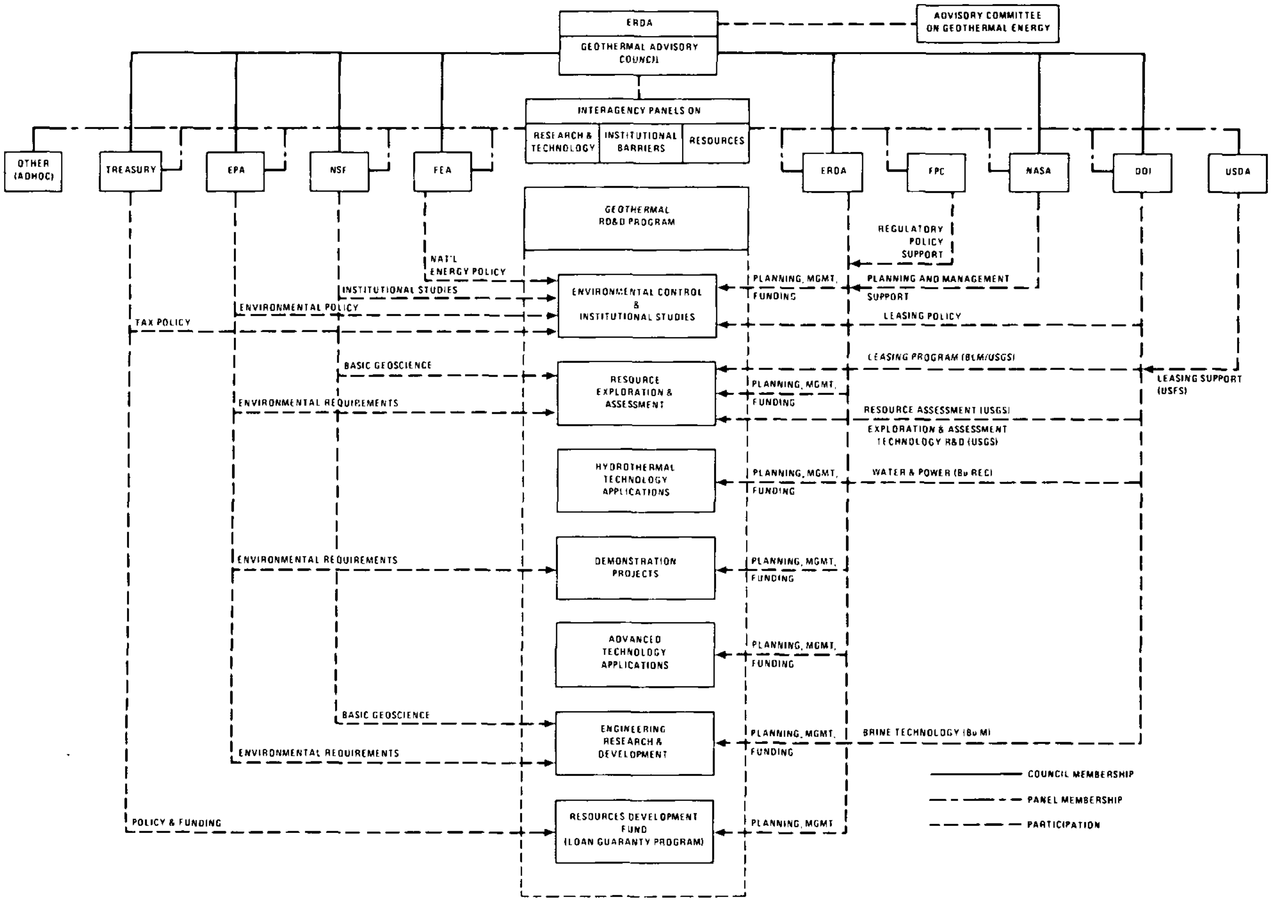


Figure 1

GEOTHERMAL ENERGY

Environmental Control and Institutional Studies

Objectives

Near-Term:
(–1985)

- Acquire the data base needed for the development of environmental standards.
- Develop appropriate environmental control technologies.
- Formulate policy options for systematic elimination of nontechnological impediments to geothermal resource development.

Mid-Term:
(–2000)

- Continue to develop environmental control technologies as appropriate.
- Continue a coordinated program of federal and nonfederal activities designed to achieve full commercial utilization of geothermal resources.

Strategy

Environmental and socio-economic implications of large-scale geothermal developments will be determined and coordinated with federal, state and local activities in setting environmental standards. Technical requirements and guidance in the development of environmental control technology will be identified and analyzed, as will legal, institutional and economic factors which impede the commercial development of geothermal energy. Policy alternatives to mitigate these programs will be developed and assessed while protecting other legitimate public interests. Finally, regional, state and local agencies will be assisted in planning for geothermal development.

Technological Status and Problems

Status:

- Much of the environmental control technology required in geothermal resources development is already available, though its utilization has been limited.

Problems:

- Technology for control of subsidence due to loss of reservoir fluids and possible seismic effects of fluid reinjection has not been demonstrated.
- Technology to control gaseous emissions from geothermal facilities has not been demonstrated on a commercial scale.

Institutional Status and Problems

Status:

- Studies of the institutional, socio-economic, and legal aspects of geothermal development, begun under the sponsorship of NSF, are continuing under ERDA. They include: regional and local development planning efforts; legal analyses identifying and assessing critical problems; state management of geothermal development, and the role of geothermal energy in utility planning.

Problems:

- Present federal and state tax policies on geothermal development and energy production have been cited as inhibiting development.
- Current federal, state and county regulatory and licensing procedures are lengthy, complex, cumbersome, and often inconsistent.
- Possible adverse socio-economic impacts of geothermal development have not been adequately assessed.
- State electric utility rate regulations do not normally allow full inclusion of geothermal development costs in rate base computations.
- Differing investment practices between utility companies and resource development com-

panies amplify the difficulties in obtaining capital for geothermal projects.

Environmental Status and Problems

Status:

- U.S. experience in geothermal environmental effects is limited mainly to The Geysers, which currently does not conform to hydrogen sulfide air pollution standards. ERDA is presently funding two studies on the removal of hydrogen sulfide from geothermal steam and one study on its removal from hot brine. Other studies involve developing recommended environmental requirements for the experimental facilities to be located in the Salton Sea area, and environmental baseline data for the entire Imperial Valley.

Problems:

- Insufficient knowledge of environmental effects of extensive and large-scale geothermal development. This lack of knowledge makes it very difficult to establish appropriate and effective environmental standards and regulations.
- Gaseous emissions and land subsidence are the main known problems in geothermal reservoir utilization.
- Biological effects are the major unknowns, but they appear to be few and controllable.
- The possibility of induced seismicity from large-scale geothermal sites is not adequately understood.
- Limited baseline data for many resource areas.
- Technologies for the control of geothermal wastes in an environmentally safe manner without disruption to local land and water use are yet to be fully developed and demonstrated.

Program Implementation

In addition to ERDA program initiatives, some of the programs in the environmental and institutional area were initiated by NSF, but are being transferred to ERDA in accordance with the provisions of the Geothermal Energy Research, Development and Demonstration Act of 1974 (PL 93–410).

Environmental Control Technology Research:

Major technological programs deal with gaseous emissions and subsidence problems. It is expected that several efforts begun in FY 76 will produce hydrogen sulfide control systems ready for testing in mid-FY 78, and that the first extensive test of subsidence control technology by reinjection of brines could occur as early as FY 79. This will also serve as a method of brine disposal.

Federal Policy Studies:

A series of federal policy studies has been initiated to assess the effect of federal tax and land policies. Recommendations of policy modifications are expected in mid-FY 77, with implementation of approved recommendations to follow.

Legal Studies:

Analyses of critical state geothermal laws and regulatory systems and model geothermal codes are expected late in FY 77.

Institutional Studies:

Reports on analyses of state utility regulatory policies and practices will be available starting in late FY 76. Studies of other institutional/investment factors will follow in late FY 77. Additional federal policy recommendations will be based on results of both institutional and economic studies.

Economic Studies:

Economic studies of geothermal development were initiated in FY 74. Results of microeconomic analyses were available in FY 75, and further results will be available in FY 76. Results of macroeconomic analyses and cost/benefit analyses, including consideration of possible adverse socio-economic impacts, are expected beginning in FY 77.

Regional/Community Planning:

Regional/community planning studies to identify site-specific and local impact problems in geothermal resource development were initiated in FY 76. The first study reports, for the Imperial Valley in California and the Gulf Coast of Texas, are expected in FY 77. Joint federal/regional/state/local design and implementation of plans and programs will follow.

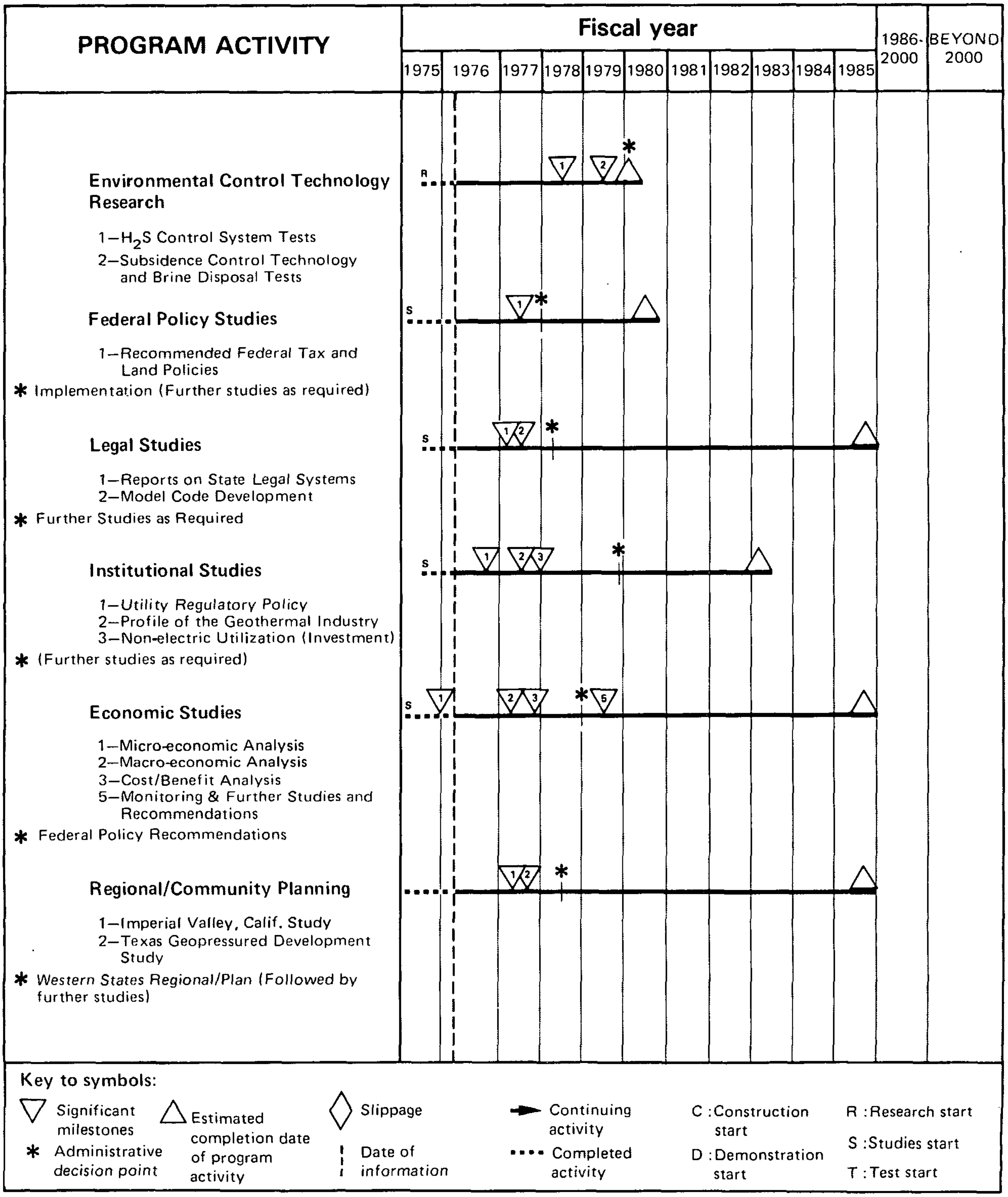
A project, well underway in Susanville, California, addresses the question of how a community can stimulate and control the development of local geothermal resources.

Criteria and Standards Development:

In the environmental area, major activities are in developing the information base and criteria necessary to develop standards for full geothermal commercialization. Specific results planned include development of EIA/EIS guidelines, site-selection methodologies and monitoring guidelines, with provision for annual updating.

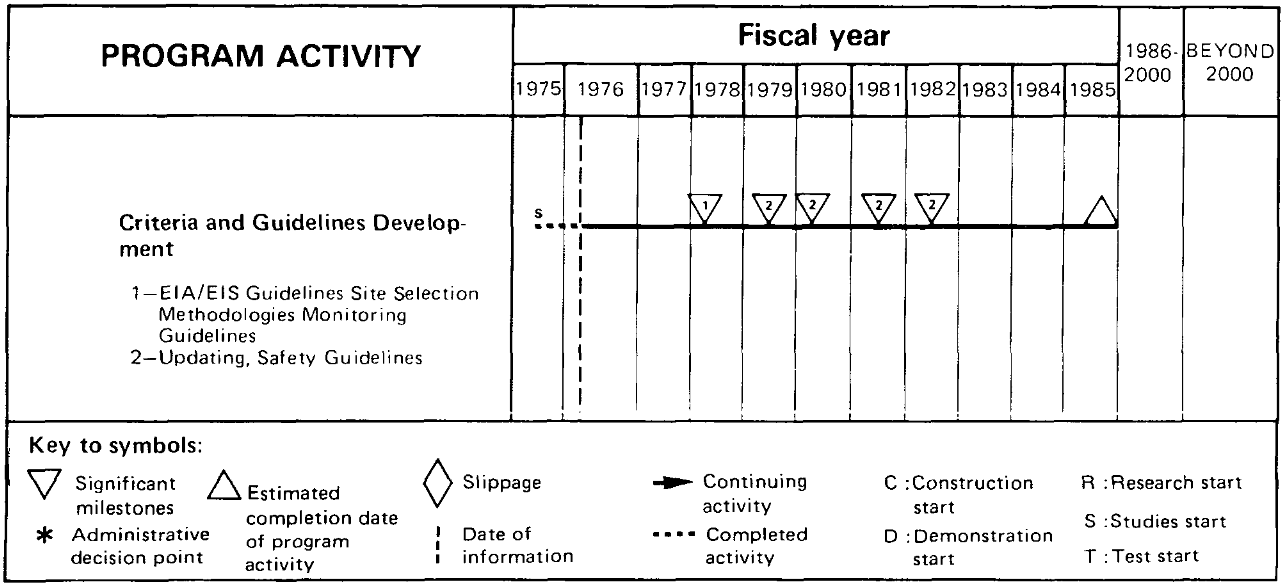
ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION

ENVIRONMENTAL CONTROL AND INSTITUTIONAL STUDIES



ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION

ENVIRONMENTAL CONTROL AND INSTITUTIONAL STUDIES (continued)



ENVIRONMENTAL CONTROL AND INSTITUTIONAL STUDIES

Federal Energy RD&D Budget **($ Millions)**

Agency	FY 1975		FY 1976*		FY 1977	
	BA	BO	BA	BO	BA	BO
ERDA						
Operating Expenses	0.5	1.2	3.9	2.5	4.8	4.8
Plant and Capital Equipment	0	0	0	0	0	0
Total	0.5	1.2	3.9	2.5	4.8	4.8

* Does not include funds for FY 1976 Transition Quarter.

GEOTHERMAL ENERGY

Resource Exploration and Assessment

Objectives

Near-Term:
(–1985)

- Provide periodic refinement of geothermal resource assessments.
- Develop and test instrumentation and interpretive techniques for geothermal resource exploration and assessement.
- Develop and test the technology for geothermal reservoir assessment and characterize the energy potential of geothermal reservoirs in support of test and demonstration facilities.
- Develop and maintain a national and regional data base on geothermal resources.
- Classify geothermal resources on federal and Indian lands in terms that will establish a fair market value for their commercial use.
- Establish and administer the procedure for leasing federal and Indian lands for geothermal resource development.

Mid-Term:
(–2000)

- Sustain activities in exploration technology and resource assessment as dictated by the rate of development of geothermal resources.
- Continue to improve data on geothermal resources as appropriate.

Strategy

Implement a program for resource exploration and assessment by initially focusing on hydrothermal, geopressured, hot dry rock resources, and later, on other geothermal resources. This will support the orderly and systematic development of the industry. Hydrothermal has first priority because it is nearest to commercialization and because the data are needed for the development of extraction technologies.

Technological Status and Problems

Status:

- Investigation of twenty Known Geothermal Resource Areas (KGRA's) have been completed for the classification and evaluation of geothermal resources on federal and Indian lands. Investigations of eleven additional KGRA's are underway or planned for the current fiscal year.
- A comprehensive inventory entitled "Assessment of the Geothermal Resources of the United States—1975" (USGS Circular #726) has been completed.
- Two successful test holes which yielded initial flows of about 1,000 gpm each of 145°C water were drilled in Idaho's Raft River area on the basis of USGS predictions.
- Seismic research in Long Valley, California, suggests that this area will become a geothermal target of significant potential.
- Geophysical and geological investigations in the Coso Hot Springs area, California, have started to characterize the extent of the underlying geothermal anomaly and have identified some of the complex surrounding fault zones.
- Isotope analysis models are being developed to serve as needed geothermometers.
- Investigative studies are continuing in other promising areas of regional scope in Western and Gulf states.

Problems:

- Scientific understanding of fundamental geothermal processes and the nature of altered reservoir rocks is incomplete.
- Detailed information and data regarding the location, size, energy potential and availability of geothermal resources are limited.
- Reliable surface exploration methods for locat-

ing subsurface concentrations of heat and water are lacking; further difficulties are encountered where there are few or no surface manifestations of the subsurface conditions.

- Deep drilling in hard rock within moderate temperature geologic formations is expensive and time-consuming; drilling in high-temperature (250°C) hard rock is beyond the present state-of-the-art.

Institutional Status and Problems

Status:

The Geothermal Steam Act of 1970 has been implemented, and the following have occurred:

- 5,500 *noncompetitive geothermal* lease applications, covering 11 million acres, have been received by the Bureau of Land Management (BLM); leases covering 811,000 acres were issued for 455 of the aplications.
- 28 sales have been held and 121 *competitive* leases covering 229,000 acres in KGRA's have been issued by the BLM.

Problems:

- A court case is in progress (*US vs. Union Oil, et al.*) to determine whether mineral rights include rights to geothermal resources.
- Delays in lease issuance, though much reduced on federal lands under BLM jurisdiction, are being caused by the needs to determine land status, formulations of special local stipulations, and environmental study requirements.
- New or special regulations may be required to protect the land surface during exploration and extraction of new forms of geothermal energy.

Program Implementation

Implementation of the Resource Exploration and Assessment effort will be accomplished within five major activities: National and Regional Resource Assessments; Exploration Technology; Reservoir Assessment Technology; Resource Information Data Banks; Leasing of Geothermal Lands, as follows:

National and Regional Assessments (USGS effort):

USGS Circular #726 is the first step in developing a National assessment. Regional assessments will be used to upgrade the national assessment and will play a significant role in identifying the potential resource areas for development. Periodic refinement will be necessary as resource data become available. Strong emphasis will be placed on identifying nonhydrothermal resources during the course of the regional assessments.

Exploration Technology (Joint ERDA-USGS-NSF):

Initial emphasis will be on the hydrothermal resources; long-range developments will successively develop exploration instrumentation and methodology for geopressured, hot dry rock, near-normal gradient and magma resources. These efforts will identify the best combinations of equipment and techniques for geothermal exploration:

- Techniques to provide enhanced electrical resistivity data from three-dimensional detector arrays are being developed to improve the available exploration technology.
- Methods are being developed that use seismic ground noise to identify and characterize hidden geothermal fields.
- The surface instrument development effort will identify, assemble and field test packages of available, improved, and new exploration equipment. Package specifications will be made available for commercial use following confirmation of performance at each phase of the development.
- Reliable down-hole instrumentation is being developed which can operate at the high temperatures characteristic of geothermal bore holes.
- Exploration methodology is being generally refined by developing appropriate mixes of surface and down-hole instrumentation and techniques, by studying the properties of typical reservoir rocks, and by extending log interpretation technology for application in geothermally altered media.

Development of the resulting exploration methodologies and alternative or new concepts will be pursued where appropriate to encourage commercial application.

Reservoir Assessment Technology (Joint ERDA-USGS-NSF):

- Improved geophysical techniques are being developed to achieve a better understanding of the physical characteristics of geothermal reservoirs.
- Theoretical studies and laboratory experiments

will be directed to the understanding of geothermal reservoirs as active chemical systems.

- The origin, evolution, structure and phenomenology of geothermal resources will be studied at a fundamental science level to better understand the nature of geothermal resources.
- Computer models are being developed that will simulate the characteristics of different types of geothermal reservoirs. Separate models will simulate physical characteristics of the reservoirs and their utilization options. Inversion models will also be developed for improvement of exploration and data interpretation methods.
- Field test data obtained for assessment purposes during development and confirmation of actual reservoirs will be used for model validation and refinement.

As confidence in the models is attained, they will be made available to the industrial and public utility communities. Alternative or new approaches to reservoir assessment will continue to be evaluated, and research and development will be continued as appropriate.

Resource Information Data Bank (Joint ERDA-DOI):

A National Geothermal Resource data bank (GRID) is planned to ensure retention and distribution of data obtained during resource exploration, assessment and research activities. A computerized data storage-retrieval project is already underway at the Lawrence Berkeley Laboratory in California, and additional regional data banks will be established as needed.

Leasing of Geothermal Lands (DOI-USDA):

In the implementation of the geothermal leasing programs, the Bureau of Land Management (BLM) is the lead agency. The BLM works with USDA's Forest Service on the leasing of geothermal resources on lands controlled by the Forest Service. The BLM is supported extensively by the USGS with field evaluations. The BLM will:

note record of filing for leases;

check for overlapping filings;

plot the applications on land status maps;

adjudicate difficulties.

The USGS performs most of the necessary technical services such as estimating the extent of reservoirs, establishing minimum fair lease prices, and conducting environmental analyses.

Geothermal leasing schedules are published in the *Federal Register*.

RESOURCE EXPLORATION AND ASSESSMENT

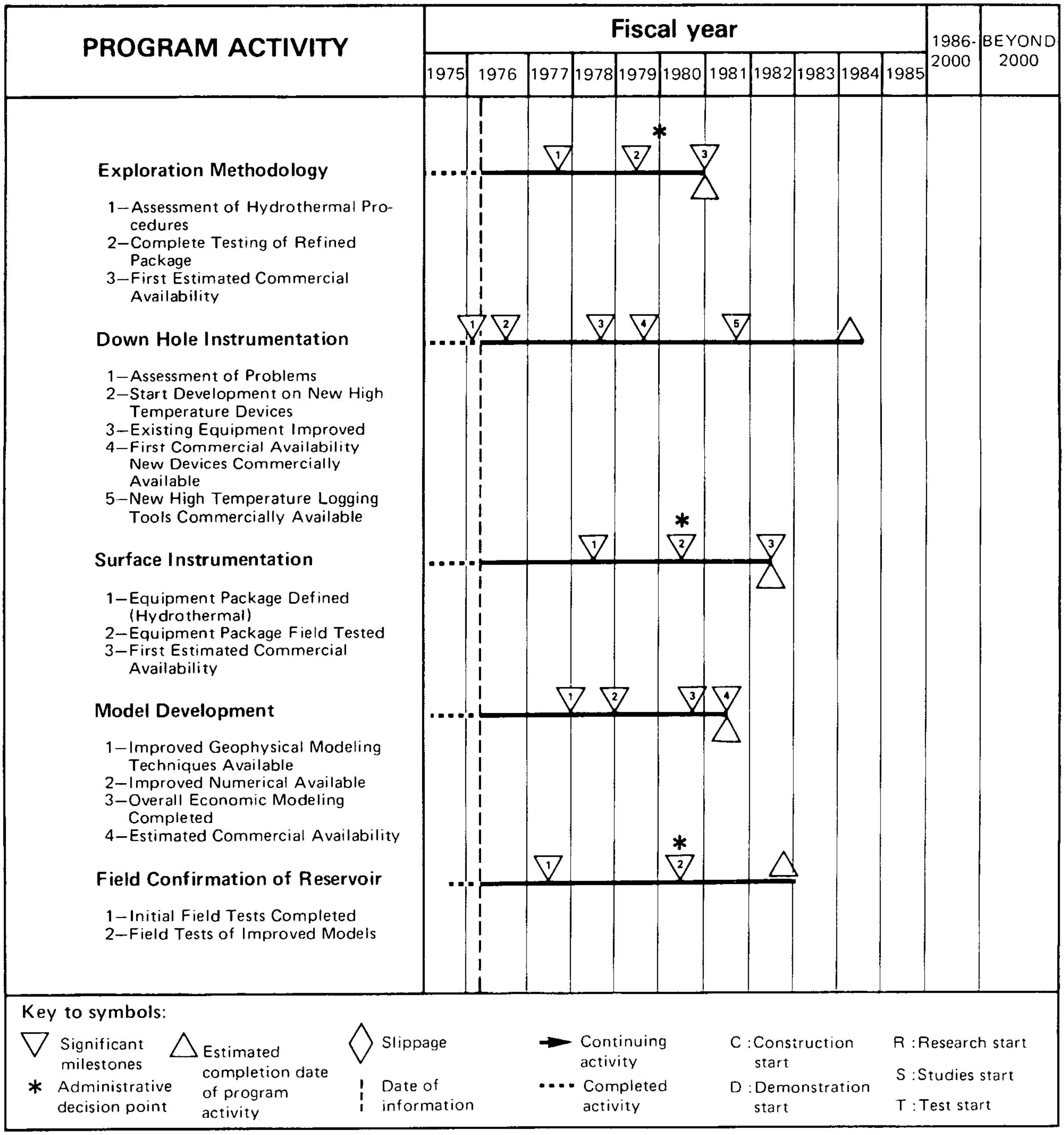
Federal Energy RD&D Budget **($ Millions)**

Agency	FY 1975 BA	FY 1975 BO	FY 1976* BA	FY 1976* BO	FY 1977 BA	FY 1977 BO
ERDA						
Operating Expenses	2.8	3.0	3.6	3.2	10.0	9.6
Plant and Capital Equipment	0	0	0	0	0.1	0.1
Total	2.8	3.0	3.6	3.2	10.1	9.7
DOI	10.4	10.2	11.7	9.6	5.4	5.3
Total	13.2	13.2	15.3	12.8	15.5	15.0

* Does not include funds for FY 1976 Transition Quarter.

ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION

RESOURCE EXPLORATION AND ASSESSMENT



GEOTHERMAL ENERGY

Hydrothermal Technology Applications

Objectives

Near-Term:
(–1985)

- Reduce the risks perceived by industry and public utilities by demonstrating the performance of the newly developed components, subsystems and systems.
- Demonstrate the feasibility of electric and thermal power production from geothermal resources.

Strategy

The federal strategy is to assist industry and public utilities in the testing of new components, subsystems, and processes by providing federally-funded field test facilities for use on the cost-reimbursable basis and through jointly-funded programs, and provide for pilot-scale testing of integrated energy conversion and nonelectric utilization systems in the field.

The wide variability of fluid characteristics from different reservoirs and their economic impacts requires a number of test facilities and projects. Priorities for these projects will be based on the estimated quantity of the resource available for commercial development, the state-of-the-art of the technology and its stimulative effect on growth. The strategy of the federal program is to use known technologies to construct test units which will demonstrate the feasibility of producing electric power at the Yuma, California, desalting plant. The next step would be development of the Mesa Anomaly, East Mesa Area of the Imperial Valley, California, for production of electric power and other byproducts.

Technological Status and Problems

Status:

- ERDA has initiated two jointly-funded efforts for the development of high-temperature (higher than 200°C), high-salinity (higher than 50,000 ppm) resources; one with San Diego Gas and Electric Co. for binary thermal test loop and the second with Southern California Edison Co. for a direct flash test rig.
- An effort has been undertaken at the Raft River geothermal field to establish the suitability of moderate temperature (near 150°C), low-to-moderate salinity (less than 20,000 ppm) hydrothermal resources for electric power production and direct nonelectric applications of geothermal energy.
- A collaborative effort is underway between ERDA and the Bureau of Reclamation to develop a test facility at East Mesa, California, for testing of geothermal energy conversion equipment for moderate-to-high-temperature (higher than 150°C), low-to-moderate salinity resources.
- Efforts in active volcanic hydrothermal resources, in cooperation with the state of Hawaii, are presently focused on the drilling of an exploratory well for resource evaluation.
- Two nonelectric applications studies are in progress. One, by the city of Susanville, California, concerns the use of local hydrothermal resources in municipal, industrial, and residential heating systems. The second involves a study and an engineering design of a geothermal heating system for public buildings in Boise, Idaho.
- A Geophysical procedure for location, evaluation and development of a geothermal resource is being tested at East Mesa.
- Desalting equipment is being tested at the East Mesa facility.
- Geothermal fluids as a source of heat have been demonstrated at specific sites in the U.S. and

elsewhere in the world (New Zealand, Iceland, Japan).

Problems:

- Basic problems being encountered in the use of high-temperature, high-salinity brines are scaling and corrosion.
- Moderate-temperature, low-to-moderate salinity hydrothermal resources cannot be economically exploited for production of electricity with existing conversion technology because present conversion efficiencies preclude their economic use.
- Feasibility of commercial utilization of active volcanic hydrothermal resources, such as may be available in Hawaii and Alaska, is unproven.

Environmental Status and Problems

Status:

- An archeological study and report have been prepared on the Mesa Anomaly study area.
- Environmental statements were prepared for the test evaporating/desalting systems, and one is in preparation for the pilot water and power plant.
- Monitoring systems have been installed for monitoring micro-earthquakes, surface subsidence, and groundwater quality.
- An Air Quality Monitoring System is planned for the Mesa Anomaly test area.

Problems:

- The impact of the release of noxious gases has not been fully assessed.
- Environmental feasibility for commercial utilization of liquid-dominated hydrothermal resources is unproven.
- A proven technology to prevent unacceptable subsidence and seismic activity does not exist.

Program Implementation

Bureau of Reclamation

Resource appraisal studies in Southern California are planned for completion in FY 78. Mesa Anomaly reservoir evaluation is planned for completion in FY 79, including an air quality monitoring system. Tests of evaporators, desalting units and power generation units are planned for completion in FY 76.

Energy Research and Development Administration

Thermal loop tests of flash-to-binary cycle using a high-temperature/high-salinity resource will be completed by the end of FY 78. Direct-flash energy conversion system tests will be completed by mid FY 78. The decision to construct a follow-on electric power pilot plant using a flash-to-binary, direct-flash, or hybrid energy conversion system is planned for the beginning of FY 79, to be carried to operational status by FY 80. Evaluation of plant operations is planned for completion in FY 82. Test facility for hypersaline brines is planned for operation FY 79 to FY 83.

A decision to install a test facility for moderate-temperature/moderate salinity geothermal fluids at East Mesa may be made in early FY 78.

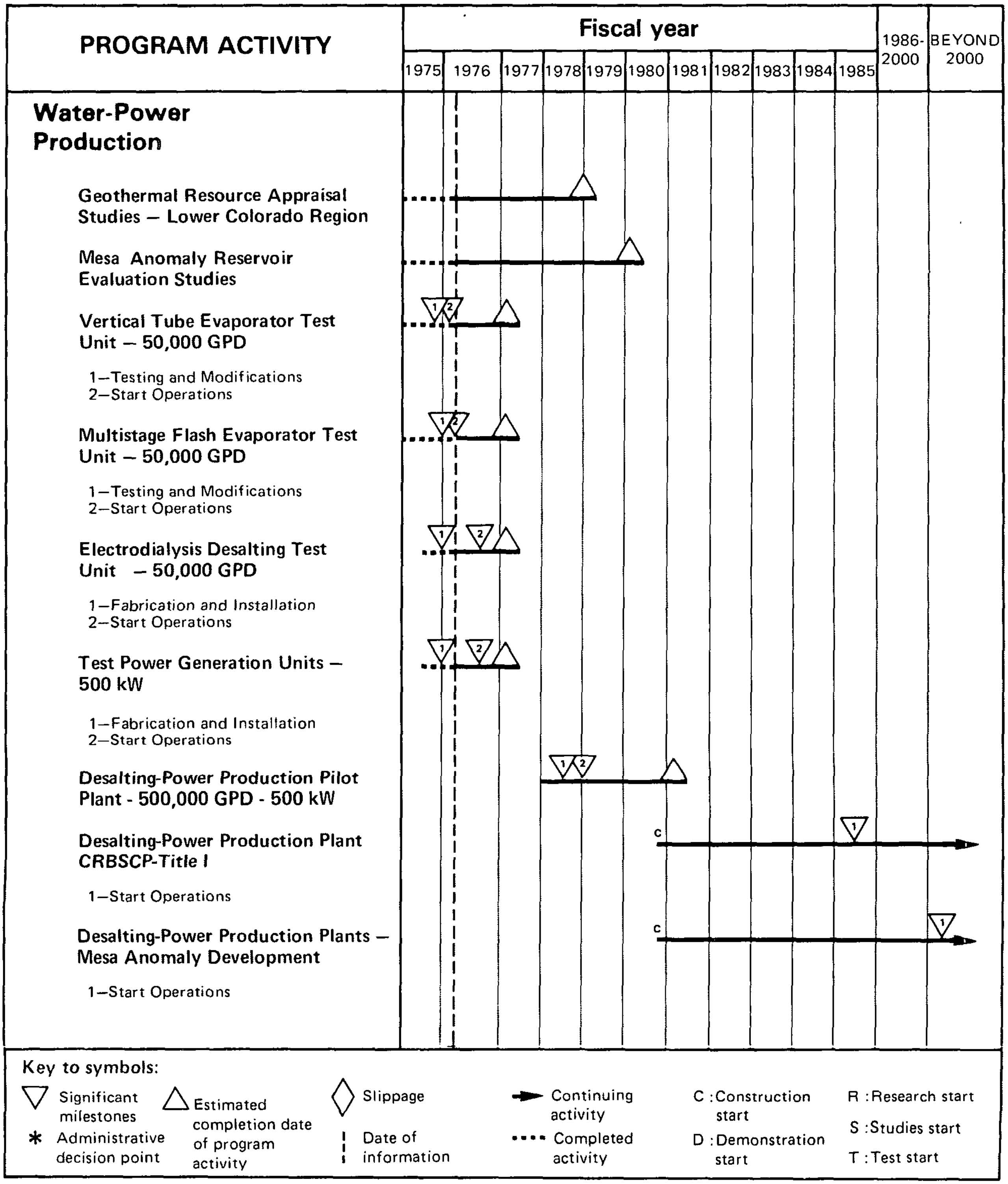
Thermal loop tests of a binary cycle system using the moderate-temperature/low-salinity reservoir at the Raft River site will be started in FY 78 following a decision point in late FY 76; planned completion of operation and evaluation would be done at end of FY 80. If results are favorable, ERDA would assist local authorities in the design, construction, and testing of a pilot electric plant in FY 80 and FY 81.

Active volcanic hydrothermal experiments run through FY 83 with decision points in early FY 78 and FY 79 concerning start of production test hole drilling and thermal loop construction respectively.

A series of engineering and economic studies of nonelectric applications using low-to-moderate temperature resources would be supported in FY 77, 78 and 79. Results of these studies will be the basis for selection of field experiments beginning in late FY 77 or FY 78 covering reservoir specific direct applications of geothermal heat in selected nonelectric industry sectors. Resulting data will be used to evaluate environmental impacts and aid in setting standards for geothermal application.

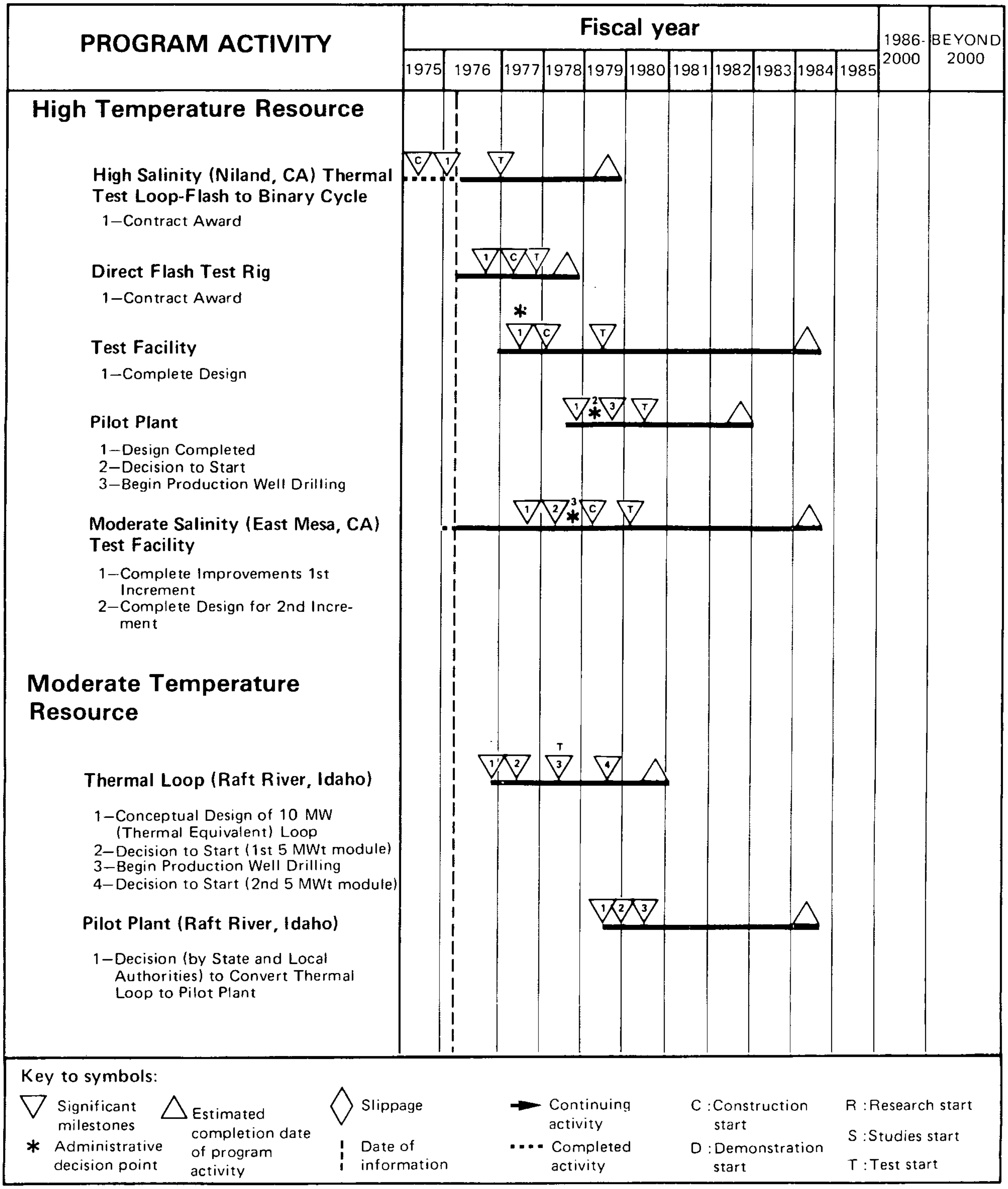
BUREAU OF RECLAMATION

GEOTHERMAL WATER-POWER PRODUCTION
HYDROTHERMAL TECHNOLOGY APPLICATIONS



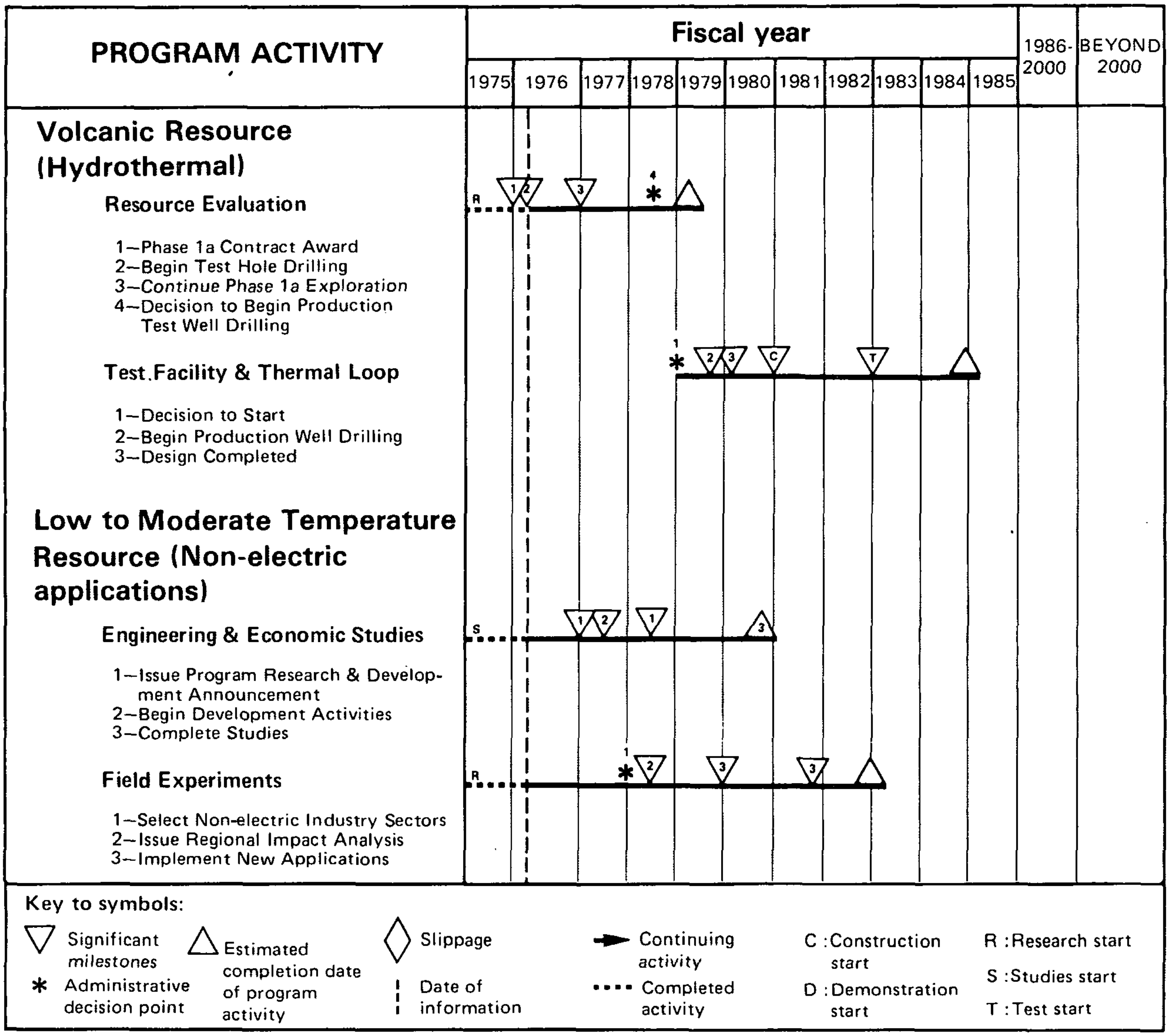
ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION

HYDROTHERMAL TECHNOLOGY APPLICATIONS



ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION

HYDROTHERMAL TECHNOLOGY APPLICATIONS (continued)



HYDROTHERMAL TECHNOLOGY APPLICATIONS

Federal Energy RD&D Budget ($ Millions)

Agency	FY 1975		FY 1976*		FY 1977	
	BA	BO	BA	BO	BA	BO
ERDA						
Operating Expenses	6.4	4.2	5.7	11.8	12.2	10.2
Plant and Capital Equipment	0.2	0.2	0.1	0.1	0.7	0.6
Total	6.6	4.4	5.8	11.9	12.9	10.8

* Does not include funds for FY 1976 Transition Quarter.

GEOTHERMAL ENERGY

Demonstration Projects

Objective

Near-Term:
(–1985)

- To accelerate industrial development of identified liquid-dominated hydrothermal resources.

Strategy

The strategy of the federal geothermal program is to alleviate the concerns of the industry and of state and local communities by directly involving them in carefully selected commercial-scale demonstration projects of new technology applications. This process also will assist industry infrastructure development.

Technological Status and Problems

Status:

- Binary cycle and flashed steam technologies are considered by some members of the industrial-user community to be sufficiently well developed for commercial use of liquid-dominated geothermal fluids. The economic viability and the environmental acceptability of these technologies have not yet been demonstrated under conditions and standards prevailing in the U.S.

Problems:

- Except for vapor-dominated hydrothermal systems, data on and estimates of plant availability (i.e., fraction of time the plant is actually operational) are unavailable.
- The site-variable nature of geothermal resources limits both the interpretation and extrapolation to new sites of extraction, reinjection, environmental, and field life data from producing reservoirs.

Institutional Status and Problems

See the Environmental Control and Institutional Studies building block, and in addition, note:

- There are no federal standards for hydrogen sulfide (H_2S). Thus, in counties or states which have no standards of their own, developers are not sure what requirements or restrictions will be imposed.

Environmental Status and Problems

See the Environmental Control and Institutional Studies building block, and in addition note:

Status:

- Techniques for controlling fluid disposal, pollution of aquifers, gaseous emissions, and subsidence effects have been devised, but have not been fully tested.

Problems:

- Because of limited experience with monitoring and abatement devices for hydrogen sulfide, ammonia, fluorides, borates, and volatile forms of mercury, there is considerable uncertainity about both the effectiveness and the costs of various technical approaches to control or abatement.
- Methods of adequately monitoring subsidence in the vicinity of geothermal sites have not been verified.

Program Implementation

Energy Research and Development Administration

Currently, options for two full-scale 50 MW demonstrations are being investigated which, when approved, would include joint industry and government funding of construction and operation of each plant. The specific locations for the projects have not been chosen. Program Opportunity Notices will be issued to indicate ERDA's intent to undertake these projects and will describe a general need, but leave the initiative with the responder to outline a specific demonstration project.

Demonstration Plant #1:

The first 50 MW geothermal demonstration plant would be designed to confirm the readiness for commercial application of an electric power plant using a high-temperature, low-to-moderate-salinity resource with a binary or flashed steam cycle. At present, only planning and preliminary design studies are being undertaken. The project duration, to the point of plant startup, would be about 35 months. Major activities in the year that the project is authorized (possibly by early FY 78) will be site planning, ordering of long lead time items, drilling of some production and reinjection wells, and the initiation of an environmetal impact study. Field construction of the power plant would begin the following year. If the project were initiated in FY 78, operation could begin in FY 80 or 81, and disposition of the federal interest in the plant would then occur in FY 84 or 85.

Demonstration Plant #2:

The second 50 MW demonstration plant being considered would be constructed at a hydrothermal reservoir in a geologically young volcanic region. It would use a different type of hydrothermal resource and a different conversion system and may also provide nonelectric energy for end use. Preliminary design activity is scheduled to start in FY 77. Subsequent to authorization, exploratory drilling and extensive assessment of the reservoir will be undertaken in the first year. Thermal loop tests at about a 10 MW level for about a year would be conducted before making a final decision to proceed with plant construction. Plant operational start-up could occur in three years, and disposition of the federal interest in six years.

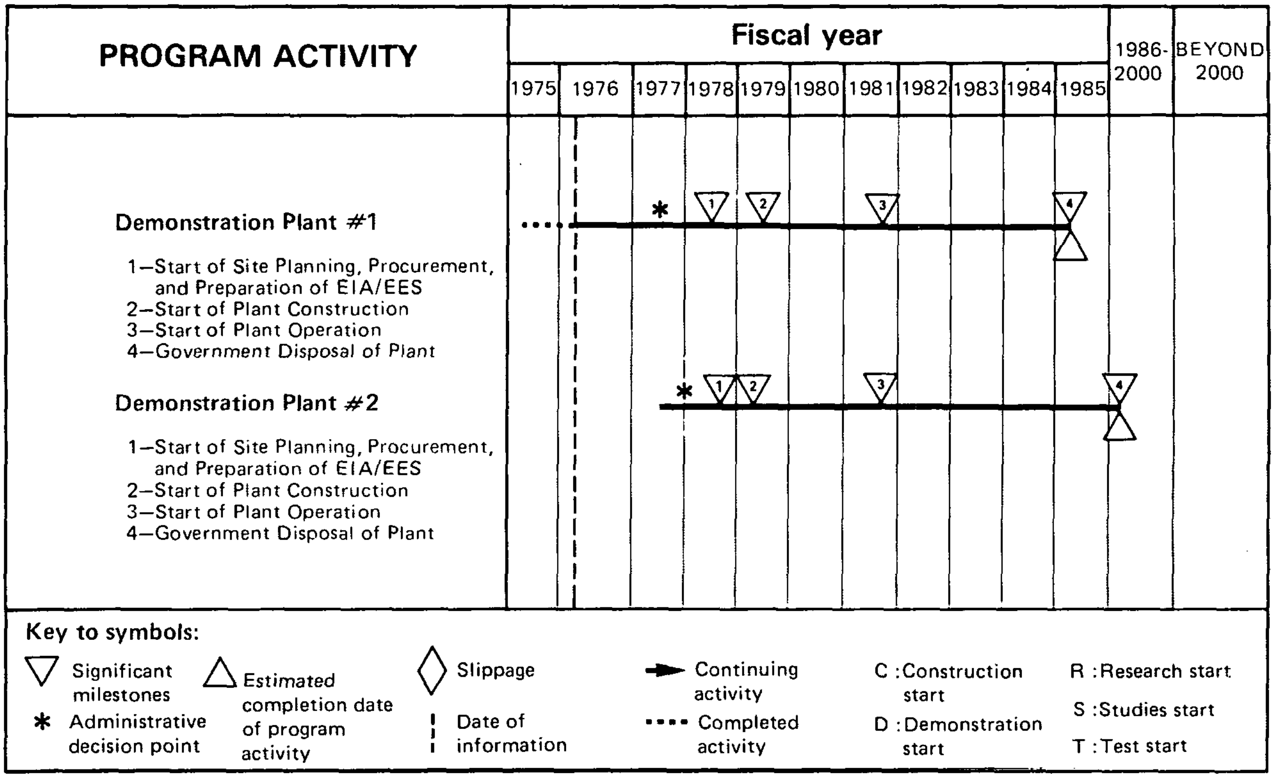
If these plants are operational in the early 1980's, they could contribute significantly to meeting the 1985 objectives for geothermal energy utilization.

Financial Data

Studies and projects leading to actual demonstration plants are not funded under this category.

ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION

DEMONSTRATION PROJECTS



GEOTHERMAL ENERGY

Advanced Technology Applications

Objectives

Near-Term:
(–1985)

- Assist industry in developing advanced technologies for the exploitation of geopressured and hot dry rock resources.

Mid-Term:
(–2000)

- Sustain activities in developing advanced technologies to assist industry in the exploitation of geopressured and hot dry rock resources.
- Assist industry in developing and applying advanced technologies to the exploitation of normal gradient, radiogenic, and other potential resources.

Strategy

The technological and economic uncertainties of utilizing geopressured, hot dry rock, normal gradient and other resource types at present preclude any major exploitation effort by the private sector. Private sector interest may be increased in these resources by direct involvement in a broad based, federally assisted program to resolve the existing problems, eventually leading to jointly-funded efforts and full commercialization. Initially the major focus will be on geopressured and hot dry rock resources.

Technological Status and Problems

Status:

- Geopressured resource: A three-dimensional computer model for identifying size, shape and location of promising onshore geopressured aquifers with the aid of available types of geological and geophysical input data is under development; a mathematical model is being developed to aid in devising production management practices for geopressured reservoirs; and planning studies outlining tasks that must be accomplished to develop a viable industry are in progress.
- Hot dry rock: At a Jemez Mountain site in New Mexico, two adjacent holes have been drilled by the Los Alamos Scientific Laboratory (LASL) in granitic rock to a depth of 9600 feet. A bottom-hole temperature of 197°C has been measured, and hydraulic fracture of the rock up to 700 feet in equivalent radius has been produced. Evidence exists for interconnection of the two holes through the fracture system, but this evidence has not yet been fully verified.
- Normal gradient and non-associated radiogenic resources: Preliminary work on these resouces has been limited to geologic investigation of near-surface conditions in some areas of the Eastern U.S. Data from the on-going development effort in France are also being evaluated.

Problems:

- Geopressured resources: Not enough is known about the major geologic, hydrodynamic and reservoir life-time characteristics of these resources and about the possibilities of efficient recovery of energy from the hydraulic pressure and thermal energy content of the brines. Well sanding problems at high flow rates may be severe.
- Hot dry rock resources: There are major uncertainties about the resource characteristics; the extraction and utilization of the energy content requires technology development.
- Normal gradient resources: The two major problems are (1) the high cost of drilling deep holes, and (2) difficulty in extracting and utilizing relatively low-temperature geothermal water. The nature and distribution of radio-

genic heat sources are not adequately understood.

Institutional Status and Problems

See the Environmental Control and Institutional Studies building block, and, in addition, note:

Problems:

- Definition of hazards and liabilities of large-scale reservoir fracturing of hot dry rock.
- Ambiguities in application of regulatory authority to the methane produced as a by-product of geopressured resource development.

Environmental Status and Problems

See the Environmental Control and Institutional Studies building block and, in addition, note:

Problems:

- Disposal of geopressured waters.
- Potential problems of the seismic effects of hydrofracturing of hot dry rock.
- Severity of land subsidence over geopressured resources, which may be more serious than for hydrothermal reservoirs.
- Definition of environmental impacts of large-scale reservoir fracturing of hot dry rock.

Program Implementation

Energy Research and Development Administration
Geopressured Resources:

- Continuation of geologic modeling and mapping and of reservoir modeling and mapping in the Gulf states.
- Regional surveys of the resource.
- Testing of existing wells.
- Exploratory drilling at representative sites.
- Construction and operation of test and pilot facilities as appropriate.

Hot Dry Rock:

- Resource assessment and characterization will be undertaken to explore the different types of hot dry rock resources in order to prove exploration criteria and techniques and to establish the magnitude and essential characteristics of hot dry rock resources.
- Energy extraction technologies will be developed for economical and environmentally acceptable recovery of heat from the different types of hot dry rock resources.
- Development, verification and demonstration of economical systems for the utilization of the resource will be accomplished.
- Industrial utilization of the resource will be encouraged by developing industrial capability in hot dry rock techniques.

Normal Gradient Resources:

- A group of studies is planned to define the factors affecting the use of the deep, low-temperature geothermal resources typical of the Central and Eastern states. These studies would be completed during 1978–1979. If these studies indicate that these applications are promising, then feasibility experiments would be initiated.
- Near normal gradient development would draw heavily upon the drilling, well stimulation, and utilization technology developed as a part of the hydrothermal and hot rock developments.

ADVANCED TECHNOLOGY APPLICATIONS

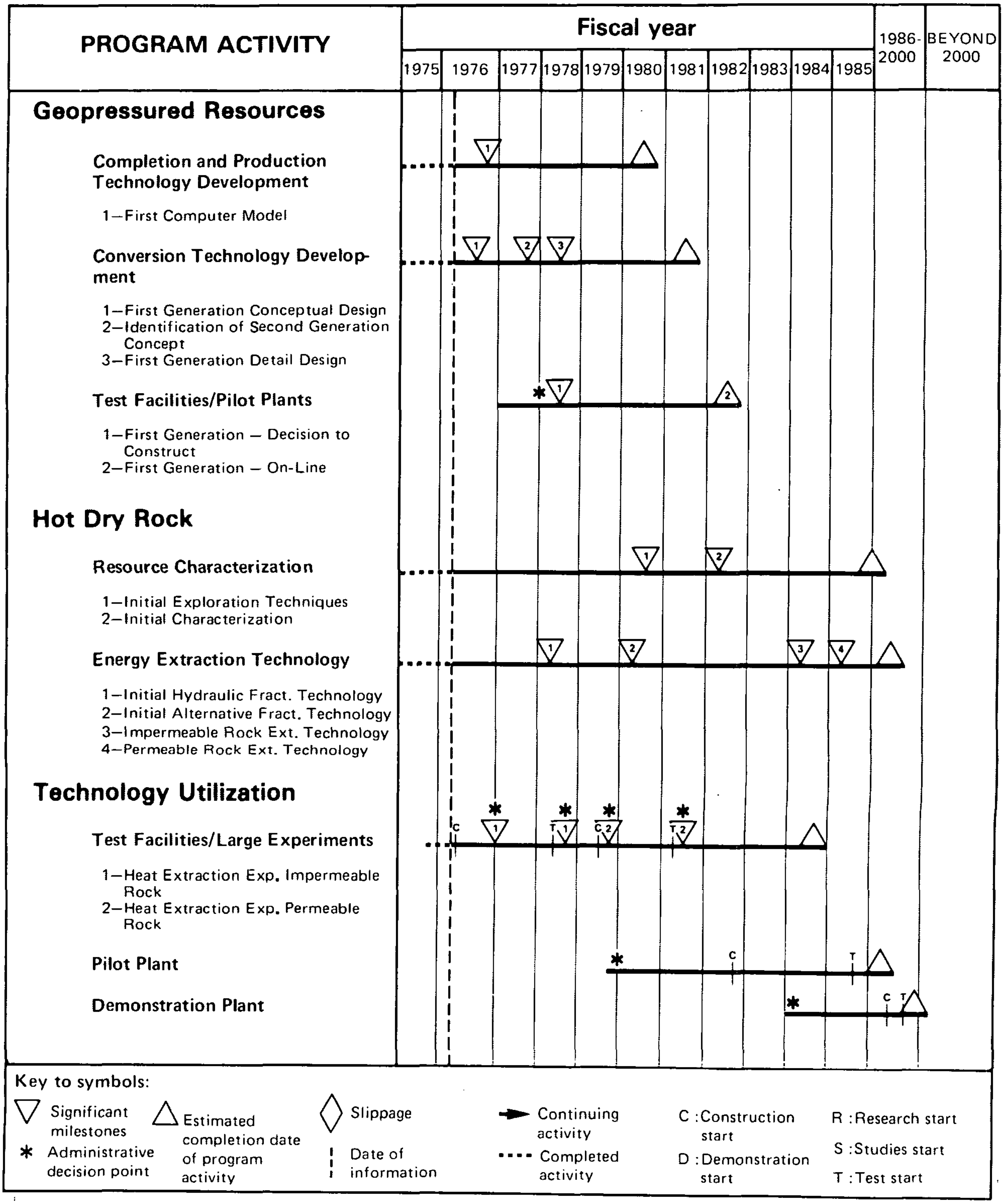
Federal Energy RD&D Budget **($ Millions)**

Agency	FY 1975		FY 1976*		FY 1977	
	BA	BO	BA	BO	BA	BO
ERDA						
Operating Expenses	4.4	5.5	6.9	4.4	10.1	8.2
Plant and Capital Equipment	0.4	0.3	0.2	0.2	0.5	0.3
Total	4.8	5.8	7.1	4.6	10.6	8.5

* Does not include funds for FY 1976 Transition Quarter.

ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION

ADVANCED TECHNOLOGY APPLICATIONS



GEOTHERMAL ENERGY

Engineering Research and Development

Objectives

Near-Term:
(–1985)

- Improve the efficiency and reduce the cost of drilling into and extracting fluids from geothermal reservoirs at temperatures up to 350°C.
- Improve the efficiency of conversion of hydrothermal energy into electrical energy, and reduce the cost through advances in low-temperature heat exchangers, pumps and prime movers.
- Identify and develop materials that can withstand the severe corrosive and erosive effects of some geothermal brines.
- Identify techniques to prevent and control scale build-up and erosion in geothermal systems.
- Develop and demonstrate techniques for hydrothermal well stimulation.
- Develop techniques for high efficiency conversion of geopressured resources and recovery of dissolved natural gases.

Mid-Term:
(–2000)

- Develop and demonstrate advanced drilling techniques for very hot, hard rock and for magma up to 1200°C.
- Continue development of high efficiency conversion devices using low cost materials.
- Continue development of materials needed to withstand the corrosive attack of geothermal brines.
- Develop materials, equipment and techniques to exploit geothermal reservoirs up to 1200°C.
- Demonstrate new methods to prevent and control scale buildup.
- Identify and demonstrate economic processes to extract and recover valuable mineral salts and metals from hot water geothermal resources.
- Develop techniques for generating usable heat exchange surface areas in hot dry rock formations.

Strategy

Government-funded contracts (including cost-sharing) will be used to increase industry involvement in the development process. Also, provide the means for, and strongly support, the rapid transfer to industry of the technological developments related to geothermal energy extraction and utilization that are taking place in the National Laboratories and within the academic community. Government support of research and development in the areas of drilling and utilization technologies will be emphasized.

Technological Status and Problems

Status:

- U.S. experience in geothermal electric power generation has been limited to dry steam conversion techniques at The Geysers.
- Some development programs begun prior to FY 76 have progressed to the stage where prototype hardware is becoming available for testing.

Problems:

- Drilling and well completion methods, which rely predominantly on existing petroleum industry technologies, are slow and very costly in the formations and at the high temperatures encountered in geothermal drillings.
- Performance of down-hole equipment, such as pumps and drill bits, is not adequate to exploit deep high-temperature geothermal resources.
- Existing well stimulation technology, based on oil industry methods and needed for low-permeability reservoirs, is of limited value in geothermal wells.

- Existing extraction and conversion processes cause geothermal brines to release dissolved solids that can form scale on the well casing and surface conversion equipment. Scale buildup restricts fluid flow and may be rapid enough to require removal within a period of a few weeks to a few months.
- Performance of low-temperature heat exchangers, operating over low temperature differences in the presence of corrosive and scale-depositing fluids, is not adequate to insure long lifetimes at reasonable costs.
- Present steam turbine design is very inefficient for use with the mixed phase (liquid and vapor) geothermal fluids that are obtained from hydrothermal reservoirs.
- Techniques for selecting optimum thermodynamic power cycles for economic energy conversion are not adequate.
- Binary plant working fluids capable of low-cost high-efficiency utilization for time varying wellhead conditions are not presently available.

Environmental Status and Problems

Status:

See the Environmental Control and Institutional Studies building block and, in addition, note:

- Most of the few electric and nonelectric geothermal installations in the U.S. were designed and built prior to the establishment of U.S. environmental standards. Without modification, many would not meet current standards to the extent that these are applicable.
- Liquid-dominated commercial generating plants operating outside the U.S. were not designed to be compatible with and do not meet U.S. environmental standards and may offer only limited technology transfer opportunities.
- Environmental control activities are being actively pursued in various federal agencies and private industries.

Problems:

- Equipment or methods for both new and retrofit use, that are both functional and economical, and that will comply with environmental standards have not been developed.

Program Implementation

Energy Research and Development Administration

Drilling Technologies:

Drilling technology development programs will be continued with field tests of some prototype hardware scheduled to begin in FY 77. The first commercial availability of these technologies is anticipated by FY 81.

Utilization Technology:

Development of conversion systems using the total flow (mixed phase) concept will continue with testing of a helical screw expander scheduled to start in FY 76. Laboratory verification of the impulse turbine concept is scheduled for FY 77.

Heat-exchanger development aimed at improving the efficiency of geothermal energy utilization will also continue. A pilot model of the fluidized bed concept is to be evaluated in FY 77 and evaluation of a pilot model of the direct contact concept is scheduled for late FY 77. Direct-contact heat exchangers promising significant cost reduction will also be evaluated during FY 77.

Tests on ferrous materials being conducted under the scaling and corrosion studies are to be completed late in FY 78. Tests on alternative materials will continue after the ferrous materials tests are complete.

First commercial availability of the down-hole pumps being developed for geothermal applications is anticipated in FY 78.

Stimulation techniques developed for geothermal reservoirs are expected to be available for commercial application by the end of FY 79 for moderate to high temperatures; and later for high temperatures.

Thermodynamic and economic analyses of total flow, hybrid and binary power plant concepts will be carried out concurrently for suitable ranges of wellhead temperatures, flow rates and chemical compositions.

Alternative or new concepts in each of the areas can be anticipated. They will be evaluated and appropriate research and development efforts implemented to insure that the basis for a commercially viable technology will be developed.

Bureau of Mines

The development of alternative materials having improved resistance to scaling and corrosion in the brines found at the East Mesa and Niland areas is continuing.

A cooperative agreement with industry is being sought to build a pilot plant for the recovery of valuable salts and metals from geothermal brines. Studies of the use of spent brine for metallurgical and chemical processing operations is scheduled to begin in FY 77, with a process development unit expected in FY 78.

Spent brine disposal studies are anticipated to lead to a process development unit in FY 79.

National Science Foundation

Theoretical analyses and laboratory experiments will be conducted concerning processes such as stress corrosion cracking, crevice corrosion, pitting, and uniform corrosion as part of NSF-sponsored basic research on physical chemistry and kinetics of reactions.

ENGINEERING RESEARCH AND DEVELOPMENT

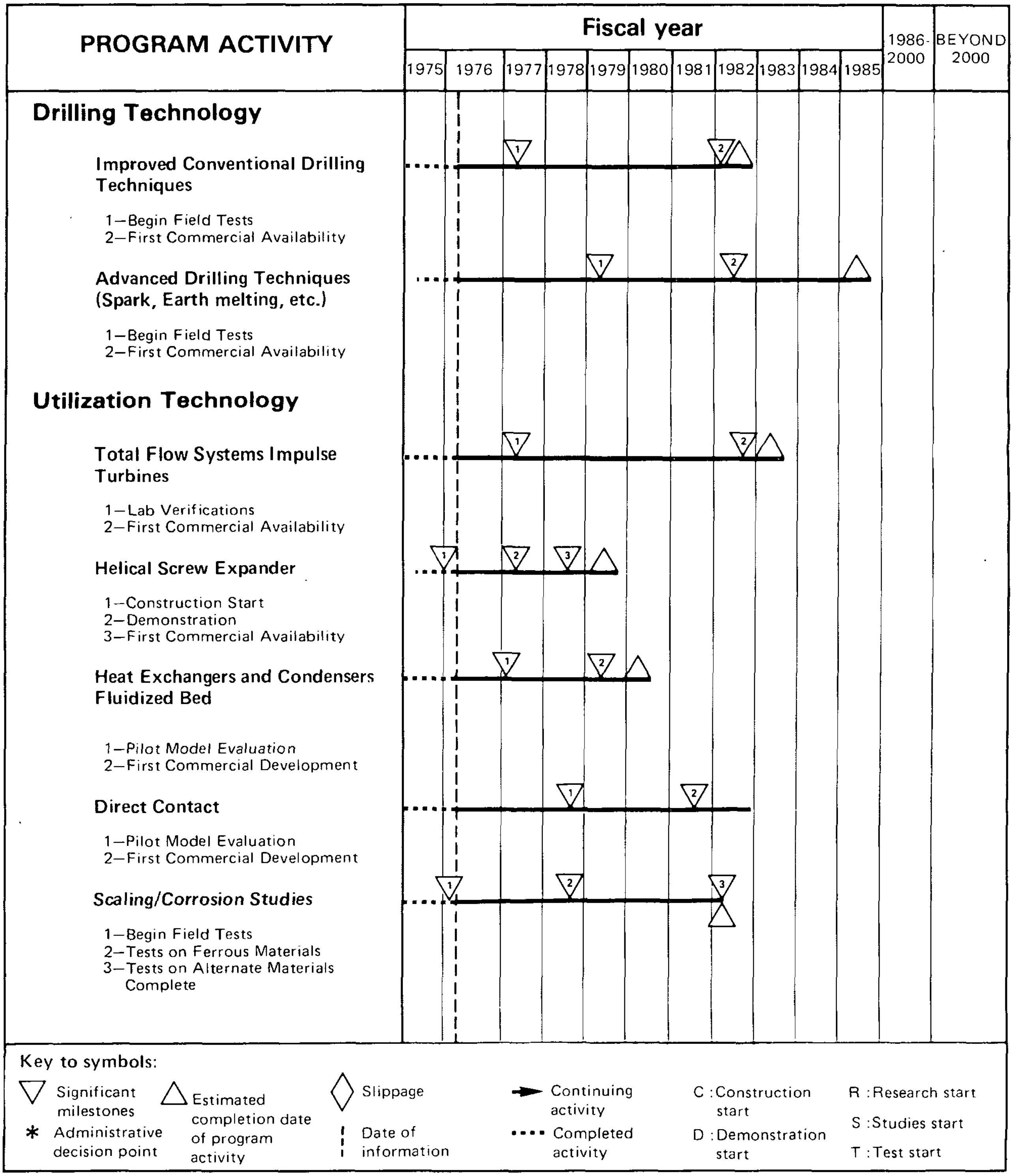
Federal Energy RD&D Budget ***($ Millions)***

Agency	FY 1975		FY 1976*		FY 1977	
	BA	BO	BA	BO	BA	BO
ERDA						
Operating Expenses	13.0	6.0	10.6	9.3	11.5	11.5
Plant and Capital Equipment	0.3	0.2	0.2	0.2	0.2	0.2
Total	13.3	6.2	10.8	9.5	11.7	11.7
DOI (Bureau of Mines)	.5	.5	.5	.5	.5	.5
Total	13.8	6.7	11.3	10.0	12.2	12.2

* Does not include funds for FY 1976 Transition Quarter.

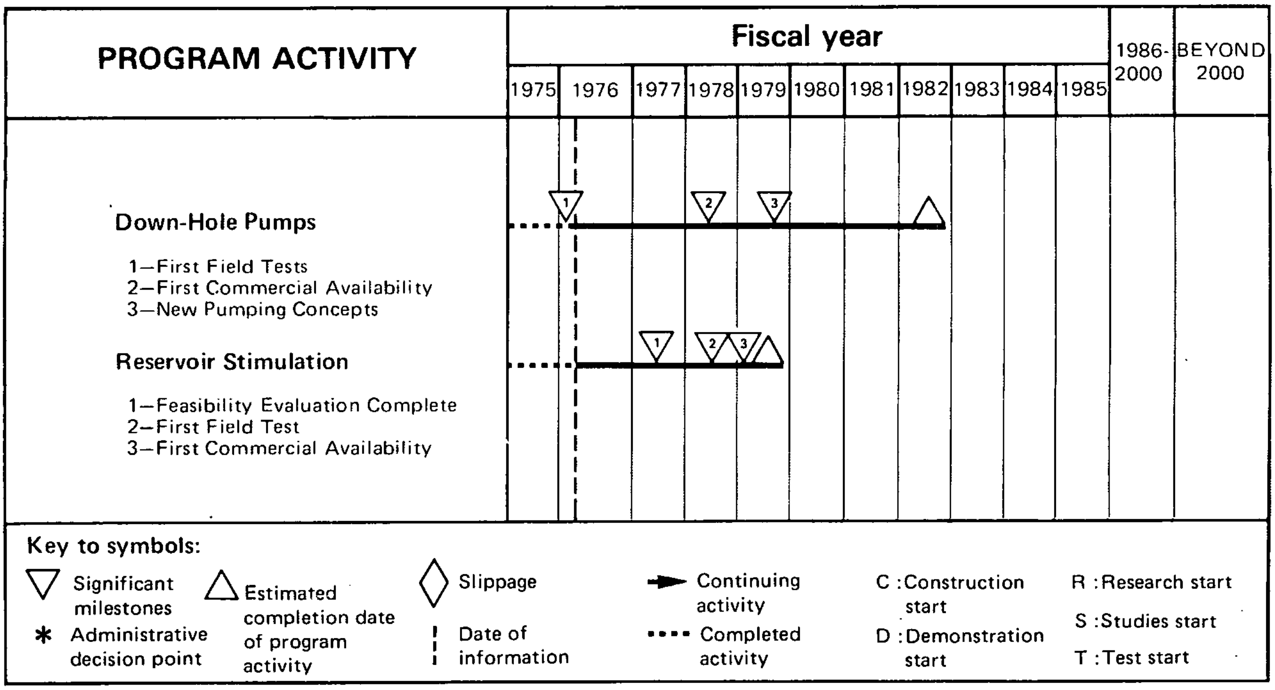
ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION

ENGINEERING RESEARCH AND DEVELOPMENT



ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION

ENGINEERING RESEARCH AND DEVELOPMENT (continued)



GEOTHERMAL ENERGY

Geothermal Resources Development Fund

Objectives

Near-Term:
(–1985)

- To encourage and assist the private sector to develop geothermal resources by reducing the lenders' financial risks, thereby enhancing the ability of developers to obtain capital.
- To foster the development of normal borrower/lender relationships and encourage the flow of credit from the private sector into geothermal enterprises.

Strategy

To reduce the reluctance of the financial community to make capital available for geothermal developments as sound and profitable business ventures. When the financial community gains experience and confidence in its ability to assess risks in geothermal development, normal borrower/lender relationships are expected to develop.

Institutional Status and Problems

Status:

- ERDA, acting in consultation with Treasury, is authorized to enter into commitments to guaranty lenders against the loss of principal or interest on loans made to qualified borrowers within certain specified terms and limits contained in Title II of Public Law 93–410.
- Inquiries received to date have been mostly for The Geysers area and indicate that most applications would be for the purpose of developing resources for production, and for the drilling of test wells to test reservoir potential.
- Implementing regulations are nearing completion. ERDA published the proposed regulations in the *Federal Register* in October 1975, allowing the public the opportunity to submit written comments within 45 days of publication. In December, final coordination of the regulations was begun, taking into account the public comments received.

Problems:

- Criteria for guarantying loans must be determined which will result in the best program leverage.
- At present, ERDA has no appropriated funds or borrowing authority with which to pay liabilities arising under the program. Lenders may be reluctant to grant loans if repayment in the event of default must await action on future appropriations.

Environmental Status and Problems

Status:

- The environmental analysis supporting the Federal Leasing Program contains a programmatic statement and assessment of environmental implications at three known geothermal resources areas.

Program Implementation

Final regulations will be established in FY 1976. At that time, the Geothermal Loan Guaranty Program will become operational, allowing lenders to begin the filing process.

With program start-up in the second half of FY 76, no defaults are assumed during this period, since projects will have just been recently initiated. Accordingly, FY 76 appropriations were not requested for the Geothermal Resources Development Fund. ERDA is proposing to ask Congress for a legislative amendment, granting borrowing authority as the most appropriate means of obtaining the funds required for prompt payment of program obligations as they may arise. Pending implementation of this proposal, an appropriation for the Fund is being requested for FY 77, based upon the experience of the Small Business Administration.

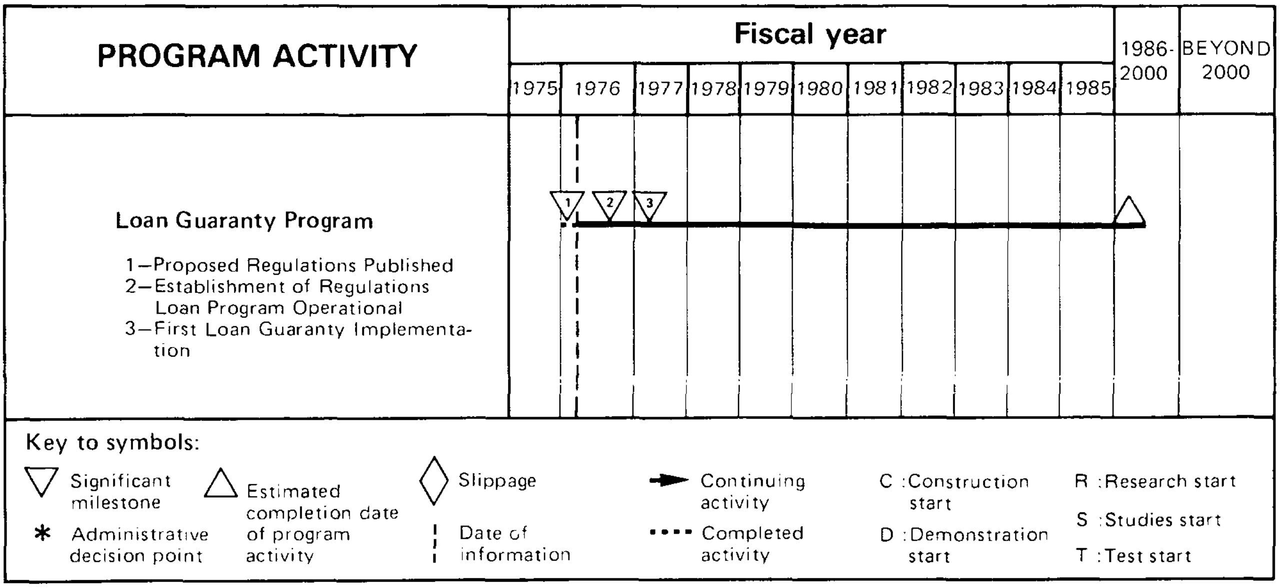
GEOTHERMAL RESOURCES DEVELOPMENT FUND

Federal Energy RD&D Budget **($ Millions)**

Agency	FY 1975 BA	FY 1975 BO	FY 1976[1] BA	FY 1976[1] BO	FY 1977 BA	FY 1977 BO
ERDA						
Operating Expenses	0	0	0	0	0	4.4
Plant and Capital Equipment	0	0	0	0	0	0
Total	0	0	0	0	0	4.4

ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION

GEOTHERMAL RESOURCES DEVELOPMENT FUND



CONSERVATION EXECUTIVE SUMMARY

The conservation programs of the federal government embrace a number of activities with the common aim of accelerating the process within the private sector by which energy use will become more efficient. This includes programs whose purpose is to speed the introduction of equipment—such as appliances, automobiles, and industrial processes—which use less energy. It includes programs to allow the public to make more informed judgments regarding their purchases and their use of energy. It also includes programs aimed at stimulating efficient energy use through such means as incentives, regulations and loans.

These broad federal programs are supported by RD&D and commercialization activities. One is concerned with the technologies by which basic processes—such as heating, cooling, transportation, food processing, electrical distribution—can be carried out with less energy. The other is concerned with the process by which new technologies come into use. This includes efforts aimed at understanding and improving the rationale by which government, industry, and the private citizen make choices that determine the way in which energy is put to use.

This summary of energy conservation RD&D may be grouped approximately into the following systems and end-use areas:

Electrical Energy Systems is directed at accelerating and complementing private sector research to ensure that technological capability will be available and in place to meet future demands on the Nation's electric energy system, with particular emphasis on satisfying needs in an efficient and reliable manner. Activities include development of overhead and underground bulk power transmission, automated distribution systems, improved load management, and methods for design and control of large-scale, more-intensely interconnected power systems. Impetus for the research is two-fold: (1) the energy savings potential of more efficient systems, and (2) the critical nature of a reliable electric energy system designed to aid the implementation of advanced energy supply and improved end use technologies.

Energy Storage Systems is directed at the reduction of fuel consumption by residential and commercial buildings, industry, utilities, and transportation. The storage activities involve batteries, hydrogen and superconducting electro-magnetic storage, flywheels, underground compressed air and underground pumped-hydro storage, and finally, thermal storage for both heating, air conditioning, and industrial processing and utility use.

Industry Conservation is directed toward assisting industry to develop economically competitive technologies to reduce industrial and agricultural energy consumption. This is being executed by evaluation of the processes and the equipment and technologies used, and by further evaluation of selected energy-intensive industrial processes to determine targets of opportunity for energy conservation.

Buildings Conservation is directed at encouraging private sector efforts in the development of energy-saving technologies for more efficient energy use in buildings, community systems and consumer products. The activity includes development of retrofit equipment for existing structures as well as new equipment for new structures, products, and communities. Part of this program consists of waste systems and utilization activities dedicated to the recovery of fuels, recyclable materials, and energy from urban and industrial waste.

Transportation Energy Conservation is focused on reducing the end-use consumption of energy in the Transportation Sector. Approaches being considered include: developing new energy efficient conversion systems and energy storage systems; formulating improved operational procedures; and encouraging use of proven as well as new technologies and methods in the air, water, rail, highway and pipeline transport modes. Initially, emphasis will be on reducing petroleum consumption and preparing the transportation system for efficient use of nonpetroleum energy sources. Later emphasis will be on reducing total end-use energy consumption, regardless of the energy source.

Energy Conversion is concerned with research and development to improve efficiency of existing and advanced energy conversion systems. These include waste heat utilization, low-grade heat with bottoming cycles and high-grade heat with topping cycles. Efficiency improvements of components such as heat-exchangers, compressors, pumps, motors and generators are studied, along with supporting technologies in materials, combustion, and fuel cell R&D. Rankine cycle, Brayton cycle, Stirling cycle, and extra high-temperature conversion machines are also of primary interest.

CONSERVATION

Federal Energy RD&D Budget

($ Millions)

Building Block	FY 1975		FY 1976*		FY 1977	
	BA	BO	BA	BO	BA	BO
Electrical Energy Systems	20.3	7.4	24.9	20.8	25.4	21.1
Energy Storage Systems	7.4	5.8	16.3	13.8	22.3	18.5
Industry Conservation	0	0	4.2	2.0	12.4	9.7
Buildings Conservation	2.4	0	12.5	8.2	21.6	18.4
Transportation Energy Conservation	8.1	8.4	12.9	10.4	23.7	20.4
Energy Conversion	2.4	0.6	9.5	7.4	15.8	4.8
Total	40.6	22.2	80.3	62.6	121.2	92.9

* Does not include funds for FY 1976 Transition Quarter.

CONSERVATION

Electric Energy Systems and Energy Storage

ELECTRICAL ENERGY SYSTEMS

Objectives

Near-Term:
(–1985)

- Develop and demonstrate higher capacity overhead and underground transmission systems characterized by high-efficiency, reliability, and reduced environmental impact.
- Demonstrate reliability and commercial viability of state-of-the-art energy storage and conversion technologies.
- Develop automatic controls and integral storage for improved load management.
- Establish the data base for evaluating intensification of electric energy systems interconnection.
- Demonstrate distribution systems technology capable of reducing losses by 20 percent.

Mid-Term:
(–2000)

- Encourage and support implementation of systems and methods capable of significant reductions in power and capital equipment requirements in the transmission and distribution, conversion and storage of energy, as well as reduction in peaking generation requirements through improvements in load management and integration of storage.

National Energy Technology Goals Supported

Primary

- Increase the efficiency and reliability of the processes used in energy conversion and delivery systems.

Secondary

- Transform consumption patterns to improve energy use.

Strategy

Electric power systems currently incur significant energy losses. Growing demands for electric energy pose serious problems of system reliability and environmental intrusion.

The national strategy is, therefore, to assess current technologies and practices, forecast the needs of more complex future power systems, evaluate present efforts to satisfy these identified needs, and complement and motivate industry research to insure that technological gaps are filled. The strategy includes the following units of activity:

- Systems Management and Structuring—Develop improved network planning theory and control methodology for managing and increasing the efficiency of the complex systems of the future.
- Electric Power Transmission—Ensure availability of new technology for increasing the efficiency and environmental acceptability of overhead and underground transmission.
- Electric Energy Systems Implementation—Test full-scale transmission, storage and conversion concepts on operational utility grids, for validation of reliability and economics prior to commercial application.

Federal Role

The federal government, through the Electric Energy Systems program, can encourage industry research in electric power systems. The federal role is to assure an orientation toward energy conservation, with adequate emphasis on total system reliability, conservation of scarce materials, objective determination and evaluation of environmental impact, public health and safety, and to assure that the power systems of the future will be capable of meeting the forecasted loads.

This program addresses an essential element of the total energy system. New nuclear, fossil, solar and advanced energy production systems, such as MHD and fusion, have varying characteristics and require different control and incorporation strategies before they can be integrated effectively into the complex national network of interconnected power systems. Energy parks are feasible only if environmentally acceptable, reliable and efficient bulk power transmission options are available for delivery of the power to the consumer. Further, due to the vastness of the electric power network and its steady expansion, even modest energy loss reductions and improved load management offer great potential energy and economic savings. As base load coal and nuclear generation, together with energy storage plants, gradually replace oil- and gas-fired generation to meet increased electricity demand (including possibly large electric transportation and heating requirements), the reliability and efficiency of the transmission and distribution system become even more crucial.

International Cooperation

Since 1973, the United States and the Soviet Union have carried on a program of cooperation in superconducting power transmission R&D, originally under the 1972 Science and Technology Agreement, and now under the 1974 Energy Agreement. The United States has agreed to furnish the USSR in 1977, on a loan basis, a large cryogenic refrigerator for use in joint experiments. The USSR will furnish the U.S in 1979, also on a loan basis, a superconducting cable for testing in this country.

Load management is another area being explored for technology exchange. Discussions with the European community through the NATO Committee on Challenges to Modern Society are scheduled to begin in early 1976.

Technological Status and Problems

Status:

- Underground transmission research is underway with a number of high-capacity system designs in the final stages of laboratory investigation and preparation for prototype tests.
- Research on increased capacity overhead transmission systems, both ac and dc, and on enclosed gas insulated substations has been initiated. Requirements for electric field effects research have been defined and activity in both the federal and private sectors is being accelerated.
- ERDA has led a critical survey of the technological state of theory and methods of systems structuring and control. A comprehensive national program is being defined and implemented to address the need for more sophisticated techniques to deal with the more complex power systems of the future.

Problems:

- If currently available equipment is used for electric system growth, energy losses will be large and the number of circuits (in terms of rights-of-way, materials requirements, cost and environmental intrusiveness) may be prohibitive.
- Existing systems design and operational methods are inadequate to meet the requirements of future, more complex systems, especially for regional and national bulk power networks.
- Traditional equipment designs may not be suitable for future systems considering expected demands.

Institutional Status and Problems

Status:

- Generated power is dispatched from approximately 140 separate control areas, within corporate or state boundaries.
- Increased interconnection between utility systems requires the support of regulatory commissions and cooperation of individual utilities.
- Interchange transactions are inhibited by lack of direct dealings, except between adjacent utilities or control areas, and by uncertainties as to resulting power flows, transmission losses and charges for intervening transmission facilities.

Problems:

- Major cut-backs in plant construction have resulted from last year's reduced load growth and the financial plight of the industry.
- There is a shortage of funds to support the high-risk and high-cost demonstration projects needed to promote the introduction of improved, more conservative technologies.
- Public acceptability of customer load control will affect any broad-scale application.
- The electric field effects of higher voltage overhead transmission systems are not adequately understood. This is already delaying construc-

tion of new lines, and could cause even greater difficulty in the construction of future, even higher voltage lines.

Environmental Status and Problems

Status:

- Present environmental concerns are primarily with overhead transmission facilities. Environmental effects are largely unknown, resulting in obstacles to the addition of 765 kV lines.

Problems:

- There may be unfavorable biological effects from the electric fields or the corona noise of high voltage lines.
- On a line-for-line basis, 1200 kV lines will require more right-of-way, although, on a capacity basis, they still are the more desirable alternative.

Program Implementation

Energy Research and Development Administration

The ERDA program is coordinated with related research sponsored by the Electric Power Research Institute (EPRI) to ensure that there is no duplication and that the total effort is complementary. Some large projects are being jointly funded with EPRI.

A number of federal agencies support ERDA in its management of the national program. The National Bureau of Standards is developing for ERDA, on standardized measurements of high electric fields, psychoacoustic response to power line noise, definition of cryogenic fluid flow characteristics, evaluation of test procedures for ascertaining flammability of transformer oils, and instrumentation for investigation of ground-current corrosion. Other federal agencies, including EPA, are concerned with the environmental effects of electric fields under high voltage lines; ERDA chairs an inter-agency committee chartered to ensure timely dissemination of information and no duplication of research.

The ERDA implementation activities include: systems analysis and integration; fundamental research on materials breakdown; systems theory; and demonstration of promising technologies on operating utility systems. These are organized into the following three principal areas with their outputs in the same order as described in the milestone chart.

Systems Management and Structuring:

- Coordinated Normal Control—aims at developing a second-generation technology of automatic generation control, to be implemented on a utility system by 1980. It includes several parallel efforts in security assessment and enhancement; it also includes research into load prediction, which is needed for efficient and economic utility system operation. Results will form a basis for a third level of coordinated operating control, hierarchical optimal dispatch.
- Emergency State Controls—is directed toward conceptualization of emergency controls, design of emergency detection methods and development of improved methods of relay coordination.
- New Technologies Integration into Utility Systems—addresses effective load management and overall system efficiency, stability and reliability. Extensive modelling, analyses and simulation are planned.
- Large Scale Systems Theory—aims at developing new techniques for mathematical modelling, systems decomposition and aggregation, hierarchical structuring, and connective stability which will be the cornerstone for design of large multicontrolled power systems.

Electric Power Transmission:

- AC Overhead Line and Compressed Gas Insulated Substation and Underground Cable—comprises research concentrated on the use of more efficient and economic higher voltages. Satisfactory achievement of 1200 kV transmission will require optimization of equipment characteristics, a new technology for compacting lines and substations, as well as resolution of environmental effects. Compressed Gas-Insulated Cables are presently, and look to be for the future, the only underground transmission candidates that can match overhead transmission in both voltage and power capability. They also exhibit a characteristic low reactive power loss.
- DC Overhead and Underground Transmission Lines—addresses dc transmission as an attractive alternative to ac transmission, particularly for bulk power transport. The effort includes work on ac/dc conversion equipment, circuit breakers, and integration of the dc and ac systems.

- Cryogenic Transmission Cables—involves investigating low temperature systems, particularly superconducting systems, which offer promise of very high power transfer capabilities and extremely high efficiency. Development work is continuing on both rigid and flexible ac superconducting line designs and on a dc superconducting line design. Fundamental research on conductors, insulation and refrigeration is included.
- Optimization of Overhead Transmission Lines—addresses ways to minimize environmental impact, a problem which grows increasingly important as voltages increase. This activity is aimed first at determination of biological and physiological effects of high voltage electric fields, including all aspects of an environmental nature, culminating in design criteria for higher voltage systems.

Demonstrations:

- Test of Advanced Storage Batteries, Converter Equipment and Controls—a battery energy storage test facility will be constructed to test alternative advanced battery designs in an operational environment prior to commercialization. This joint ERDA-EPRI test bed will provide validation of reliability, and essential designs for power conditioning and controls.
- Demonstration of Fuel Cells Power Plant—some assistance is also planned for joint-funding with EPRI. A number of utilities have already placed orders for fuel cell plants contingent on successful completion of the demonstration.

Federal Energy Administration

The FEA is presently engaged in demonstrating electric utility use of time-differentiated rate structures through cooperative agreements with state and local governing bodies and utilities. Attention has been directed to residential, commercial, and industrial rate structures. The different rates under study include time-of-day, interruptible, and flattened energy charge. Quarterly progress reports are prepared for each rate demonstration to ensure minimum delay in the transfer of useful information. As sufficient information is secured and positive benefits have been ascertained, new rate schedules for appropriate customer class will be advocated.

Department of the Interior

The Bonneville Power Administration is designing and constructing prototype 1100 kV electrical test lines. These will be used to investigate environmental and mechanical performance factors, and to test the performance of insulators and hardware. Construction and maintenance techniques will also be developed. Testing will start in early 1977. These test lines and the station will be used by ERDA for prototype testing of equipment and quantification of actual levels of corona noise and electric fields.

ELECTRICAL ENERGY SYSTEMS

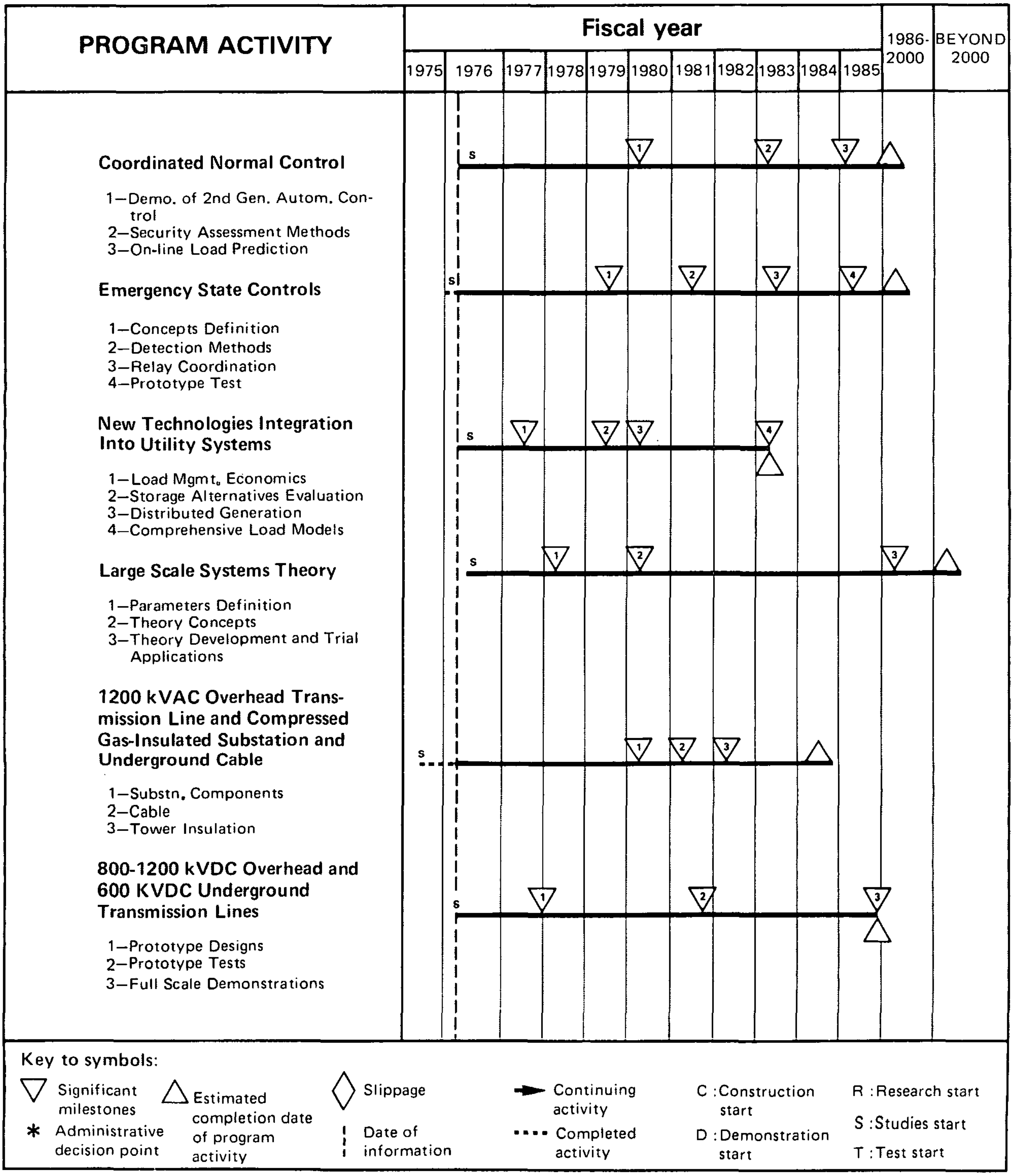
Federal Energy RD&D Budget **($ Millions)**

Agency	FY 1975		FY 1976*		FY 1977	
	BA	BO	BA	BO	BA	BO
ERDA						
Operating Expenses	15.9	6.0	17.9	12.6	21.0	17.9
Plant and Capital Equipment	0.4	0.2	1.7	1.5	3.5	1.5
Total	16.3	6.2	19.6	14.1	24.5	19.4
DOI	4.0	1.2	5.3	6.7	.9	1.7
Total	20.3	7.4	24.9	20.8	25.4	21.1

* Does not include funds for FY 1976 Transition Quarter.

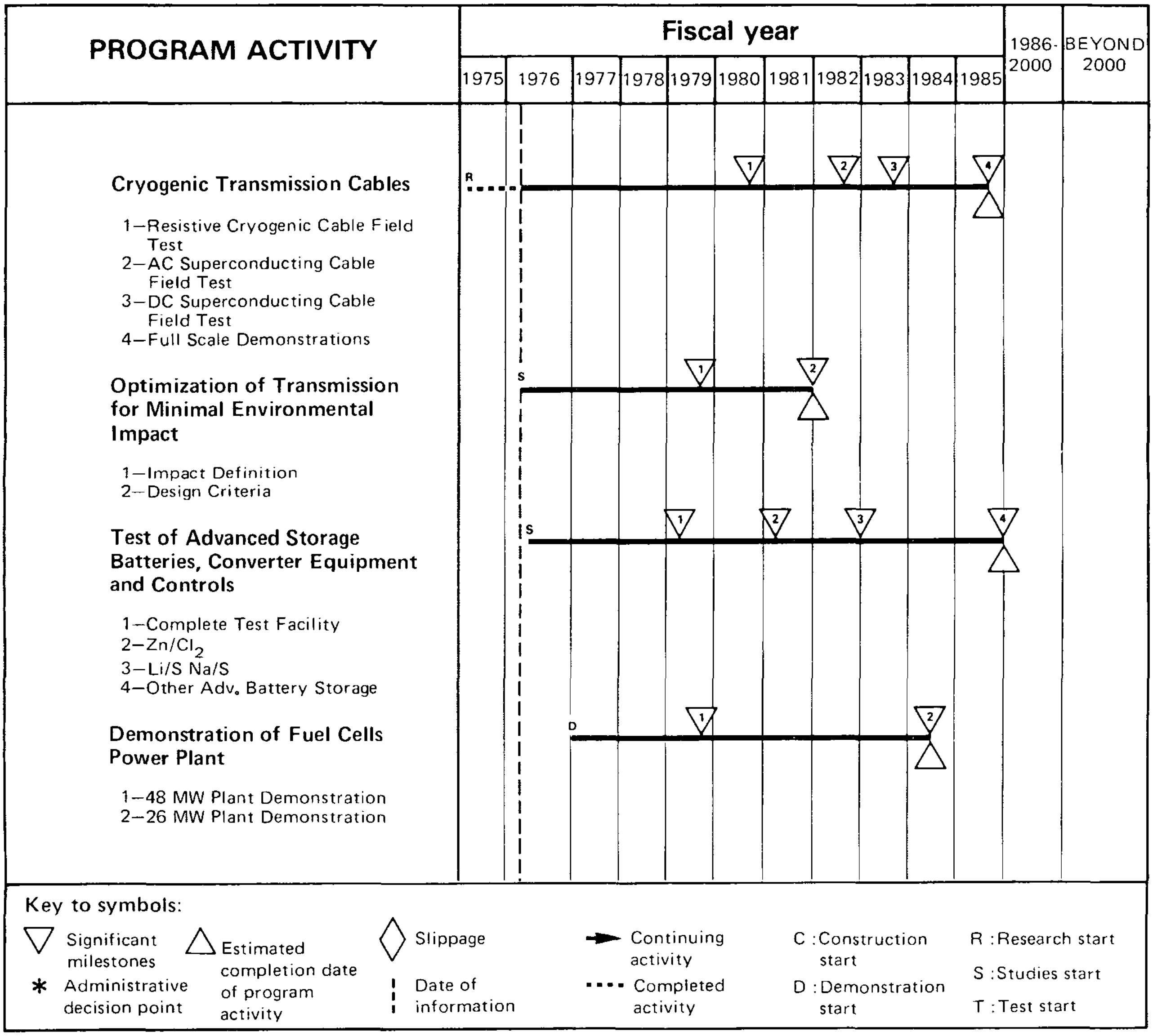
ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION

ELECTRIC ENERGY SYSTEMS



ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION

ELECTRIC ENERGY SYSTEMS (Continued)



CONSERVATION

Electric Energy Systems and Energy Storage

ENERGY STORAGE SYSTEMS

Objectives

Near-Term:
(–1985)

- Develop improvements in the battery, thermal, flywheel, compressed air, pumped hydroelectric and superconducting magnetic energy storage technologies.
- Formulate and prove the concepts for improved energy storage systems for use in vehicle propulsion, electric utility peak power, industrial waste heat recovery, space and water heating and cooling, and in solar energy systems.
- Provide support for the implementation of energy storage systems in the end-use areas.

Mid-Term:
(–2000)

- Develop and demonstrate hydrogen production, storage, transmission and utilization systems to test the feasibility of using hydrogen as a substitute for petroleum and natural gas.
- Develop chemical storage systems to facilitate the use of solar and nuclear heat.

National Energy Technology Goals Supported

Primary

- Increase the efficiency and reliability of the processes used in energy conversion and delivery systems.

Secondary

- Transform consumption patterns to improve energy use.
- Increase end-use efficiency.

Strategy

Energy Storage options will be developed to more fully utilize energy sources whose availability does not coincide with periodic demand of energy: (1) providing a key element of the technology for the electric automobile and for electric power peaking; (2) facilitating use of solar energy; and (3) providing efficient transport of thermal energy through chemical storage. The strategy is to: (1) conduct systems studies to identify technologies and applications with potential for the greatest impact on the energy economy; (2) conduct laboratory and industrial programs using industry and government laboratories to validate assumptions of the systems studies, to advance the technologies, and to narrow the range of candidates; (3) develop operating equipment and provide guidance for changes to laws, regulations and codes. Key decisions as to which strategy best fits which application will be made during 1977–1980.

Federal Role

Federal participation will be oriented toward speeding up the rate of development of energy storage technologies to realize the energy-saving potential these developments make possible. The principal federal role is to support high-risk R&D to increase private sector participation and thus accelerate technological developments.

International Cooperation

There will be international exchange of data for all energy storage systems. Plans to implement the U.S./Japan Bilaterial Energy R&D Agreement in the area of battery developments are being defined in discussions that began in December 1975.

Three International Energy Agency Agreements on research and development are being implemented: one on hydrogen production by electrolysis of water; one on hydrogen production by thermochemical methods; and one on thermal energy storage for residential and utility applications.

Technological Status and Problems

Technological status and problems of the energy storage program vary with the ultimate use for which the technology is being developed. Therefore, they are described below in four main application areas: utilities, transportation, intermittent energy sources, and buildings and industry.

Utility Applications

Status:

- Studies now suggest that hydrogen enrichment of natural gas electrolysis using off-peak electrical power is a near-term possibility.
- Design of a 100MJ model to demonstrate superconducting magnetic energy storage has been completed and construction started.
- The advanced battery program now includes five key technologies: zinc/bromine; zinc/chlorine; sodium/sulfur, lithium/sulfur and redox systems.
- Laboratory work on an advanced no-oil concept for underground energy storage has been initiated; the conceptual design for storing compressed air in water-bearing rock has been completed.
- Contracts have been initiated to define the retrofit opportunities for introducing thermal energy storage, and underground heat storage prototypes for utilities are under investigation.

Problems:

- Developmental work is required to increase the lifetime and decrease the cost of storage batteries.
- Structural limits and interference with groundwater inhibit application of pumped storage using natural or man-made geological reservoirs.
- Cost reductions and improved efficiency are needed to make storage technologies competitive.

Transportation Applications

Status:

- Lithium/sulfur battery cells have been developed that are approaching the lifetime goals established for automotive application.
- Assessment of a "heat battery" for Stirling engine applications has begun.
- Flywheel hardware development for automobiles is underway.

Problems:

- All current storage technologies for vehicle propulsion have a high weight-to-output ratio and lack the necessary range for many applications.
- Currently, widespread commercialization of these systems is inhibited by the high cost.

Intermittent Energy Sources Applications

Status:

- Thermochemical and electrolytic hydrogen production may be particularly applicable to solar as well as nuclear energy installations. Economic and technical studies of hydrogen production have been initiated.
- Technology studies on storing solar thermal process heat are continuing; work has begun on phase change storage materials for solar heating.

Problems:

- Capital costs of storage systems used in conjunction with solar energy need to be lowered.
- Catalytic reforming of carbon monoxide plus hydrogen to produce methane must be optimized for the closed loop chemical heat pipe, which will be used to store and transport solar energy.

Buildings and Industry Applications

Status:

- Developments leading to improvements in furnace cycle design by incorporating thermal storage have been initiated.
- Programs to achieve significant energy savings by using storage in several energy intensive electrochemical processing industries have been identified and are now underway.
- An experimental program for the massive storage of low-grade waste heat for subsequent reuse in community heating or other total energy systems has been initiated.

Problems:

- Technologies and designs suitable for energy storage in space conditioning and other domestic applications are required. These must consider differing seasonal conditions.
- To be commercialized, storage technologies must meet industry requirements in terms of

rates-of-return and payout periods. In many instances, cost and efficiency improvements must be made.

- Identification and development of cost-effective recovery systems employing chemical, electrochemical, and thermal energy storage in industrial processes is necessary.

Institutional Status and Problems

Status:

- Some states and localities are trying modifications to regulatory structures that should provide financial incentives for the use of energy storage.

Problems:

- The application of energy storage in electric power generating systems has been inhibited by conflicting or overlapping requirements for land use.
- Introduction of stored energy vehicles may require establishing special facilities for service and maintenance. Modification of local permit and labor practices may be needed.
- Time-of-day pricing and other rate structure policies changes are needed to increase the use of storage systems in buildings and industrial applications.
- Industrial applications of energy storage may be discouraged by labor practices and restrictions since in some cases, stored heat crosses trade union jurisdiction boundaries.
- Economic incentives for installing energy storage devices are lacking.

Environmental Status and Problems

Status:

- The environmental effects of conservation of energy through the use of energy storage are in the early stages of investigation. However, many energy storage developments are expected to affect the environment favorably rather than unfavorably.
- A model of an aquifer system is being developed that will permit appraisal of the environmental impact of the underground storage of heated water.

Problems:

- Constraints on land use may limit the application of storage techniques that utilize natural or man-made geological reservoirs.
- In some locations, safety considerations may constrain the use of toxic- or high-temperature heat storage materials such as molten salts, and of large superconducting magnetic storage devices.
- Flywheel systems may have associated noise and safety problems.
- Batteries involving high temperatures and alkali metals may present environmental hazards.

Program Implementation

Energy Research and Development Administration

A sequence of energy storage development activities is underway that includes technical and economic feasibility studies, additional research where indicated, concept development, design of pilot models, and demonstrations of the concepts. These are described in the paragraphs below and the corresponding milestone charts.

Energy Storage in Electric Power Generating Systems—To meet the diverse requirements of the various electric utilities, a number of technologies including batteries, flywheels, compressed air, underground pumped-hydro, chemical and superconducting magnetic energy storage are being developed. Those most effective from the standpoint of oil conservation, cost-effectiveness, and environmental acceptability will be chosen for continued development and demonstration. Specific activities include:

- Short-term developments for electric utility load leveling: compressed air storage, batteries, underground pumped-hydroelectric and thermal energy storage retrofit system.
- A chemical storage (hydrides) prototype may be completed by FY 1978.
- Installation of the first commercial load leveling advanced battery system. This may be accomplished by FY 1982.
- Continued development of superconducting magnetic energy storage. Limited prototype demonstration is scheduled for 1980.

Energy Storage in Transportation—There are three main thrusts to the energy storage program for transportation; batteries, flywheels, and thermal storage devices.

- The most promising batteries for transportation applications are the high-temperature systems, lithium/metal sulfide and sodium/sulfur. The lithium/metal sulfide battery demonstration may occur as early as FY 1979. Since commercial introduction of these batteries for electric autos may be as much as 10 years away, other candidates (nickel/zinc, nickel/iron, zinc/air, and iron/air) are also being investigated in the search for a battery for an acceptable near-term vehicle.

- ERDA's flywheel development began with a feasibility study in 1975. Research and development in technical areas such as rotor configuration, materials, and bearings will be conducted in 1976 and 1977. Three systems are being explored for further development: the boosting/braking systems, the primary propulsion system, and the heat engine/flywheel hybrid.
- Application of thermal storage to transportation is a longer-range program. Studies in FY 1977 and a decision to continue or abandon the development will be made in 1978.

Energy Storage in Buildings—Four developments are being pursued: (1) demonstration of improved utilization efficiency with thermal energy storage, (2) demonstration of advanced thermal technology for seasonal heat storage, (3) development and demonstration of flywheel energy storage for buildings, and (4) development and demonstration of thermal energy storage for solar heating/cooling of buildings. Specific tasks include:

- A study of the feasibility of using thermal storage to improve utilization efficiency of heating plants. Started in FY 1975, the research continues in FY 1976. Plans for a possible demonstration are currently being developed.
- A program leading to the development of a flywheel energy storage technology for buildings began in FY 1975. A program continuation decision is scheduled for 1978.
- A feasibility study of flywheel energy storage technology for seasonal heat storage. A decision on the continuation of this program is planned for FY 1977.
- Economic incentives for installing thermal storage on the customer's side of the meter to provide electric load leveling are being studied. Development of several forms of thermal energy storage for use in solar heating and cooling of buildings is being conducted in FY 1976. Some of the more promising could be demonstrated in 1980.

Energy Storage in Industry—Near-term thermal, chemical and flywheel developments are being pursued as follows:

- Study of thermal energy storage for recovery and use of waste process heat began in 1975. A technology demonstration is planned for FY 1980. A related program pursues development and demonstration of thermal energy storage for solar-generated process heat. Studies and research now underway lead to a program continuation decision in FY 1978. Demonstration of the technology is planned for 1982.
- Studies of the use of flywheels to store energy for standby purposes began in 1975. A program continuation decision is scheduled for FY 1978.
- A planned program to develop and demonstrate thermal energy storage for application to autonomous energy systems will begin in 1977. The program continuation is scheduled for 1978 and the technology demonstration for 1982.

Other Federal Agencies

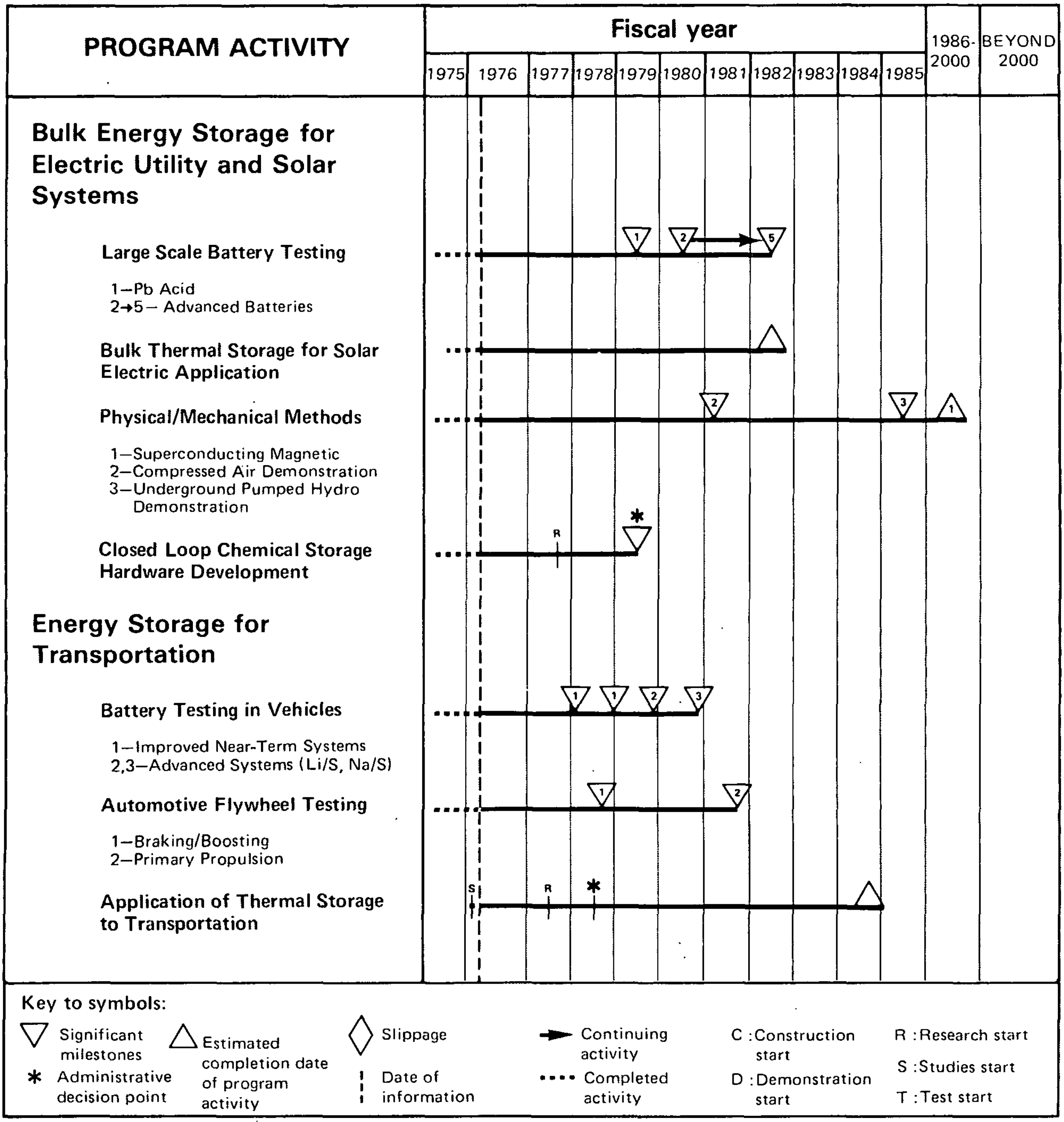
Other government agencies sponsoring energy storage research and development include: the Departments of Transportation, and Defense (Army, Navy), and the U.S. Postal Service sponsoring R&D in flywheels; and the National Science Foundation sponsoring basic research in compressed air storage. TVA's program involves review and assessment of technology developments applicable to electrical power systems, but no experimental research.

ERDA and NASA are cooperating in the development of redox batteries and thermal storage for utilities. The U.S. Geological Survey and ERDA are jointly conducting a program to implement seasonal storage of heat in underground aquifer systems. The Bureau of Reclamation and ERDA are cooperating on the development of underground pumped storage. ERDA, the Navy, and industry are cooperating in a program to improve lead acid batteries.

The National Academy of Sciences is studying the potential of advanced energy storage systems. The Electric Power Research Institute has joined ERDA and other government agencies in sponsoring several storage development activities that have promise for electric utility applications. The programs sponsored by other agencies are being coordinated with ERDA to assure the maximum transfer of technology.

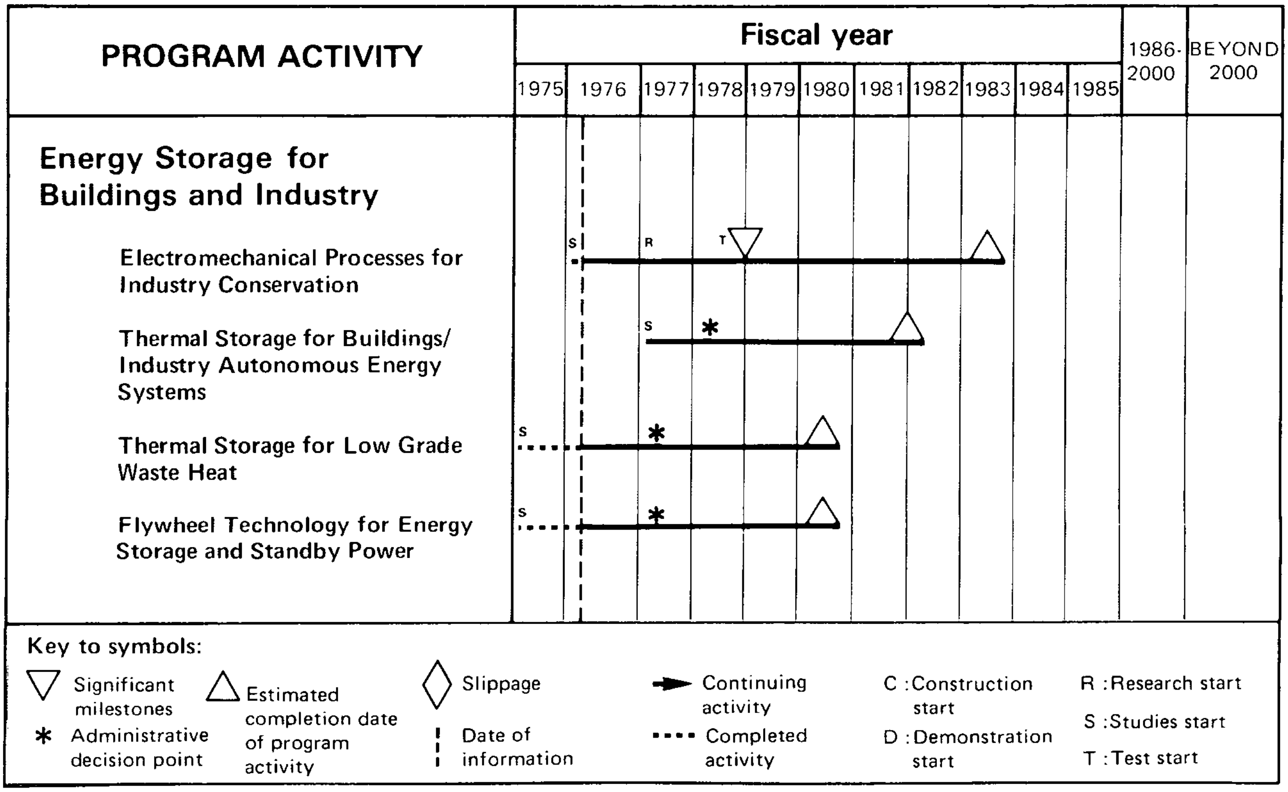
ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION

ENERGY STORAGE SYSTEMS



ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION

ENERGY STORAGE SYSTEMS (Continued)



ENERGY STORAGE SYSTEMS

Federal Energy RD&D Budget **($ Millions)**

Agency	FY 1975 BA	FY 1975 BO	FY 1976* BA	FY 1976* BO	FY 1977 BA	FY 1977 BO
ERDA						
Operating Expenses	7.2	5.6	15.6	13.2	20.8	17.9
Plant and Capital Equipment	0.2	0.2	0.7	0.6	1.5	0.6
Total	7.4	5.8	16.3	13.8	22.3	18.5

* Does not include funds for FY 1976 Transitions Quarter.

CONSERVATION

Technologies to Improve Efficiency and End-Use Conservation

INDUSTRY CONSERVATION

Objectives

Near-Term:
(–1985)

- Develop economically viable technologies for reducing energy consumption in industry and agriculture.

Mid-Term:
(–2000)

- Accelerate industrial initiatives and promote the acceptance of new technologies.
- Establish national technical leadership to guide the development and implementation of economically viable techniques for improving the efficiency of industrial processes.

National Energy Technology Goals Supported

Primary:

- Increase end-use efficiency.

Secondary:

- Transform consumption patterns to improve energy use.
- Perform basic and supporting research and technical services related to energy.

Strategy

The general approach to reducing energy consumption in the industrial sector through federal efforts involves system analysis of processes, unit operations and technologies to determine major energy losses and hence "targets of opportunity" for energy conservation. The most promising technologies will be established and verified through laboratory-scale experiments and/or pilot plant experiments. Simultaneously, detailed assessments of the impacts (including environmental, economic and social) associated with the introduction of the selected technologies will be conducted. The results of the experimental efforts and impact analyses will determine the acceptability of the energy conserving concept in the industrial sector. At early points in the program the various approaches for introducing the technology into the market will be evaluated and those most applicable to the technology or concept involved will be pursued.

The federal government will conduct those RD&D programs for which the expected benefits would spread widely, but which the private sector would normally not pursue on its own because of economic, regulatory or other reasons.

The federal program will focus on two areas: (1) increasing the efficiency of commonly employed unit processes used in a broad spectrum of industrial processes, such as crushing, grinding, heat exchange, evaporation, drying, and distillation; and (2) improving the efficiency of highly energy-intensive processes in such industries as primary metals (steel, aluminum, copper), petroleum refining, petrochemical, cement, glass, pulp and paper, and food processing.

Evaluations will be conducted to determine feasibility and the likely cost of improving each process and bringing the improvements into common use.

Federal Role

Industry development and implementation of energy-saving technologies and operating methods will be encouraged by the following federal participation:

- Fund the development of basic technologies that are promising, but not close to commercialization.

- Encourage technical information exchange within and across industries.
- Support materials and process R&D which reduces the total energy required to provide final products.
- Establish voluntary targets of conservation for the ten most energy intensive industries (FEA's statutory function).
- Develop voluntary energy efficiency targets for process equipment.
- Develop legislative and other incentives for the implementation of industrial energy conservation technologies, where required.

International Cooperation

Various professional staff members of the federal R&D community have held, and will continue to hold, key leadership positions in well recognized international organizations such as the International Energy Agency (IEA), the Organization for Economic Cooperation and Development (OECD) and the NATO Committee for the Challenges of a Modern Society (CCMS). In addition, various bilateral relationships, such as the U.S./Japan Energy R&D Agreement, are being developed.

Examples of specific international project areas within CCMS are: data collection and possible demonstration of energy efficiency in industrial processes (cement and steel); utility load management (dual use of energy and off-peak power); energy conservation incentives; and barriers and methods for ensuring technology transfer.

IEA Implementing Agreements are in process for the areas of thermal characteristics of buildings, heat pumps, thermal storage and heat transfer/heat-exchangers. Future efforts include heat cascading, combined cycles, transportation and utility systems.

Technological Status and Problems

Status:

The possibility of fuel allocation and a national gas cutoff has generated concern about fuel substitutions and energy conservation. Additional improvements in efficiency are possible. For example:

- Fifty percent of the energy consumed in industry is rejected as waste heat.

Problems:

- Technological developments, in many instances, are required for improved efficiency in new industrial processes.
- Developments may be required to efficiently and economically recover rejected energy from existing processes.
- Technology to reduce the energy consumption in the agricultural sector relative to the net output of food, fiber and forest products.
- Substitutes for petroleum and natural gas in some of their uses are not available.

Institutional Status and Problems

Status:

- Industrial processes and equipments for production of products and commodities have evolved over many years and are well established; capital equipment investment approaches 725 billion dollars.
- Sophisticated techniques exist for evaluating the relative merit of new or modified processes and equipments; despite potential benefits, many projects will be rejected on the basis of risk and capital requirements.
- In many industries, energy costs are generally a small portion of total product cost. Emphasis is generally not placed on impaired energy utilization.

Problems:

- Large investments in existing facilities will defer the date that new or modified energy-efficient processes would be initiated.
- Availability of capital is limited and new demands are being made to satisfy present regulations in the areas of environment, health and safety.
- Interests of organized labor may significantly impact adoption of energy conservation technology if changes affect existing job structure.
- Local regulations, e.g., capital inventory taxes, may inhibit changes to industrial facilities.

Environmental Status and Problems

Status:

- Recent federal and local residual and air quality standards have caused serious constraints on industry.
- Resource availability often limits siting and expansion of industrial facilities.

Problems:

- Conformance to environmental regulations competes for available capital.

- The conflicting interests between environmental and energy constraints must be balanced.
- Switching to alternative fuels such as coal may cause negative effects on the environment.

Program Implementation

Department of Agriculture

The Department of Agriculture gives priority to the maintenance of crop and forest yields and livestock output with consideration for technology modifications which are more energy efficient.

The spectrum of studies supported range from basic research focusing on development of new technologies, to applied research which may incorporate energy aspects into existing technologies in production, processing, marketing, distribution and utilization of food, fiber and forest products. The program continues through the commercialization stage by close interaction with the Cooperative Extension Service for extending energy conservation information to participants throughout the system. Conservation guidebooks and field days are used for this purpose.

Initial emphasis has been on the production phase, with resources distributed as follows: production, 61%; processing, 27%; marketing and distribution, 9% and utilization, 3%. From FY 1979 to 2000, research emphasis will be oriented to the processing and marketing areas as the potential for energy conservation appears greater in these areas.

Department of Commerce

Provides management and engineering information to assist industry in implementing energy conservation programs. Management and Engineering Guidebooks have been published and are planned in Energy Conservation Management and Waste Heat Engineering. Reports and technical papers have been and will be published, and demonstrations will be made relating to improved measurement technology for industrial processes.

Industry studies are being undertaken to identify and qualify the energy requirements resulting from environmental controls for the various unit processes in the respective industries. Data will be developed on existing and projected pre-plant, and post-plant consumption of energy for attainment of existing state and federal air and water pollution control requirements, and alternative control options which would consume less energy while remaining consistent with the need to protect public health in the case of air pollution under the Clear Air Act and best practicable technology for water pollution as defined in P.L. 92–500.

Energy Research and Development Administration

The ERDA program in energy conservation is a relatively new government activity. Other government agencies, and indeed the industries themselves, have been concerned with and have conducted energy conservation projects for several years. Thus, a body of knowledge has already been accumulated which permits ERDA to enter into the overall plan at different stages for different industrial processes.

ERDA's role will be to lead and coordinate the federal program for RD&D on new technologies for conserving energy in industry.

The industry conservation effort is comprised of the following five activities:

1. Unit Operations and Equipment Efficiency

This activity is directed at detailed examination and evaluation of unit operations and associated equipment and technologies which may have broad application to a spectrum of industrial processes. Examples include:

- *Fuel Combustion:* The average industrial furnace achieves an efficiency of converting the energy content of the fuel to steam of about 70 percent. Direct heating (as used in glass kilns, cement kilns, soaking pits, reheat furnaces, remelt furnaces, etc.) processes are much less efficient, sometimes as low as 20 percent.
- *Stack Heat-Loss:* Direct heating furnaces consume 56 percent of industrial energy and are about 25 percent efficient. Thus, 8 to 10 quads of thermal energy are discharged up the flue at temperatures ranging between 1400–3000°F. Indirect heating systems (steam boilers, etc.) have stack discharge temperatures ranging between 400–800°F; both systems represent significant energy loss and potential technologies for reducing such losses will be investigated.
- *Product Heat Loss:* Many thermal processes involve a change in the material under treatment creating residual gases, liquids or solids which may have energy content of significant value. Potential technologies for reducing or recovering such losses will be investigated.
- *Basic Process Losses:* Many processes, by the discontinuity in time of sequential process steps,

waste significant energy by reheat requirements. Potential technologies for reducing such losses will be investigated.

2. Process Analysis and Modifications

This activity is directed at detailed examination of energy balances and materials flow in high energy consumption industries and the examination of techniques for optimizing such processes for minimum energy consumption. This program will identify those processes within such industries which offer the most promising opportunities for verifying technical feasibility. Examples include:

- Boiler Efficiency Experiment—Could save up to 10 percent of boiler energy per year. Applicable to small boilers—replaces oil and gas with coal.
- Blended Cement Program—Establish duraability strength characteristics and ASTM standards. Could save up to 30 percent of the input energy in selected applications.
- Paper Fiber Optical Imaging Program—waste paper characteristics by optical imaging. Goal is greater recycling of high grade papers.
- Processes using heat will be investigated for potential modifications of input materials to permit a reduction of heat.

3. Alternative Fuel, Materials and Processes

This activity is directed toward the evaluation of the technical feasibility of using coal or waste matter (either directly or as derived substances) as fuels and to investigate their use as material feedstocks in industrial processes, to investigate means for waste reduction and reuse of recycling of waste materials, and to explore the substitution of biological and catalytic processes for more energy intensive chemical processes. Typical activities include:

- Evaluation of total energy content of selected products.
- Use of pulverized coal in reheat furnaces.
- Use of coal as chemical feedstock.

4. Agriculture and Food Industries

This activity is directed toward improvement of the energy efficiency of planting, tilling, harvesting, and processing; and analyses of the structure of the agricultural industry and associated factors. Research on factors affecting agricultural productivity has been initiated, and studies of energy conservation opportunities in the food processing industry are being sponsored. Examples include:

- Simultaneous application of microwaves and vacuum to grain drying.
- Vacuum blanching of food crops in canning/freezing.
- Complete food/fiber energy system analyses.

5. Industrial Information and Technology Transfer

The objective of this activity is to promote the acceptance of new and existing means to improve the efficiency of industrial energy usage.

The program is designed to disseminate information on energy savings measures to energy consumers through a variety of channels and to promote the commercialization of technologies developed by ERDA and others. Means to accomplish this include direct interfaces with industrial firms and trade associations, working with state or university outreach programs, and by interfacing with other existing federal information transfer programs, e.g., FEA, Department of Commerce, Department of Agriculture, and the National Laboratories. Reliance must be placed on existing information transfer programs whenever possible.

In FY 1976, seminars were held for industrial representatives (e.g., engineers and plant designers) on such topics as unit operations, industrial heating, annealing furnaces, and fuel/air rates control methods. Fact sheets, design manuals, "how to" guidebooks and handbooks on such subjects as "Energy Conservation Manual for Industrial Furnace Operations," "Energy Conservation in the Operation of Evaporators," "Assessment of Industrial Insulating Materials," and "Effects of Alternative Fuels on Refractories," were developed and disseminated. Work also commenced on the development of an industry/government cooperative Energy Conservation Program.

In FY 1977, as research results from FY 1976 become available, it is expected that additional technical manuals, guidebooks and seminars will be developed on topics such as "use of byproduct gas," "dry coke quenching," "computer applications for energy conservation," "combined steam/power generation," and "energy conservation in industrial dryers." In addition, films, research application newsletters, and static and dynamic convention exhibits will be added to the products developed for active dissemination. Also, industrial technology case histories and fact sheets will be prepared as the results of the application of research results become known.

Federal Energy Administration

Industry-By-Industry Initiatives—This program to encourage improving energy efficiency in ten of the most energy-intensive industries is continuing with the following objectives: identifying conservation potentials; identifying and working to remove constraints; evaluating energy usage, determining goals, and encouraging energy saving investments; obtaining data; and identifying and developing energy conservation policy initiatives.

Industry-Specific Initiatives—This is a technology transfer program oriented toward dissemination of appropriate technology information on industrial energy conservation potential, including: a series of case histories; technical studies and capsule reports on the energy use and conservation potential in selected basic industries; seminars on energy conservation in the cement industry; energy conservation guidebooks for the food service industry, retail food stores, and six different areas of agricultural production; and pilot energy audits, followed by seminars, in the meat packing and baking industries.

Process/Equipment-Specific Initiatives—This is a technology transfer program to disseminate appropriate information on energy conservation potential and the associated technologies including, as examples: a boiler efficiency program, including operators' workshops, manuals and study courses; waste oil programs; an update/supplement to the Energy Conservation Program Guide for Industry and Commerce (EPIC); and the analysis of various energy conservation opportunities and strategies regarding industrial equipment.

Company-Specific Initiatives—This is a program with the following two basic efforts: (1) individual contact with selected companies on a voluntary basis to seek individual energy conservation goals, program summaries, support materials such as guidebooks, and the willingness to allow review and follow-up by FEA: and (2) the implementation of a nation-wide energy conservation seminar/workshop program encompassing an integrated four-part series of basic program elements broken into executive conferences; and industrial energy conservation, building energy management, and vanpooling workshops. The principal objective of the executive conferences is to enlist the support and participation of top management, while the aim of the workshops is to present facts and materials to functional managers and technical personnel in order that they may be motivated to organize and implement specific energy conservation measures and programs.

Legislated Initiatives—This is an effort under the EPCA (P.L. 94–163, Section III Part D). FEA, in consultation with DOC and ERDA, is directed to not only continue current programs promoting energy efficiency by American industry, but also to establish voluntary energy efficiency improvement targets for at least the ten most energy consumptive industries utilizing a three-step process.

INDUSTRY CONSERVATION

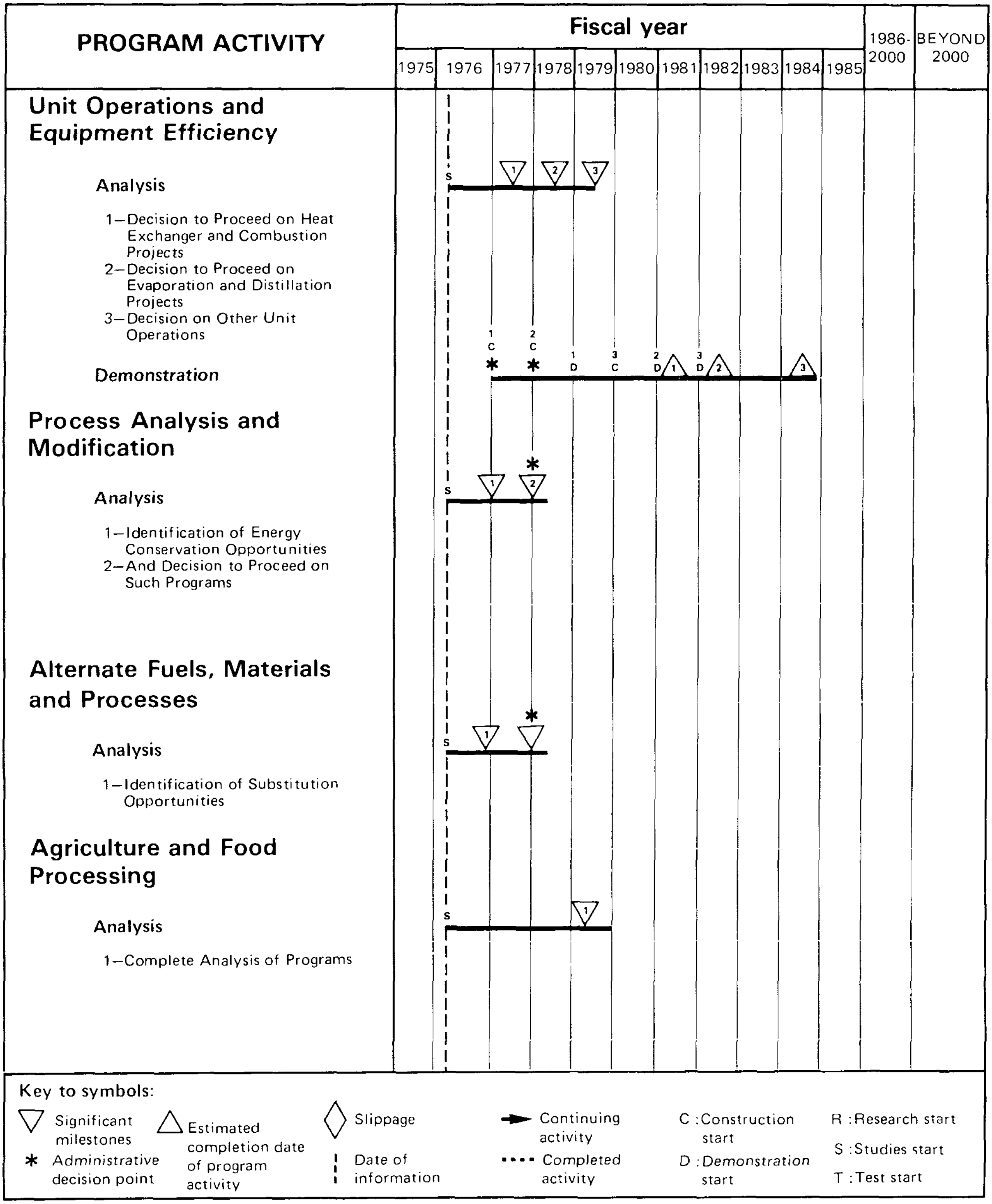
Federal Energy RD&D Budget **($ Millions)**

Agency	FY 1975		FY 1976*		FY 1977	
	BA	BO	BA	BO	BA	BO
ERDA						
Operating Expenses	0	0	4.2	2.0	11.4	9.3
Plant and Capital Equipment	0	0	0	0	1.0	0.4
Total	0	0	4.2	2.0	12.4	9.7

* Does not include funds for FY 1976 Transitions Quarter.

ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION

INDUSTRY CONSERVATION



CONSERVATION

Technologies to Improve Efficiency and End-Use Conservation

BUILDINGS CONSERVATION

Objectives

Near-Term:
(–1985)

- Encourage public and private research, development and demonstration activities that accelerate energy conservation in buildings and community systems.
- Foster acceptance of energy-saving technologies and more effective energy use in buildings, community systems, and consumer products, with minimum socio-economic and/or environmental impacts.
- Encourage the development of more energy efficient appliances and equipment and their introduction to achieve a reduction in energy consumption.

Mid-Term:
(–2000)

- Introduce further new technologies, designs, and operating methods to permit a decrease in the unit consumption of energy in existing and new buildings and community systems.
- Develop conservation technologies to assist in the widespread use of inexhaustible resources, including solar energy, for heating and cooling buildings.

National Energy Technology Goals Supported

Primary

- Increase end-use efficiency.

Secondary

- Transform consumption patterns to improve energy utilization.
- Perform basic and supporting research and technical services related to energy.
- Efficiently transform fuel resources into more desirable forms.
- Protect and enhance the general health, safety, welfare and environment related to energy.

Strategy

The overall national strategy for attaining the program goals will be to:

- Encourage and support the installation of energy-efficient existing technologies as soon as possible.
- Develop new energy-efficient technologies.
- Address institutional barriers to expedite the use of energy-efficient technologies and methods.
- Develop systems which will reduce the dependence on petroleum and natural gas.
- Disseminate information about existing and new technologies concerning efficient energy systems.

Information will be developed for locating opportunities with greatest potential, setting R&D priorities and recommending federal policy actions.

RD&D activities will be undertaken when technologies offer significant energy savings and the private sector appears unable to pursue without federal assistance.

The participation of state and local governments, and private industry in the RD&D and commercialization program will be actively encouraged.

Federal Role

The federal role is to provide leadership to properly consider life-cycle costing; and assist in overcoming the institutional barriers to improved utilization efficiency in the areas of buildings, community-land use planning, on-site total energy, and integrated utility systems, etc. The federal government will provide impetus for undertaking those research, proof-of-concept experiments and evaluation activities, leading to uniform energy performance standards for voluntary and/or mandatory adoption by state and local governments.

International Cooperation

The United States is participating in international forums. Various professional staff members of the federal R&D community have held and will maintain key leadership positions in international organizations such as the International Energy Agency (IEA), the Organization for Economic Cooperation and Development (OECD) and the NATO Committee for Challenges of a Modern Society (CCMS), and the International Center for Buildings (CIB). Additionally, staff members participate in various bilateral relationships such as the U.S./Japan Energy R&D Agreement. A direct result of these international activities has been a coordinated evaluation effort of various technologies which helps avoid U.S. duplication. A specific example is in the Annual Cycle Energy System (ACES) Program, and the direct involvement in the IEA Experts Group on heat pumps, which revealed that a rock/water combination was being evaluated in Austria and a large ice/water systems was being demonstrated in the Federal Republic of Germany. These two efforts are now being coordinated with the U.S. through an IEA Implementing Agreement which maximizes return per research dollar for those participating.

Technological Status and Problems

Status:

- Many federal agencies (e.g., FEA activities under PL 94–163 and the Federal Energy Management Program), state and local governments, etc., are involved in technology development and implementation of energy conserving policies and regulations. ERDA, as lead agency for energy conservation RD&D, will seek to assure that the best technological options are made available on a timely basis. An activity specifically related to the coordination function has been the establishment of the Federal Interagency Task Force on Buildings Energy Conservation R&D chaired by ERDA.
- Performance criteria for new construction, consistent with cost, habitability, health and safety constraints are being developed.
- Combustion, pyrolysis, biconversion, hydrogasification and materials recovery processes and techniques for urban waste exist and are in use in a small number of installations of various size in the U.S.

Problems:

- Energy efficient equipment for space conditioning, lighting, computerized building controls, heat recovery and thermal storage within buildings, both for new and retrofit applications, have only begun to be explored by equipment manufacturers. Technology development for more efficient building system components and building envelopes is in a very early stage.
- More efficient components and subsystems for total energy or integrated utility systems applications and for systems which can utilize fuels other than natural gas and fuel oil are only beginning to be explored by equipment manufacturers. Methods and techniques for load leveling at the community level have not been developed.
- Techniques for performing impact assessments of the technologies being developed are needed. Structually-sound, durable, easy to install new materials which are energy efficient are not in the near-commercialization stage. Reliable, low-cost measurement techniques and equipment are needed to evaluate compliance with standards. Architectural design, building techniques and materials which allow solar heating and cooling to be cost-effective when coupled with energy efficient buildings have not yet been defined.
- The diverse and fragmented nature of the buildings industry makes efficient dissemination of information on conservation opportunities very difficult.
- Economics of urban waste to energy must be assessed and improved through higher efficiency, reliability, maintainability and operational costs.

Institutional Status and Problems

Status:

- The building industry is very dispersed and is inhibited by traditional financing that tends to be based on first cost rather than total cost considerations.

Problems:

- The building owner-operator has been able to pass through increased operating costs to the consumer and thus there has been no incentive to make investments that reduce operating cost.

- Building codes, property taxes, regulations and construction practices in many cases inhibit the use of innovative technologies.
- Labor practices, field construction traditions, etc., may tend to inhibit introduction of new practices.

Environmental Status and Problems

Status:

- Major environmental problems are not foreseen because increased utilization efficiency tends to decrease the environmental impact of energy consumption.
- The environmental effects of conservation of energy through the utilization of urban wastes are currently being investigated.

Problems:

- Indoor air quality may be a potential problem as air infiltration is reduced in the structure to save energy.
- The systems have environmental problems: incinerators have air, aesthetic and potential water and land use effects; and bioconversion has land, water and potential aesthetic effects.
- Potential pollutants are created from the release of chlorides, heavy metals and presently unknown quantities of other hazardous substances in waste streams. Few standards exist.

Program Implementation

Department of Agriculture (DOA)

Research will evaluate new uses of wood building materials as an energy conserving measure. DOA's energy conservation ideas for farmstead buildings are being combined with ideas from other federal agencies and sources, and will be provided to rural residents through the Cooperative Extension Service. Workshops and seminars are being planned. Field days are conducted to demonstrate the research in progress.

Department of Commerce (DOC)

Under voluntary programs, labels for room air conditioners are now in use; labels for industry refrigerators, combination refrigerator-freezers, water heaters, clothes washers and dryers, and television receivers are planned for use starting in 1976; labels for dishwashers, ranges, ovens, central air conditioners and central heating are planned for 1977. The Energy Policy and Conservation Act (PL 94–163) calls for implementation of labelling on a mandatory basis, and Commerce will work with FEA in meeting the objectives.

Manufacturers agreed to participate in an industry energy usage reduction program by July 1975. Final programs for all appliance categories will be published in FY 1976. Program monitoring will be continued through FY 1981. Public Law 94–163 calls for setting energy efficiency targets and DOC will cooperate with FEA in meeting the requirements of the Act.

Department of Defense (DOD)

DOD is investigating new concepts in building methods, including evaluation of new building materials using computer analysis and selected on-site tests. Total energy systems and total energy communities are also being evaluated.

The DOD is developing techniques for energy recovery from waste material processes, not otherwise economically recyclable.

Federal Energy Administration (FEA)

Consumer Products Labeling Program—Under the requirements of the Energy Policy and Conservation Act, FEA is responsible for a program which includes the development of test procedures and the establishment of energy efficiency improvement targets for products covered by the legislation. Under the Act, FEA is also directed to develop a program to educate consumers as to the significance of estimated annual operating costs, to determine how comparative shopping can save energy and money and to identify other ways to save energy in the use of consumer products. The program will be carried out in close coordination with the Federal Trade Commission and with the assistance of NBS.

Buildings Conservation Program Area—Existing Buildings—This program area seeks to reduce energy consumption in existing residential, commercial, institutional and federal buildings. Owners, operators, and occupants of these buildings will be reached with information on a number of energy conservation options which use commercially available technologies.

FY 1976 Activities include:

- Project Conserve—The first phase consists of the distribution of a three-page, computerized conservation questionnaire to single-family homeowners. It provides cost and savings information for individual homes.

- Federal Energy Management Program—This is a continuation of a monitoring of conservation activities in federal buildings and facilities, and development of plan for multi-year retrofit of such buildings.
- Schools—This consists of initial testing of computerized energy forms for school conservation analyses.

Buildings Conservation Program Area—New Building Standards—FEA is encouraging adoption of state and local building codes which reference acceptable energy efficiency standards. FEA, with ERDA participation, will work through national organizations of code officials to provide technical assistance and training. FEA will attempt to obtain commitments to efficiency goals from appropriate jurisdictions.

Implementation will proceed in two broad phases, each involving testing of training methods and commitments from state and local jurisdictions. The first phase will use existing prescriptive standards; the second will use energy performance standards, once they are developed by the federal government. These activities frequently will be joint projects with other federal and state agencies.

FY 1976 activities include:

- Development of training programs for code officials as described above, and initial contacts with state officials to obtain commitments to participate.
- Several activities with the architectural profession, including design competition at architectural schools and the development of training materials for seminars with practicing architects.
- Surveys of current practices in the financial community as they relate to energy conservation, aids assessment of alternative programs.

General Services Administration (GSA)

Reports, studies and guidelines relating to several areas and specialties concerned with the design, construction and operation of federal buildings have been published.

In the area of new construction, design factors which impact energy consumption are receiving major considerations. Areas considered range from energy analysis, life-cycle costing and computerized central control consoles for efficient energy utilization to architectural and construction features such as reduced fenestration, increased wall mass, site orientation and feasibility of solar collector systems. Two GSA Energy Conservation and Environmental Demonstration Federal Buildings will be completed in 1976. Performance data from these highly instrumented buildings will be collected beginning early in FY 1977.

As the forerunner of a future, larger energy conservation retrofit effort, twenty existing federal buildings are presently being analyzed for conservation opportunities. Ten of these buildings are also being studied to determine the feasibility of adding solar collector systems along with improvements in order to make the buildings more energy efficient.

Energy conservation operation policies have been initiated for existing office buildings occupied by all agencies striving for heating, cooling and ventilation adjustments for conservation. Fiscal year 1975 energy consumption was 30% below the base fiscal year 1973 for these buildings.

Department of Health, Education and Welfare (HEW)

The Office of Facilities Engineering and Property Management in the Office of the Secretary is sponsoring five related projects in energy conservation, described as follows:

Integrated Utility System (IUS) Application Project. Two college campuses have been selected as being representative of a community system. The objective of the project is to prepare feasibility studies and conceptual designs for the two campuses showing how fire utility systems within a community (electricity generation, heating and cooling, solid waste incineration, sewage treatment, and potable water management) may be integrated to conserve energy and water and induce the two campuses to install an IUS with their own funds. The goal of the project is to bring about technology transfer and induce other campuses and medical complexes to develop integrated utility systems.

Campus-Community IUS Project (CCIUS). It has been found that many campuses share utility services with surrounding residential, commercial and industrial communities. The CCIUS proposes to select several such sites and prepare feasibility studies for integration of campuses and community utility systems. The studies will demonstrate the mutual advantage in a CCIUS and the gains in energy and other resource conservation to both parties. The purpose is to stimulate the marketing of the concept in the private sector in order to demonstrate that, upon showing the need and the technology, the private sector will respond without government subsidy.

Community Utility/Energy Program Systems (CEUS). This is the logical final step in community systems in HEW. The goal is to bring about decentralized grid-connected coal-based power production. These will be the various campus-community sites throughout the country developed under CCIUS. It is expected that the fully-matured CEUS site will be a community of about 100,000 persons and that enough power will be generated to feed into the grid.

Life-Cycle Budgeting and Costing as an Aid in Decision Making. This project differs from other efforts in that the techniques developed will show how trade-offs can be estimated in three interrelated areas—long-term cost, functional or programmatic effectiveness, and energy consumption.

Energy Performance Standards for Health Facilities. This is a project to develop energy budgets or norms for specific spaces in health facilities. The norms will cover a range of facility types and sizes in various climatic zones and they will be in terms of Btu's per square foot per unit of time. These norms may be used as guides for planners and designers of health facilities.

Department of Housing and Urban Development (HUD)

Construction of a Modular Integrated Utility System (MIUS) will begin in FY 1976 based on state-of-the-art technology. Construction is expected to be completed within two years. Analytic activity will continue to thoroughly document and evaluate the operation of the MIUS, to identify subsystems requiring further development by others, and to provide information necessary for market acceptance as appropriate. Thermal performance standards for new residential and commercial buildings are to be developed according to schedules that will be set in legislation currently pending before Congress. It is anticipated that standards will be completed within three years of enactment.

Energy Research and Development Administration (ERDA)

The Buildings program is directed at assisting the private sector in overcoming the technical and institutional factors which inhibit the implementation of new technologies and practices which could significantly increase energy utilization efficiency in this sector. The basic methodology applied in the Buildings program involves an analysis of the buildings sector to identify priority targets of opportunity. Subsequent target assessment will identify relevant technological limitation, applicable institutional barriers (code constraints, financial obstacles, trade practices, etc.) and establish the basis for research, development and demonstration programs. Evaluation of the results, including consideration of environmental, economic and social impacts, will determine the acceptability of the energy conserving concept in the building sector.

ERDA will coordinate the national program for RD&D on new technologies for conserving energy and improving the utilization of energy in buildings, community systems and consumer products, developing criteria to evaluate and to reduce energy consumption, and identifying institutional and economic barriers. These activities include:

1. Architectural and Engineering Systems

Procedures will be developed and implemented to establish relationships with other federal agencies, state and local governments and the private sector. RD&D activities will be undertaken to identify institutional barriers to innovation and to provide options for overcoming such barriers. Energy use data will be collected and analyzed to assist in determining the implications of implementing new technologies. Projects will be undertaken to assist industry with the development of the new heating and cooling technologies, such as heat pumps for residential and commercial application.

Three specific demonstrations were initiated in FY 1976:

- The Annual Cycle Energy System (ACES) demonstration house, in which the energy required for heating is extracted from water by a heat pump. The cooled water is stored and used during the summer for cooling air conditioning.
- The minimum-energy house in which energy conservation techniques are incorporated into low- to medium-priced housing in a large development to obtain data which can support life-cycle approaches to residential financing.

Specific R&D activities will be initiated which may lead to near-term demonstrations of improved energy management systems. RD&D activities will be undertaken to make available new materials and methods for efficient retrofit of existing buildings, as well as the development of new building forms and subsystems. Financing in this sector is usually based on initial cost of buildings, appliance net total cost (capital plus operating). Development of minimum energy criteria for new buildings will be initiated, which have the potential for significant energy savings by 1985.

2. Community Systems

Procedures will be established to expedite coordination with other federal agencies, state and local governments and the private sector. An initiative will be undertaken to identify and recommend methods to overcome institutional barriers to innovation. Analyses to evaluate innovative financing techniques which will promote energy efficiency will be undertaken. In addition, those demonstrations required to gain acceptance by institutions which impact on the building industry will also be considered. Research, development and proof-of-concept experimentation activities may be undertaken to evaluate the role in community development for integrated utility systems; urban density/energy relationships; zoning and land use patterns and innovative technologies for communities.

3. Technology and Appliances

This activity is designed to identify institutional barriers to innovation in consumer products and to provide options to overcome such barriers. Impact analyses for all programs in consumer products are directed toward the identification and evaluation of technological oppotunities for more efficient utilization of energy in appliances. The program is directed at identifying and evaluating technological opportunities for more efficient utilization of energy in building components, advanced lighting systems, insulating materials, window control sytems, and comfort conditioning equipment. Of particular interest is the joint effort with the natural gas industry to aid in the development of a thermally-activated heat pump.

4. Waste Systems and Utilization

ERDA has a mission to assist in the development of new energy sources, including solid waste. In performing this mission, ERDA establishes priorities for federal development efforts for a wide range of energy technology developments, of which energy recovery from solid waste is one.

ERDA is generally responsible for input and evaluation of the energy research-related portion of projects, and EPA for the input and evaluation of the economic, institutional, administrative, and environmentally-related portions of projects (including solid waste disposal). Formal coordination functions have been established with EPA.

5. Information and Technology Transfer

During FY 1976 brochures, design guides, seminars and case histories, on such topics as ACES, Pasadena TIES Project, and Advanced Technology Mix Energy System (ATMES), were developed and disseminated through various channels. Where appropriate, primary reliance will be placed on utilization of currently operational programs such as: Cooperative Extension Service, state or university outreach programs, and other existing federal information transfer programs, e.g., FEA, HUD, DOC, and the national laboratories.

In FY 1977, as additional research results become available for implementation, technical manuals and guidebooks (on topics such as materials, methods and processes involved in retrofitting commercial buildings, retrofit of family housing units, integrated utility systems, etc.), research newsletters, seminars and workshops, etc., will be used to assist in the dissemination of information.

Environmental Protection Agency (EPA)

EPA has a mission to ameliorate the adverse environmental impacts of solid waste, as well as to recover useful products from solid waste. As such, EPA's interest extends to the collection as well as to the recycling, use and disposal of solid waste and to the characterization and control of pollutants that may arise from solid waste.

It is ERDA's policy to encourage existing programs in other agencies that can help meet federal energy RD&D objectives. Primary new project responsibility will generally rest with EPA. Formal coordination functions have been established with ERDA to facilitate program and project planning and to eliminate gaps and overlaps.

EPA assesses, develops, and evaluates equipment and systems for processing wastes for materials recovery, for preparing fuels and feedstocks for energy recovery via all conversion processes, and for converting wastes to fuels via biological conversion processes. Analyses will determine the optimal composition of waste inputs, energy balances, materials balances, emission and residuals, effectiveness of emission controls and residue handling systems, needs for new types of pollutant control equipment, life-cycle costs, economic viability, and other aspects.

Tennessee Valley Authority (TVA)

TVA has designed a demonstration system for processing wood waste to a condition of 50 percent passing a ¼-inch screen and 15 percent passing a No. 40 screen with a moisture content of less than 10 percent (wet basis). It was determined that processing the wood to these conditions would ensure successful burning with no major problems. However, this system was found to be economically feasible only at coal prices greater than $34/ton. Studies will continue to evaluate simpler, less expensive systems. Funds for FY 1976–79 are predicated on carrying out a demonstration program for this less expensive processing system.

BUILDINGS CONSERVATION

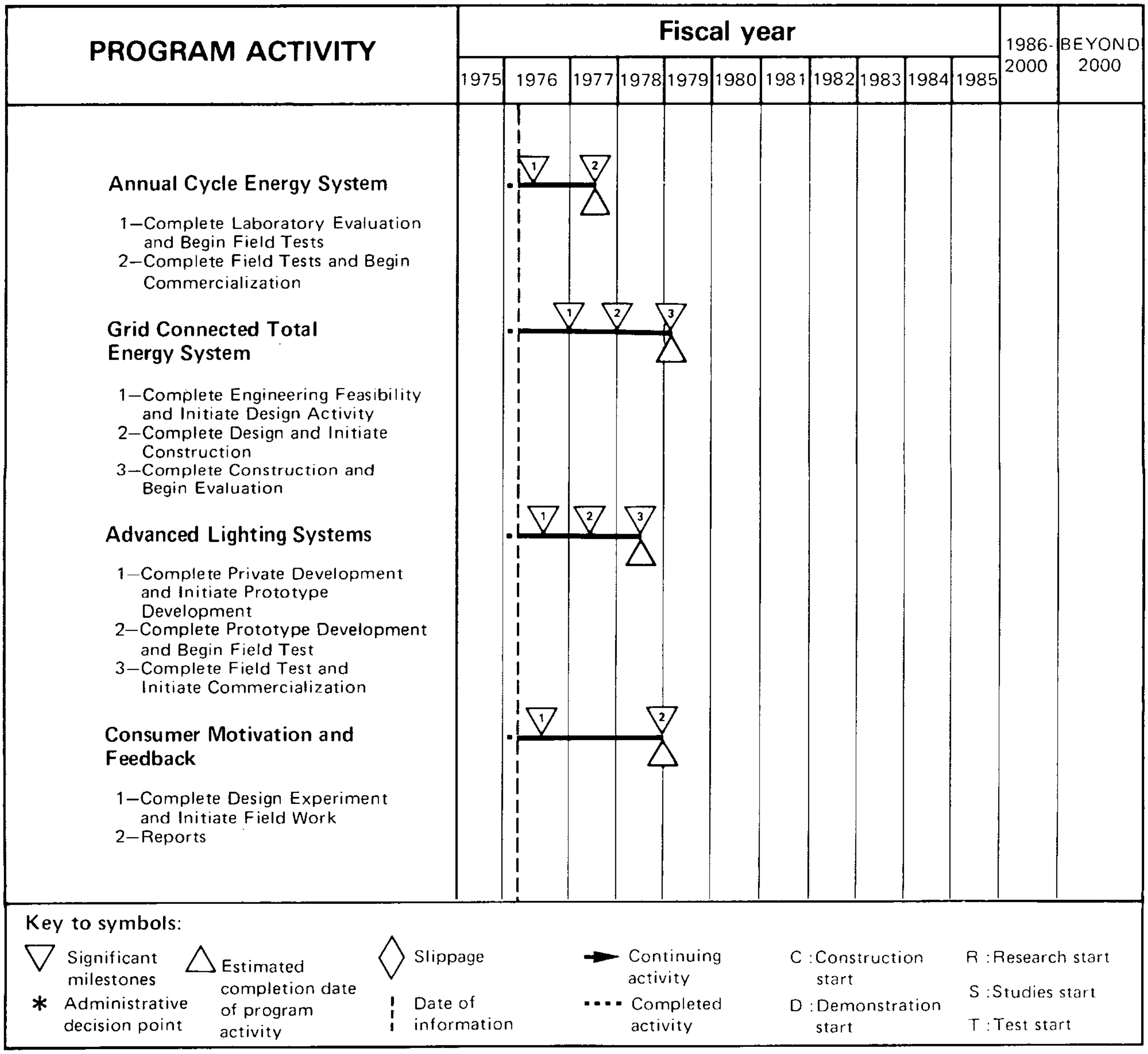
Federal Energy RD&D Budget ***($ Millions)***

Agency	FY 1975		FY 1976*		FY 1977	
	BA	BO	BA	BO	BA	BO
ERDA						
Operating Expenses	2.4	0	12.5	8.2	21.6	18.4
Plant and Capital Equipment	0	0	0	0	0	0
Total	2.4	0	12.5	8.2	21.6	18.4

* Does not include funds for FY 1976 Transitions Quarter.

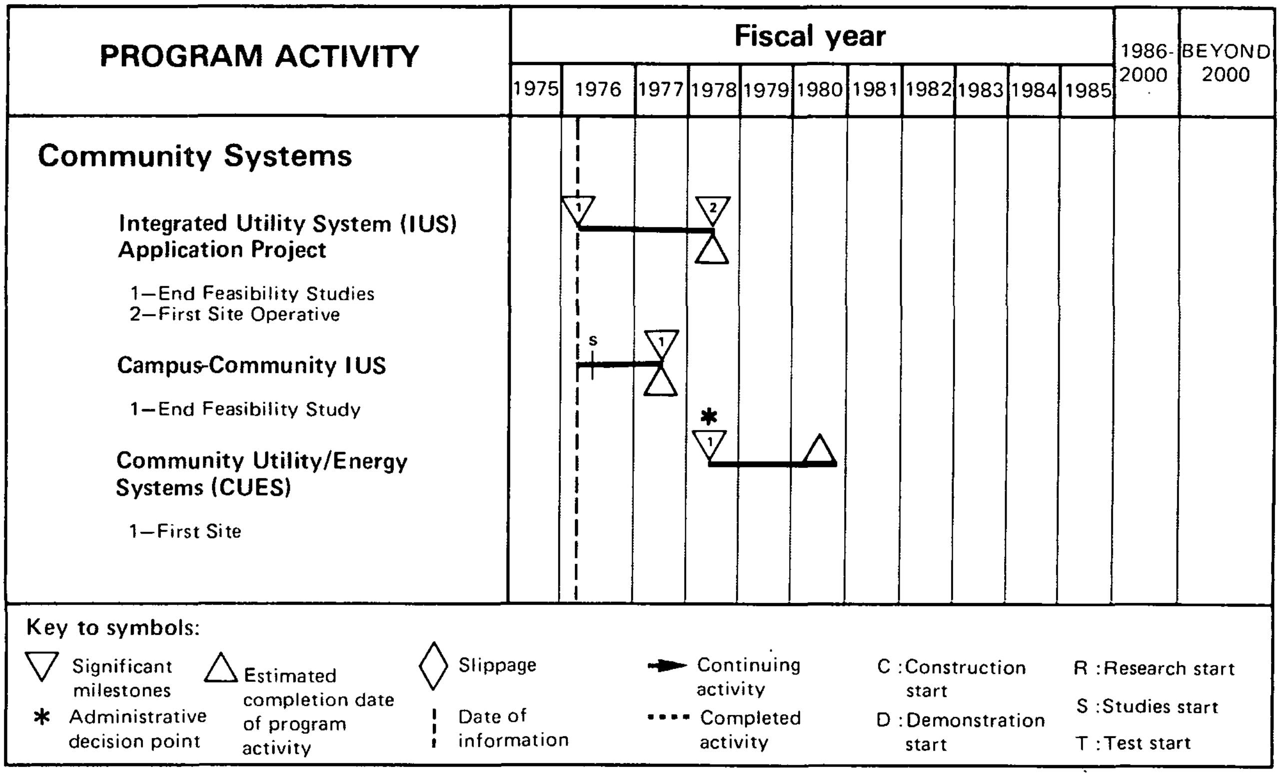
ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION

BUILDINGS CONSERVATION



DEPARTMENT OF HEALTH, EDUCATION AND WELFARE

BUILDINGS CONSERVATION



CONSERVATION

Technologies to Improve Efficiency and End-Use Conservation

TRANSPORTATION ENERGY CONSERVATION

Objectives

Near-Term:
(–1985)

- Identify and recommend possible solutions to operational and institutional barriers inhibiting efficient energy use.
- Reduce near-term petroleum consumption by encouraging the commercialization of new technologies.
- Promote known efficient operating procedures, support applied research programs, and develop new technologies which contribute to the reduction in petroleum consumption.
- Further reduce dependence on petroleum during the period 1980 to 1985; at the same time realize significant energy savings by developing new technologies, encouraging their commercialization, and aiding in the reduction of institutional barriers.

Mid-Term:
(–2000)

- Minimize dependence on petroleum and achieve continued energy savings by assisting the private sector in introducing more advanced technologies and systems.

In each case it is understood that the objectives are to be pursued within appropriate environmental constraints.

National Energy Technology Goals Supported

Primary

- Increase end-use efficiency.

Secondary

- Transform consumption patterns to improve energy use.
- Protect and enhance the general health, safety, welfare and environment related to energy.
- Perform basic and supporting research and technical services related to energy.

Strategy

The nation's transportation system is virtually 100% dependent on petroleum. Since the proven domestic supply of petroleum is diminishing rapidly, it is imperative that means be found to shift the transortation sector toward a nonpetroleum based technology. Recent improvements in the environmental impact of transportation must also continue.

The program strategy includes the following:

- Ferreting out proven but unused technologies and encouraging their use by industry.
- Determining the improvements that can be obtained by changing operational procedures.
- Identifying institutional barriers which currently impede efforts to reduce energy consumption.
- Accelerating the development of new technologies which offer the potential of major increases in the efficiencies of energy conversion and usage in the Transportation Sector.
- Pursuing cost-sharing with industry in major hardware development projects and fostering early commercialization of the technologies.
- Aiding in the development of relatively long lead time systems which offer the potential of increased energy efficiency coupled with utilization of nonpetroleum base fuels.
- Supporting applied research programs aimed at providing the understanding necessary to develop improved energy efficient transportation systems.
- Aiding in the development and demonstration of technologies and techniques offering the

potential for significant energy savings in the Transportation Sector.

- Aiding in the assessment of changes in the transportation system, including the social, economic, energy and environmental impacts.

An important aspect of the strategy will be participation with state and local governments, municipal traffic flow control personnel, and other individuals and organizations affected by public mass transit.

The priorities of this effort will be determined by the potential offered for energy savings, chances for success in development and in commercialization, the extent of on-going or planned industry efforts, and the cost-effectiveness of the estimated expenditures of federal funds.

Federal Role

Federal participation contributes to the national objectives by:

- Encouraging the commercialization and/or use of more efficient mature technologies (FEA). Programs will be considered to assist the private sector in the development of new propulsion, vehicular, aviation, rail, marine, and pipeline systems in areas normally considered as high-risk and not pursued by industry on its own, including the associated applied research.
- Balancing energy conservation requirements with possible conflicting requests related to environment and safety.
- Serving as a catalyst to bring in new concepts and technologies originating outside of the primary industries.
- Encouraging beneficial institutional changes which can best be pursued at the federal level.

International Cooperation

ERDA is represented on the NATO Advisory Group for Aerospace Research and Development (AGARD), Propulsion and Energetics Panel, where aeronautical technical information is exchanged at semiannual meetings among NATO countries. Participation in AGARD activities is being expanded.

A program of information exchanges on motor vehicle research in the area of low emissions, improved fuel economy, low noise, and nonpetroleum fuel use is implemented through a multilateral Memorandum of Understanding under the auspices of the NATO Committee on the Challenges of Modern Society (CCMS). The multilateral agreement is with the Federal Republic of Germany, France, Italy, the Netherlands and the United Kingdom. This program also allows for bilateral agreements such as the agreements currently being negotiated with Sweden and Japan. The United States is the pilot nation for the CCMS program. Cost-sharing of R&D programs by a number of countries on related projects is anticipated in the future, possibly under the aegis of the International Energy Agency. These programs would be oriented toward basic research.

Direct contacts have been established with most major foreign auto and aircraft manufacturers and foreign personnel in charge of key private and government sponsored programs.

Technological Status and Problems

Status:

- Studies are underway or complete to identify target R,D&D areas within the non-highway transport modes.
- System studies have been initiated for the advanced Stirling cycle engine and completed for the new gas turbine for autos; energy saving features of the gas turbine have been verified in component test and the complete system is being fabricated and assembled for system testing to begin June 1976.
- Engine dynamometer testing has begun to verify performance of a variable displacement internal combustion engine. Fuel economy improvements of 30% are projected.
- Design for efficient engine accessory drive systems have been completed and testing of a continuously variable transmission is underway; successful developments are estimated to offer economy improvements of 10% and 20% respectively.
- Tests have proven that a waste heat utilization system (bottoming cycle) operating off normal waste heat from a Diesel truck engine improves the truck engine fuel economy by 13%.

Problems:

- The commercial viability of some advanced technologies for pipeline, rail and marine applications is not known.
- Materials deterioration, lubrication, and phase separation problems in the usage of methanol in conventional automotive engines require solution.

- There is at present no low cost combustor for the gas turbine engine that will satisfy the statutory emission requirements.
- Practical use of the electric vehicle requires improved battery design and development of improved motors, controllers and drive trains.
- Desired efficiencies for the turbine and Stirling engines depend upon development of high-temperature, low-cost, ceramic materials.

Institutional Status and Problems

Status:

- Some current regulatory control measures for motor vehicles exhaust emissions have not been in consonance with energy conservation goals.

Problems:

- Large capital investments will be required to promote shifts in types of land transportation.
- The "Consent Decree" prevents the cross-flow and dissemination of technology interchange between members of the auto industry except at formal technical symposiums.
- The investment required to implement major engine or vehicle changes is large.
- Uncertainty within the auto industry over changing regulations tends to negate R&D efforts and discourages large investments and/or long-range programs.

Environmental Status and Problems

Status:

- Prototype combustors for gas turbine and Stirling cycle engines have demonstrated the capability of satisfying the most stringent statutory automotive emission standards.
- Health effects research are being conducted to determine the effects of NO_x and SO_x on pulmonary functions.

Problems:

- Diesel engine improvements are required to achieve a satisfactory solution to the nitric oxide and particulate emission problem.
- Currently used NO_x control measures for spark ignition engines increase fuel consumption.
- Use of oxidation catalysts provide improved fuel economy compared to control techniques used before the 1975 model year. However, still lower HC and CO emissions apparently cannot be achieved without resorting to adding air to the catalyst. One result of this is increased sulfate emissions which are difficult pollutants to control in autos.
- Development of high temperature ceramics for advanced engines would permit use of higher operating temperatures and therefore better fuel economy; however, the problem of maintaining low NO_x emissions under these conditions may prove difficult.
- Early assessment of the potential health, safety and environmental impacts of using alternative fuels (e.g., liquid fuels from coal or shale, methanol, hydrogen, etc.) as additives or as replacements for conventional transportation fuels, may prove difficult.
- Early assessment of health, safety, waste management and secondary pollution effects of large-scale deployment of electric vehicles (battery outgassing, manufacture, disposal and vehicle accidents), may prove difficult.
- Identification of potential toxicities of secondary pollutants (trace metals, particulates) that might be generated by advanced engine systems (i.e. high-temperature gas turbines), may prove difficult.

Program Implementation

Federal involvement in the Transportation Sector has a long and complex history. As a result, a number of federal agencies have programs which contribute directly or indirectly to transportation energy conservation. ERDA is coordinating its RD&D programs with these diverse activities through formal Memoranda of Understanding, inter-agency agreements and informal agreements to periodically review on-going and planned agency programs, to share research results, and where appropriate, to cost share the conduct of jointly related studies.

Federal efforts related to improving end-use efficiency of energy use include:

Department of Agriculture (USDA)

This agency is involved with activities aimed at improved efficiency in the movement of agricultural products (food, fiber and forest products).

Department of Commerce (DOC)

The Maritime Administration is supporting the development of advanced marine transportation systems and operational procedures. A possible energy conservative strategy is being investigated through

DOC's current assessment of the replacement of travel by telecommunication techniques. The National Bureau of Standards is responsible for the independent evaluation of energy conservation related conventions.

Department of Defense/National Aeronautics and Space Administration (DOD/NASA)

DOD and NASA conduct the major RD&D activities related to energy conservation in the air transportation area. These include fuel efficient aircraft, engines and vehicle R&D, advanced materials development, and development activities related to batteries. The U.S. Army TACOM is sponsoring research and development in advanced automotive engines, drivetrain, and vehicle systems for military applications.

Energy Research and Development Administration

Definite progress has been made over the past year toward meeting the objectives defined earlier. The initial program plans have been formulated. The internal responsibiilties and authorities to implement the program plan have been clearly defined within the Office of Conservation.

The nucleus of the current Heat Engine Highway Vehicle Activity resides in the personnel and contracts transferred from EPA to ERDA as called out in the ERDA enabling legislation. The new scope of this subprogram is much broader than the original EPA activity and now includes: autos, trucks, and buses; electric and hybrid systems; energy, environment, and practical aspects of achieving more energy efficient low-cost transport systems.

Most short-term work on highway vehicle systems will be left appropriately to industry. The state-of-the-art of conventional components and vehicle configurations, such as continuously variable transmissions, accessory hp reduction, waste heat utilization, and modifications in the spark ignition engine, will be advanced in order to achieve improvement in fuel economy on a near-term basis. Demonstration of these technologies can be accomplished during the 1977 to 1980 period and near-term commercialization in the early 1980's when the need for a federal role can be clearly established. The higher-risk projects underway are those which could be demonstrated in the early 1980's and commercialized later in the decade. Examples are Stirling engine and high-temperature gas turbine engine development.

Work is in process to determine the ERDA roles in the air, rail, water and pipeline transport modes. These findings coupled with results of ongoing studies to determine targets of energy savings opportunities in the nonhighway area and the assessments of industry work will provide the basis for a program plan to assist other federal agencies in introducing new, energy-efficient technology in these areas.

The Systems Studies activity has been organized since July 1975 and work is already underway to support and guide the technology-oriented activities in areas such as technology assessments, and determining transportation growth patterns. Studies and evaluations in this area include: understanding the consequences of changes in the transportation system (technological, operational, institutional changes, etc.); determining and evaluating which barriers impede commercialization of changes in technologies, and recommending ways to overcome these; determining the economic parameters, and the role the federal government can play in fostering commercialization of energy efficient operational and technological methods; evaluating new concepts related to energy conservation in transportation offered by citizens, universities and firms not associated with the transportation industry; and providing credible consistent data on energy consumption, past and projections for the future, nationally and on a local basis for use throughout the transportation energy conservation program.

The Implementation activity is also newly created and will focus on determining the economic factors guiding industry decisions on production of energy saving technologies; on finding means to stimulate industry interest and participation; and on maximizing the usefulness of ERDA demonstration programs to the transportation industry.

Technologies to permit the efficient use of alternative fuels derived from coal, shale, hydrogen sources, and waste materials will be developed and demonstrated. Universities and industry will be utilized in the testing of many nonpetroleum fuels to determine their characteristics from an emissions, handling, storage, materials compatibility, economic, and safety standpoint. The coal/shale effort will relate to the Synthetic Fuels Commercial Demonstration Program now being developed by ERDA. In addition, a comprehensive multi-disciplinary applied automotive research program is being planned for incorporation into the ERDA transportation energy conservation program. This program is aimed at providing important information to fill technology gaps. It will include activities in the areas of general combustion, engine cycles, materials, alternative fuels, engine controls, diagnostic instrumentation and friction reduction.

A comprehensive development program is being undertaken within ERDA to advance the technology of battery storage devices, and combine those advanced energy storage system with improved electrical and mechanical components for integration into vehicles designed and optimized specifically for an electrical propulsion system. Improvements in the state-of-the-art for current batteries are required to achieve early commercialization and interest by the consumer of electric vehicles. A large number of electric vehicle users are not expected by 1980. Advanced battery powered vehicles will start to appear in the mid-1980's. Reduction in highway system demands may be felt around 1990 as electric cars begin to displace vehicles in the limited- or moderate-range category. Technology improvements in lithium-sulfur and sodium-sulfur high temperature batteries can begin to penetrate longer-range vehicle markets by that time.

In addition, ERDA is supporting several high-risk projects. Highest-risk projects are those to which industry would contribute least in the early phases and which, if successful, could be commercialized in the 1990–2000 time period. Examples of this type of project are: practical storage and use of hydrogen as a fuel for autos and trucks; use of thermal storage for autos and trucks; and development of hybrid systems utilizing fuel cells for energy conversion.

In every transport mode where this ERDA program participates, it is intended that much of the work be conducted by the affected segment of the industry. This is especially true where major systems development is required. For example, cost-sharing contracts with the auto and truck industry members make abundant sense where the end product would be produced by that industry (gas turbine and Stirling engine) and where development costs are high. The infusion of more advanced technology into the program will come about through contracting directly with small high-technology firms with specialized skills for development of components and subsystems, etc. One exception to this approach is in the development of the electric vehicle where it is planned to promote the innovative concepts and designs of new and complete vehicle systems for possible production. In this particular area new ventures and firms appear likely and therefore will be especially encouraged.

Environmental Protection Agency (EPA)

EPA is directly involved in the testing and evaluation of emissions as well as fuel economy, for production vehicle certification to meet federal automotive emissions standards. In addition, they are involved with the testing of new vehicles and retrofit devices.

Federal Energy Administration (FEA)

The emphasis of the FEA program in the transportation energy conservation area is in the education, demonstration and encouragement of the adoption of energy conservation techniques by the public and commercial end-user. This includes changes in operational techniques, improved driving techniques, driver aids, and the use of available improved hardware. One program, in conjunction with DOT, is aimed at the reduction of nationwide fuel consumption of heavy duty trucks and buses without detriment to the essential service of the industries through adoption of improved technologies, operating efficiencies, and decreased operating constraints; and motivation of the trucking industry to voluntarily adopt fuel conservation principles and techniques.

Another FEA program provides information on automotive fuel economy information to the public via the publication and dissemination of a guide. This guide is aimed at promoting a market shift toward vehicles with better fuel economy.

FEA is also sponsoring a program to demonstrate and disseminate techniques for conserving fuel in the existing automobile fleet through improved operational practices, driver habits, and vehicle maintenance procedures, and to develop second-generation vehicle-in-use conservation techniques which are capable of reducing automotive fuel consumption 5% by 1980. Outputs of this activity will include handbooks, training aids and evaluation reports.

General Services Administration/ Federal Supply Service

The GSA is sponsoring the demonstration and testing of passenger shuttle vehicles with state-of-the-art batteries and components.

Department of Interior (DOI)

DOI's activities are related to the transportation of natural resources related to the total effort in transportation energy conservation.

National Science Foundation (NSF)

NSF has sponsored policy and research planning studies, and has been supporting combustion and materials research aimed at improving automotive energy consumption.

U.S. Postal Service

The demonstration and evaluation of mail delivery jeeps is being conducted, using state-of-the-art battery and electric component systems.

Department of Transportation (DOT)

In order to support the formulation of transportation energy policies, the Department of Transportation is conducting many activities aimed at acquiring knowledge of the facts of energy use and opportunities for energy conservation in the near-term (through 1985). These activities cover the spectrum of transportation options from highway vehicles (autos, trucks, buses) to nonhighway vehicles such as rail systems, and airplanes. Furthermore, these efforts are being conducted by various parts of DOT such as the Office of The Secretary (OTS), Federal Aviation Administration (FAA), Federal Railroad Administration (FRA), Urban Mass Transit Administration (UMTA), National Highway and Traffic Safety Administration (NHTSA), and the U.S. Coast Guard.

In the highway vehicle area the Automotive Energy Efficiency Program in OTS is concerned with the characterization, evaluation, and testing of automotive components aimed at reducing fuel consumption, and the reassessment of energy efficient vehicle-in-use in the near-term. This program has also provided the basis for: (1) DOT-EPA Fuel Economy Study of 1974, and (2) Inter-agency Task Force on Motor Vehicle Goals Beyond 1980. The DOT-EPA study was the basis for legislation to establish mandatory fuel economy standards. Other DOT activities in the highway vehicle area include transportation energy policy studies, investigation of methods to reduce highway congestion, cost-benefit studies on increasing the allowable size and weight of commercial vehicles (for fuel savings), the investigation of materials and methods to reduce the consumption of energy in the construction of highways, and modal shift studies.

In the rail transportation area, energy conservation activities include fuel consumption reduction by operational improvements, investigation of aerodynamic drag of trains, and the demonstration of flywheel storage technology for improving the efficiency of yard-switch locomotives.

Other programs in DOT include (1) UMTA programs which are aimed at shifting urban trips from automobiles to more efficient transportation modes, and (2) the FAA program which is structured towards improving the efficiency and safety of commercial avaition. The U.S. Coast Guard is evaluating low-friction, anti-fouling hull coatings to improve the fuel efficiency of ships.

TRANSPORTATION ENERGY CONSERVATION

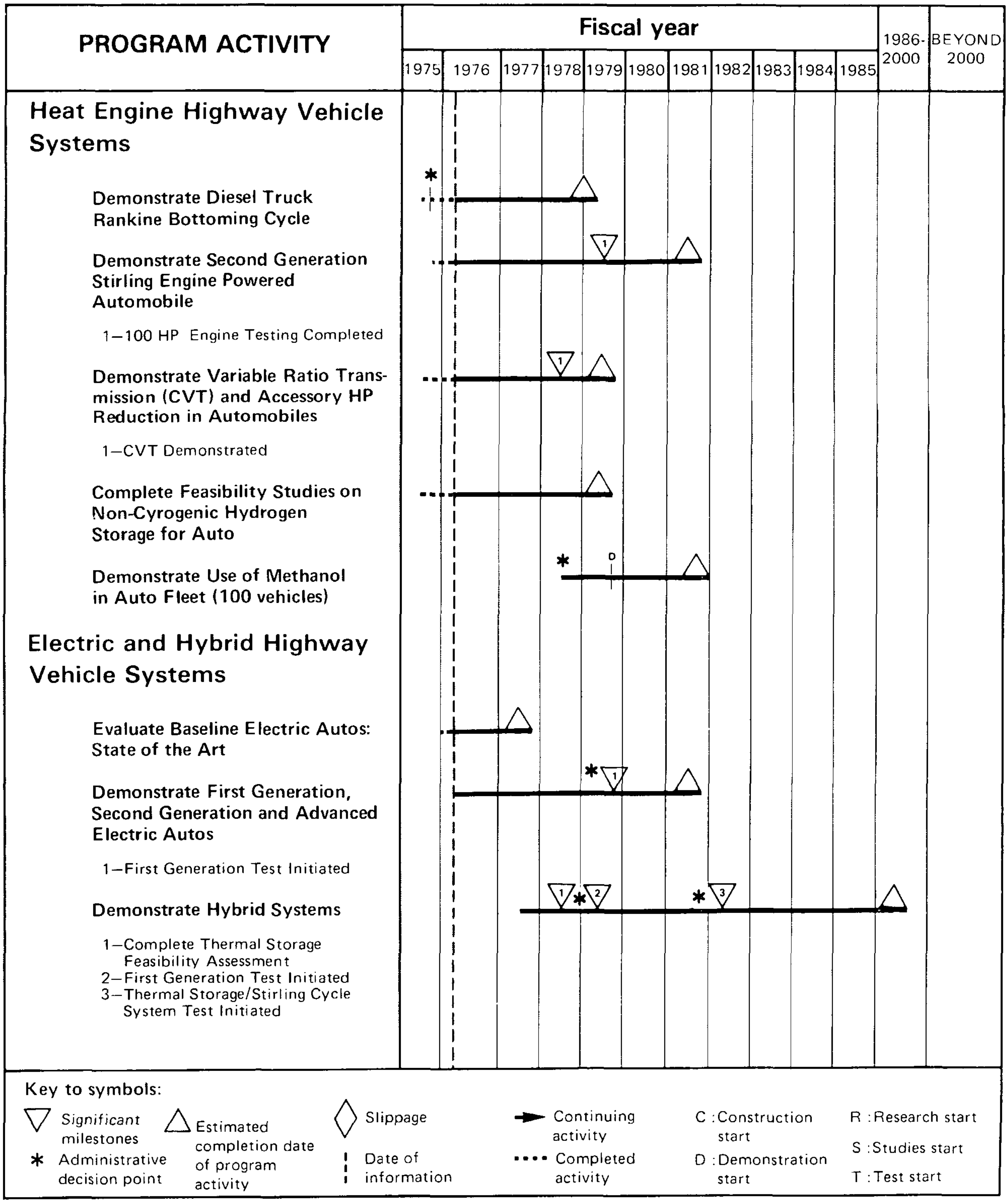
Federal Energy RD&D Budget *($ Millions)*

Agency	FY 1975		FY 1976*		FY 1977	
	BA	BO	BA	BO	BA	BO
ERDA						
Operating Expenses	8.1	8.4	12.5	10.0	23.2	20.2
Plant and Capital Equipment	0	0	0.4	0.4	0.5	0.2
Total	8.1	8.4	12.9	10.4	23.7	20.4

* Does not include funds for FY 1976 Transition Quarter.

ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION

TRANSPORTATION ENERGY CONSERVATION



ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION

TRANSPORTATION ENERGY CONSERVATION (Continued)

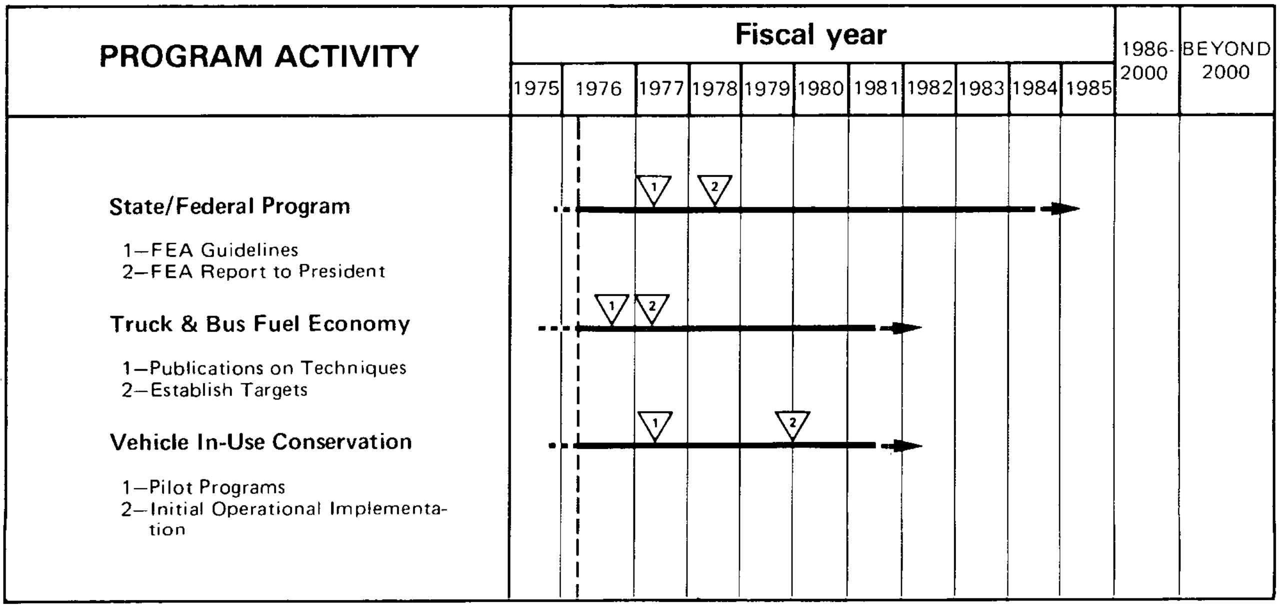
PROGRAM ACTIVITY	Fiscal year 1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986-2000	BEYOND 2000
Complete Economic Analysis for New Transport Aircraft		—	△										
Complete Economic Analysis and Detail Design of Pipeline Pumping Station with Waste Heat Recovery		—	△										
Complete Operational Analysis of Transport Aircraft		—	△										
Complete Study of Coal Transport R&D Needs		—	△										

Key to symbols:

- ▽ Significant milestones
- * Administrative decision point
- △ Estimated completion date of program activity
- ◇ Slippage
- ¦ Date of information
- ➔ Continuing activity
- ▪▪▪▪ Completed activity
- C : Construction start
- D : Demonstration start
- R : Research start
- S : Studies start
- T : Test start

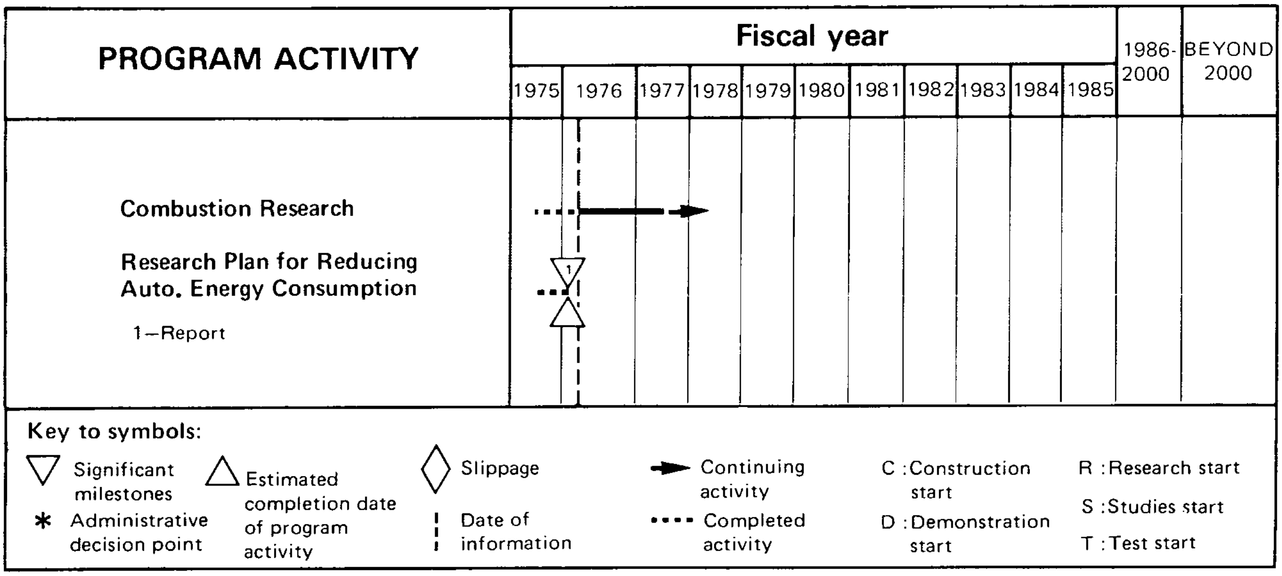
FEDERAL ENERGY ADMINISTRATION

TRANSPORTATION ENERGY CONSERVATION



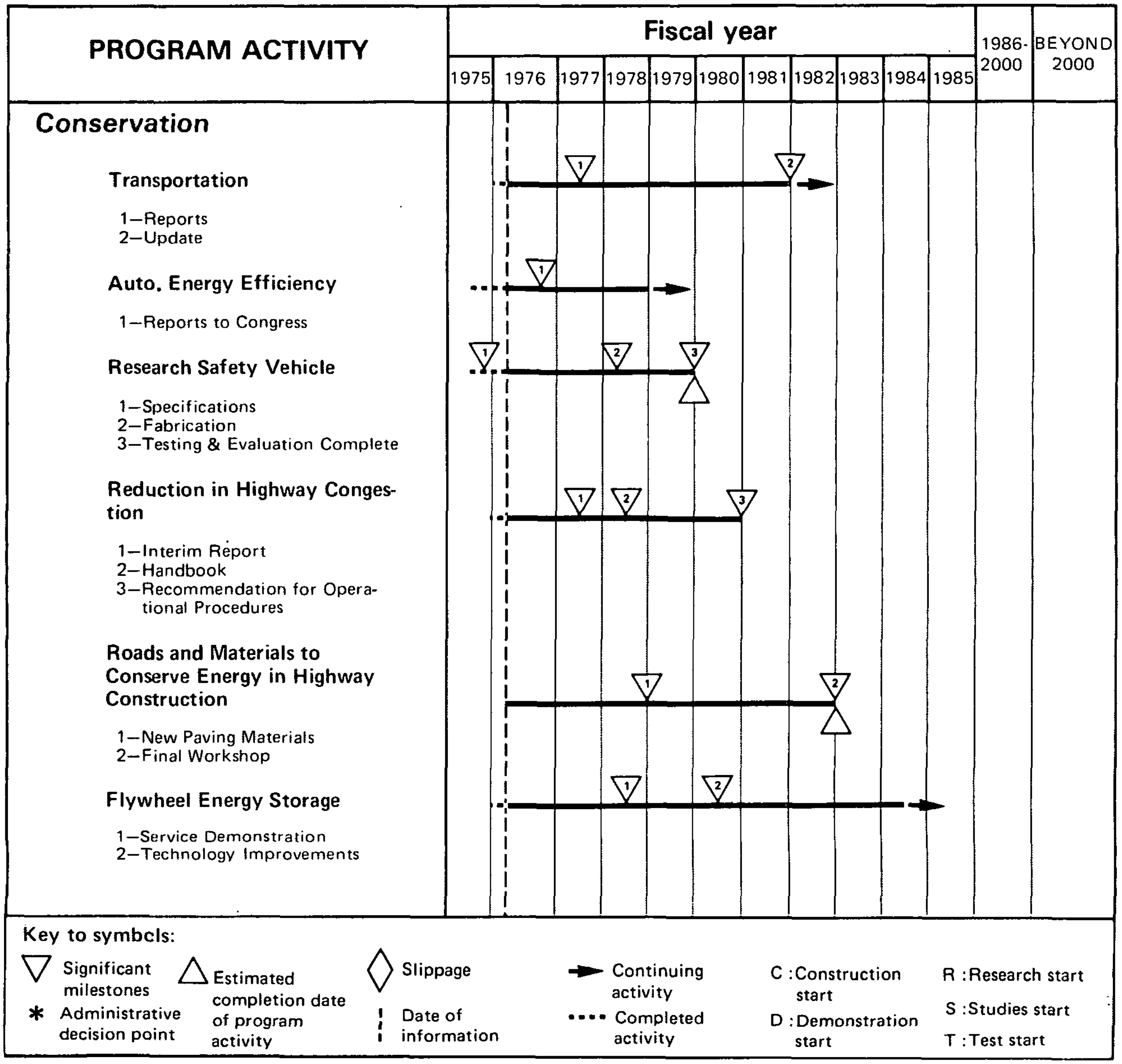
NATIONAL SCIENCE FOUNDATION

TRANSPORTATION ENERGY CONSERVATION



DEPARTMENT OF TRANSPORTATION

TRANSPORTATION ENERGY CONSERVATION



CONSERVATION

Technologies to Improve Efficiency and End-Use Conservation

ENERGY CONVERSION

Objectives

Near-Term:
(–1985)

- Develop systems which increase the extent to which waste heat can be recovered economically.
- Improve the efficiency of commonly used components such as heat-exchangers, compressors, pumps, motors, generators.
- Develop advanced combustion technology required to improve efficiency and utilize alternate fuels in combustion equipment.
- Develop high-temperature materials and fabrication techniques to allow improved performance of energy conversion systems.
- Develop fuel cells for economically viable end-use applications.

(Mid-Term:
(–2000)

- Develop the necessary technologies and encourage implementation of advanced conversion systems of improved efficiency which will result in a decrease in nonrenewable resource energy consumption of 25%.

National Energy Technology Goals Supported

Primary

- Increase the efficiency and reliability of the processes used in energy conversion and delivery systems.

Secondary

- Increase end-use efficiency.
- Transform consumption patterns to improve energy use.

Strategy

Energy conversion processes are an integral part of all end-use technologies.

The program strategy is to assign priority to those efforts which are integral to end-use which can effect the most effective savings of petroleum and natural gas resources. Emphasis will be given to areas which have the potential for near-term energy savings.

Alternative parallel approaches will be pursued to a point where sufficient data are available to allow go/no-go decisions. For example, in the high-temperature heat utilization technology category, thermionic converters, helical expanders and closed Brayton cycyle gas turbines are being pursued in parallel. These technologies will be pursued through proof-of-concept experiments to reach individual go/no-go decisions.

These efforts will be conducted with continuing private sector participation to ensure that all input is appropriately considered and to ensure an effective transfer of technology. Each technology will be developed with a strong emphasis on capital, operation, maintenance and fuel saving economics to maximize the benefits. Those regulations or incentive actions which may be required to improve the rate of implementation will be identified.

All available RD&D resources (government, national laboratories, industry, non-profit organizations and universities) will be considered for participation in this work. The federal agencies involved include FEA, NASA, DOD, NSF, EPA and ERDA.

Federal Role

The federal role involves assisting the private sector in the development of those conversion efficiency improvement concepts which promise maximum energy savings. The federal role also includes the development of high risk technologies to the point where R&D cost versus risk become acceptable for the private sector to complete the development.

International Cooperation

Energy conversion staff personnel hold key positions and play a leadership role on well recognized international agencies such as the International Energy Agency. Technological cognizance is maintained in several areas so that programs derive the maximum benefit from foreign developments and that opportunities for further cooperation can be identified and pursued.

ERDA has negotiated the transfer of a stratified charge combustion chamber from Volkswagon to Sandia Labs Livermore. The chamber will be used in a joint United States-West Germany program to study stratified charge combustion.

Technological Status and Problems

Status:

- Current conversion techniques are relatively inefficient when compared to theoretical efficiencies in all of the end-use sectors—transportation, buildings, industry and electrical generation.
- State of technology of energy conversion industry generally is less advanced than other industries—e.g., aerospace and nuclear power—which have benefited from comprehensive R&D efforts.
- Many existing concepts for energy conservation—e.g., waste heat utilization, catalytic combustion, and ceramic engine components—lay relatively dormant for lack of R&D support.
- Fuel cells are proven high efficiency conversion devices but have received only limited, specialized use in space vehicles.

Problems:

- High temperature materials and fabrication techniques for components of more efficient conversion systems presently have unsatisfactory reliability and cost.
- Components and systems have not yet been scaled to a practical and economic size.
- Combustion processes are not adequately understood to allow design optimization of combustors and substitution of new fuels.
- Operational data on improved efficiency systems are inadequate to assess process viability and reliability.
- Advanced conversion devices, such as fuel cells employing high-cost technology, are not economically competitive with existing, less-efficient options.

Institutional Status and Problems

Status:

- Available capital in the electric utilities industry is typically invested in the construction of future generating plants rather than in research and development of more efficient conversion technologies.

Problems:

- Skilled labor in critical technology areas such as materials fabrication is generally unavailable. Manufacturing and maintenance labor for advanced conversion technologies such as organic Rankine cycles or fuel cells is not available.
- Benefits of advanced technology applied to energy conversion are not recognized.
- Institutional and economic factors associated with current equipment lifetime inhibit the rapid implementation of improved-efficiency equipment.

Environmental Status and Problems

Status:

- The environmental effects for many improved energy conversion techniques have yet to be determined. Studies of environmental effects are being done in conjunction with the technology projects, and several programs such as the fuel cell and combustion programs have secondary objectives of significantly reducing environmental effects.

Problems:

- While it is generally held that conservation of energy will be an aid in the reduction of environmental problems, specific techniques to accomplish this end all have important areas of concern which must be investigated. Among these are: (1) the potential toxicity problems from toxic fluids used in heat exchange processes; (2) the potential toxicity problems associated with the production of certain catalysts for fuel cells; and (3) the possibility of toxicity problems from new high-temperature materials.

Program Implementation

Energy Research and Development Administration

In order to achieve the energy conversion program objectives, the following research, development and demonstration subprograms are being implemented. Systems trade-off technology assessment, cost benefit, and commercialization studies are under way to provide the basis for setting priorities.

Heat Utilization—Technology development efforts are underway to allow utilization of both low-temperature and high-temperature waste heat. These include:

- Evaluation of the technical and economic feasibility of utilizing low-grade waste heat from industrial, electric public utility and heavy transportation areas utilizing bottoming cycles with various cycles and working fluids. The first demonstration is expected by 1979.
- Development and demonstration of the technical and economic feasibility of systems utilizing high-grade waste heat and high temperature topping cycles. Demonstration is planned for 1980.

Improved Component Efficiency—The technology required for the improvement of efficiency and reliability of components such as heat-exchangers, compressors, pumps, motors, and generators is being studied. Initial results are expected in FY 77.

Combustion Technology—Development of advanced technology required to improve efficiency and to utilize alternate fuels in combustion equipment. Major subprograms:

- Combustion technology development—investigation of advanced equipment design concepts.
- Applied combustion research—development of advanced design methods and a supporting data base.
- Combustion technology transfer—promotion of advanced technology utilization and assessment of safety, environmental, social, and economic impacts.

Materials and Fabrication Technology—Supporting technologies to the overall conversion conservation are being pursued in:

- High temperature materials.
- Fabrication technologies, including materials reclamation processes.
- Catalyst development for fuel cells.

Advanced Cycles—Development of the technology and verification of the economic and technical feasibility of the following advanced conversion cycle improvements are being initiated. Topics include:

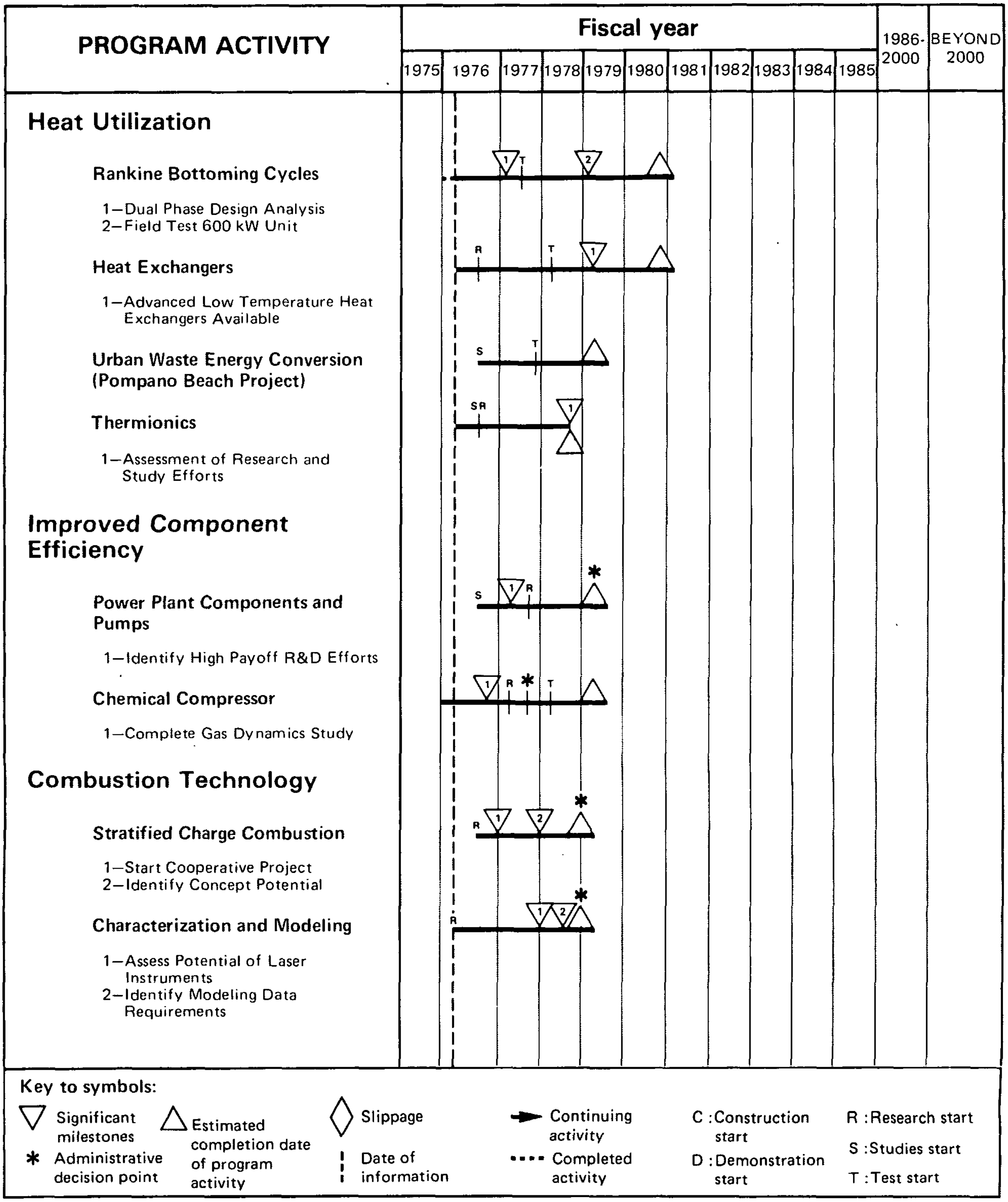
- Steam Rankine cycles—to increase reliability through the use of improved feed water pumps and improved materials for utility use.
- Closed Brayton cycle gas turbine—to enable use of any high-temperature heat source and develop efficiencies up to 50 percent.
- Ultra high-temperature conversion machines—capable of operating above 2800°F; such as helical expanders, open-cycle gas turbines, and thermionic converters.
- Fuel cells for utilities, residential, industrial, and transportation capable of operating with efficiencies greater than 45 percent on a synthetic fuel. First generation fuel cells will be available by 1979 with operating efficiencies of 40 percent.

Industrial cost-sharing will be fostered in all of the program developments.

The charts show near-term milestones for programs currently being initiated in each category. Additional programs/projects will be initiated as warranted by the results of current projects and continuing studies.

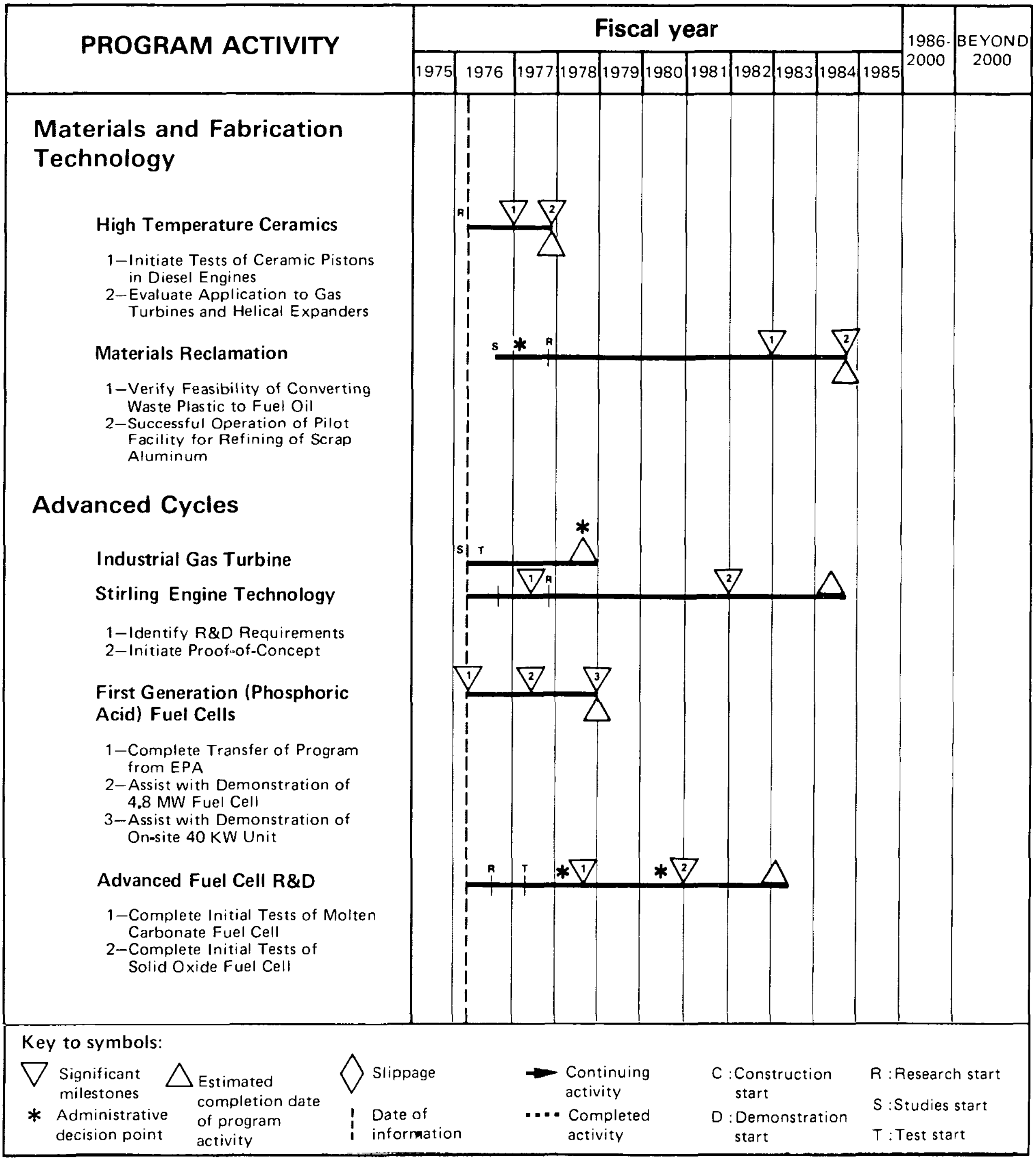
ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION

ENERGY CONVERSION



ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION

ENERGY CONVERSION (Continued)



ENERGY CONVERSION

Federal Energy RD&D Budget **($ Millions)**

Agency	FY 1975		FY 1976*		FY 1977	
	BA	BO	BA	BO	BA	BO
ERDA						
Operating Expenses	2.3	0.5	8.9	6.9	15.0	4.3
Plant and Capital Equipment	0	0	0.2	0.2	0.5	0.3
Total	2.3	0.5	9.1	7.1	15.5	4.6
DOI	0.1	0.1	0.4	0.3	0.3	0.2
Total	2.4	0.6	9.5	7.4	15.8	4.8

* Does not include funds for FY 1976 Transition Quarter.

FUSION POWER R&D

Magnetic Fusion Program Summary

Objectives

Near-Term:
(–1985)

- Produce and understand the behavior of reactor level hydrogen plasmas*. Produce quantities of thermal energy in the First Fusion Test Reactor using deuterium-tritium fuel.

Mid-Term:
(–2000)

- Produce electrical energy in quantities in two Experimental Power Reactors in the latter 1980's. Operate commercial-scale Demonstration Power Reactor in the latter 1990's.

Long-Term:
(Beyond 2000)

- Begin to supply a fraction of the nation's energy demand using abundantly available fuel in economically viable and environmentally compatible electricity generating plants.

National Energy Technology Goals Supported

Primary

- Increase the use of essentially inexhaustible domestic energy resources.

Strategy**

The fusion power program is organized to conduct the research and development necessary to demonstrate the physical, engineering and commercial feasibility of producing electrical power and other forms of energy utilization from nuclear fusion. The primary emphasis now is toward developing sufficient physical understanding of plasma behavior to allow containment of plasmas at the temperatures, densities and confinement times necessary to produce useful net energy. Engineering developments common to near-term experiments and ultimately fusion reactors, such as superconducting magnet systems, neutral beam systems and the like, are conducted in parallel to and coordinated with the scientific studies of plasma production, containment and heating. Laser fusion research is covered in another section of this report.

The fusion process can produce significant quantities of energy in the form of energetic neutrons. Its principal application will be for the production of electricity, but other uses—such as space heating and industrial process heat production—are possible. The use of fusion neutrons is being investigated on a supplementary basis for direct application in chemical processes, transmutation of fission waste products, synthetic fuel production and fissile fuel breeding.

Because the energy-producing characteristics of fusion systems improve with increasing size, a series of progressively larger experimental devices is planned to provide needed knowledge of fusion plasma physics and engineering under prototypical fusion conditions. This will permit the development of the requisite physics knowledge and an evaluation of the leading types of fusion systems. Further, these physics and engineering experiments will serve as the basis for the design and operation of fusion power reactors.

The most promising magnetic confinement concept at this time is the tokamak, which represents about sixty-five percent of the present programmatic effort. The authorized Tokamak Fusion Test Reactor (TFTR) will be the first energy-producing fusion experiment. Plans call for at least the first Experimental Power Reactor (EPR) to be a tokamak. Sub-

* Plasma is an extremely hot gas in which atoms have been dissociated into electrons and ions.

** A detailed description is contained in *Fusion by Magnetic Confinement, Atomic Energy Commission,* WASH–1290, February 1974, available from the U.S. Government Printing Office. An updated program plan will be published by June, 1976.

sequent large fusion systems will be based on data obtained not only from these large tokamaks, but also from the backup theta pinch and magnetic mirror programs and the several exploratory concepts currently under study. The theta pinch and magnetic mirror options each receive about fifteen percent of program funding; about five percent is allocated to exploratory concepts. They are supported with the intention of building a Fusion Test Reactor utilizing one of these approaches when and if data from smaller experiments and predicted reactor characteristics warrant it.*

A combination of National Laboratory, industrial and academic institutions will be used with additional funding support from the Electric Power Research Institute (EPRI) and utility consortiums, where available, to expand the scope, hasten the pace and prepare the technology for full commercialization. Privately funded research in this program area now totals more than five million dollars annually. Enlarging the industrial role will be required as research, development and demonstration (RD&D) proceed to establish the base for a viable fusion power industry when commercial demonstration is achieved in the 1990's. All resources and program efforts are interrelated with the goal of supporting a successful fusion power demonstration by the most promising concept in the manner that makes the most effective use of manpower, available funds and time.

Priority continues to be given to the critical path physics theory and experiments as well as the technologies needed for the TFTR and EPR. The fusion plan has target milestones that culminate in commercial demonstration of magnetic fusion power near the turn-of-the-century. In the case of a major unanticipated physical result, either positive or negative, a careful review will be made to assess its full implications either to capitalize on success or to minimize the impact of setback. Utilization of a dynamic planning process that charts milestones and includes alternate approaches assures that such reviews can be completed promptly and effectively. There is an extensive review to present program plan being conducted by the Division of Magnetic Fusion Energy (MFE). It will include a number of logics and options that carry the MFE program through to a demonstration reactor in the 1990–2000 time frame.

An active program of systems studies and advanced engineering is employed to provide timely analyses of the possible benefits and identified technological problems associated with each present or potential fusion power concept. Events that have a potentially significant impact on the fusion power program priorities or directions are considered in depth by the Fusion Power Coordinating Committee and an appropriate course of action is recommended. This body, which meets quarterly, is made up of the senior staff of the ERDA Division of Magnetic Fusion Energy and the fusion program directors from the four major laboratory programs. Consultants to the Coordinating Committee include scientific leaders from government, universities and industry.

Federal Role

The goal of the federal government is to develop fusion physics technology and support the development of a fusion power industry to the point at which the private sector can supply and utilize fusion power systems.

More than 95 percent of the Magnetic Fusion Program now is financed by the federal government. Because of the long lead time (25 years or more), large commercial uncertainties, and financial risks currently associated with fusion power research and development, major support from nonfederal sources is not available. In the near-term, greater use will be made of industrial capabilities, particularly in engineering research and development.

The principal role in fusion research, development and demonstration is currently performed by four major laboratories. The Princeton Plasma Physics Laboratory and the Oak Ridge National Laboratory emphasize tokamaks; the Los Alamos Scientific Laboratory, the theta pinch; and the Lawrence Livermore Laboratory, the magnetic mirror. Major technology development programs are also underway at Oak Ridge National Laboratory, Lawrence Livermore Laboratory, Los Alamos Scientific Laboratory, Argonne National Laboratory and Battelle Pacific Northwest Laboratories. Significant industrial programs are supported by the government at General Atomic Company, United Technologies Research Center and Westinghouse Electric Corporation.

The Electric Power Research Institute cooperates closely with federal programs in supporting

* Detailed descriptions of the status and future needs of each of the three major magnetic confinement concepts were published by ERDA in May, 1975. These reports, *Tokamak Study, 1975, Mirror Study, 1975*, and *High Beta Study, 1975*, are available on request from the Division of Magnetic Fusion Energy.

fusion research and development, including assistance in funding the conceptual design of the large Doublet III Tokamak now being built with federal funds at General Atomic. EPRI also supports several studies of the implications of fusion technology from the electric utility user point of view. Other privately funded efforts are underway on a smaller scale.

An important principle in proceeding with the Tokamak Fusion Test Reactor is that industry should be heavily involved in its design and construction. Increasing private sector participation in the development of technologies and devices for the fusion program is being encouraged. Increased nonfederal financial contribution is expected as commercial applications become more certain.

International Cooperation

The objective of international cooperation in fusion research and development is to reduce the time and cost required to develop fusion power by gaining from the experience and knowledge of others in a reciprocal manner.

A bilateral Protocol for Cooperation in fusion research was signed with the U.S.S.R. in February 1974. An active exchange program is underway with some ten visits totaling 165 man weeks in each direction in calendar year 1975. The exchanges cover the full range of magnetic confinement fusion science and technology and include short meetings for seminars and general orientation and working visits of several months duration to provide maximum transfer of concepts and information. For example, in an October 1975 working group at Princeton, an American-Soviet team was able to make a major advance in a tokamak subsystem design capable of meeting the needs of both programs. In early 1976 a U.S. team spent a month in Moscow working on the new T–10 Tokamak there. This was followed by a Soviet visit to Princeton to work on the just completed Princeton Large Torus Tokamak. These are the largest tokamaks in the world.

The United States also participates in the multilateral fusion programs of the International Atomic Energy Agency and the International Energy Agency. Active, informal exchanges of information and personnel take place on a continuing basis between the U.S. fusion program and the related programs in Japan and the Euratom countries.

Technological Status and Problems

Status:

- While the simultaneous achievement of the number densities, containment times and temperatures required to demonstrate controlled fusion have not yet been accomplished in a single experiment, the basic physics of magnetic fusion power is sufficiently understood so that extrapolations to the next generation of larger experiments can be made with the confidence that fusion power will eventually become a practical source of electrical energy.
- The magnetic fusion program is moving into the phase of technology and development—in parallel with a strong research program. This next phase will provide the capability to capitalize on research success.

Problems:

- There is not sufficient experimental data nor theoretical understanding to perform a full evaluation of the various fusion power concepts. Such an evaluation will require: a) the design, construction, and operation of large and complex reactor facilities; and b) the acquisition of physical data from the experiments that constitute the facilities.
- There is not sufficient data on the effects of high-energy neutrons on reactor materials (new and unique facilities are required to obtain it).
- The modeling of plasma behavior is not (yet) possible, due to an insufficient analytic and computational capability.
- A significant number of technologies must be developed for next generation experiments, near-term test facilities and power reactors.

Institutional Status and Problems

Status:

- The government has established working relationships among utilities, industry, universities and other elements of the private sector.

Problems:

- The cost and time necessary to develop fusion power make priority setting within the federal research and development program a very difficult task.
- The high cost and risk of fusion research and the long lead time to commercialization dis-

courage substantial early private sector participation.

Environmental Status and Problems

Status:

- A final Environmental Impact Statement has been issued for the Princeton Tokamak Fusion Test Reactor and an environmental analysis of the fusion R&D program is in preparation. A draft environmental impact statement for the Intense Neutron Source has been issued.
- A survey of the safety of the current fusion R&D facilities is being performed to assure that they are being operated in a safe manner and to determine whether there are needs for interim or near-term safety standards and guidelines beyond the normal procedures of ERDA, the Environmental Protection Agency, the Occupational Safety and Health Administration, and the Nuclear Regulatory Commission.
- Presently, there is no on-going reactor safety research program which provides adequate safety technologies, such as particulate and gaseous containment and cleanup systems. Analytical tools, such as safety analysis methodologies and component failure rate experience files, for determining the safety of fusion reactors must be utilized.

Problems:

- Studies of the environmental behavior of tritium and neutron activation products, the potential health effects of low-level magnetic fields, and the potential genetic and somatic effects of tritium have not yet been conducted.
- There have been no safety analysis reports prepared for major tritium handling facilities such as the TFTR, the Intense Neutron Source and the Experimental Power Reactors.
- A comprehensive reactor component testing and quality assurance program needed to assure the licensability of the Demonstration Fusion Power Plant (to be operated in the late 1990's) has not been conducted.

Program Implementation

The ERDA Division of Magnetic Fusion Energy is responsible for the implementation of the magnetic confinement fusion program, utilizing research and development services performed by industry, universities and other private sector laboratories, and the National Laboratories. Four organizational elements within the Division are responsible for the implementation of: Confinement Systems, Reactor Projects, Development and Technology, and Applied Plasma Physics.

The Confinement Systems activity fabricates and operates experiments to model many of the features of fusion reactors. *Reactor Projects* has the responsibility for the construction of the large facilities needed by the other activities according to their designs and for their subsequent operation.

Development and Technology develops technical solutions to problems associated with the design and construction of the next generations of plasma confinement devices, test systems and fusion reactors. *Applied Plasma Physics* conducts theoretical and experimental research to determine practical methods to achieve the conditions necessary for fusion power.

In carrying out the next phase of fusion research and development, tests and experiments will be performed wtih the use of a series of large facilities. The most important of these facilities, with the fiscal years in which capital funding is projected to begin for each, are as follows:

1976	Tokamak Fusion Test Reactor (I) Rotating Target Neutron Source (I)
1977	Intense Neutron Source (I)
1978	Two of the following three devices: Technology Test Assembly for Superconducting Magnet Coils (II) Large Mirror Experiment (III) Large Theta Pinch Experiment (III)
1979–1981	First Experimental Power Reactor (II) Fusion Enginering Research Facility (II)
1980–1982	Second Fusion Test Reactor (III)

Numerals in parentheses indicate the following:

I—Approval, authorization and construction underway

II—Carried in commitment projections

III—Future proposals.

Following is a more detailed discussion of the four Magnetic Fusion activities.

MAGNETIC FUSION
Federal Energy RD&D Budget
($ Millions)

Building Block	FY 1975		FY 1976*		FY 1977	
	BA	BO	BA	BO	BA	BO
Confinement Systems	51.7	46.2	76.9	67.2	88.8	79.6
Reactor Projects	0	0	17.3	5.1	91.8	44.0
Development and Technology	33.0	28.9	41.5	34.7	67.5	49.0
Applied Plasma Physics	33.5	20.2	31.0	37.8	43.0	41.4
Total	118.2	95.3	166.7	144.8	291.1	214.0

* Does not include funds for FY 1976 Transition Quarter.

FUSION POWER R&D

Magnetic Fusion

CONFINEMENT SYSTEMS

Technological Status and Problems

Status:

- Recent experimental results from the 2X–II–B magnetic mirror system at Lawrence Livermore Laboratory, the Ormak at Oak Ridge National Laboratory, and the Alcator at Massachusetts Institute of Technology have brought the program closer to the simultaneous achievement of the number densities, containment times and temperatures required to demonstrate reactor conditions in systems whose characteristics can be predicted with increasing confidence.*

Problems:

- Plasma scaling laws for tokamaks must be determined, stabilization techniques for high-density systems need to be demonstrated, and plasma formation and stabilization techniques for open systems must be developed.

Program Implementation

The primary emphasis is to demonstrate and perfect containment and heating of high-temperature plasma while optimizing the plasma configuration to minimize fusion reactor cost. Three large tokamak experiments will be built and operated by 1980. The high-density (theta pinch) and the open system (magnetic mirrors) options will be further developed. This work is aimed at a possible decision in the 1979–81 period on proceeding with a second fusion test reactor based on one of these concepts. Key steps in this implementation plan are as follows:

FY 1976:

- Begin operating the Princeton Large Torus (PLT) at the Princeton Plasma Physics Laboratory (PPPL) to study scaling in size and plasma temperature.
- Extend confinement time-scaling with temperature in a magnetic mirror. Demonstrate plasma stability in a theta pinch torus or large sector.
- Evaluate progress and prospectives in magnetic mirror and theta pinch programs and determine near-term direction of each.

FY 1977:

- Decide on whether to proceed with the Technology Test Assembly with Plasma, a superconducting tokamak, to demonstrate many of the technologies necessary for an Experimental Power Reactor.

FY 1978

- Initiate operation of the Doublet III at General Atomic Company to study the stability and establish the feasibility of tokamak plasmas with non-circular cross section at reactor-like conditions.
- Initiate operation of the Poloidal Divertor Experiment at Princeton to study impurity control.
- Achieve fusion reactor-like conditions of temperature, density, and confinement time in hydrogen plasmas. These events will demon-

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* "Stabilization of a Neutral Beam Sustained Mirror Confined Plasma," F. H. Coensgen et al. Phys. Rev. Letters *35*, 1501 (1975)

"California Fusion Experiment Reaches Reactor Level Temperature," ERDA News Release No. 75–144, July 30, 1975

"Major Success in Fusion Power Research and Development Announced," ERDA News Release No. 75–227, November 5, 1975

All three experiments were discussed at the meeting of the American Physical Society, Division of Plasma Physics, in St. Petersburg, Florida, November 10–14, 1975. Further details will be published.

strate solutions to the problems of heating and confinement that are the essential goals of this program.

FY 1980:

- Select a concept as the basis for a possible second fusion test reactor.

CONFINEMENT SYSTEMS

Federal Energy RD&D Budget **($ Millions)**

Agency	FY 1975		FY 1976*		FY 1977	
	BA	BO	BA	BO	BA	BO
ERDA						
Operating Expenses	45.6	41.4	68.2	62.1	80.3	74.6
Plant and Capital Equipment	6.1	4.8	8.7	5.1	8.5	5.0
Total	51.7	46.2	76.9	67.2	88.8	79.6

* Does not include funds for FY 1976 Transition Quarter.

FUSION POWER R&D

Magnetic Fusion

REACTOR PROJECTS

Technological Status and Problems

Status:

- An understanding of the behavior of reactor-level hydrogen plasmas and the associated technology has reached the stage at which it is practicable to undertake the design, construction and operation of a Tokamak Fusion Test Reactor (TFTR). The operation of this facility, which will demonstrate fusion energy production from the burning of deuterium and tritium under reactor conditions, will make it possible to extend the transport and scaling laws of fusion reactor physics.

Problems:

- Development of essential components and a major design and construction effort are required to bring the TFTR into operation.
- The construction and operation of facilities capable of producing intense neutron sources are required to obtain needed data on the effects of high-energy neutrons on materials. These problems are elaborated in the Development and Technology building block.

Program Implementation

The FY 1976 budget includes initial funding for design and construction of the TFTR. An ERDA Princeton Area Office has been established with responsibility for project administration, including contracting, for the conventional facilities. Princeton Plasma Physics Laboratory is the prime contractor for management of design and fabrication of the experiment and associated hardware with the assistance of a major industrial subcontractor. The final conceptual design will be completed during FY 1976. Construction is scheduled for completion in about five years.

In most areas, the TFTR design is based on a relatively direct extrapolation of the existing technology. Neutral beam technology and injection systems are being developed under the Development and Technology program to meet TFTR requirements. In initial operation, the TFTR will use hydrogen and deuterium plasma to gain basic physics data and to assure proper operation of all components before proceeding with operation with deuterium and tritium. After completion of construction and checkout, the operation will become the responsibility of the Confinement Systems program.

High-intensity neutron sources will be designed, constructed and checked out in the Reactor Projects program. Then they will be assigned to the Development and Technology program for generation of required materials data.

Milestones

FY 1976:

- Select the architect and engineer and the principal industrial subcontractor for the TFTR.
- Initiate TFTR site work.
- Complete preliminary design of TFTR device.

FY 1977:

- Complete TFTR device final design.

FY 1978:

- Complete construction and checkout of Rotating Target Neutron Source (RTNS) at Lawrence Livermore Laboratory.

FY 1980:

- Complete construction and checkout of Intense Neutron Source (INS) facility at Los Alamos Scientific Laboratory.

- Complete TFTR neutral beam system final design.

FY 1980–81:

- Complete TFTR facilities construction.

FY 1981–82:

- Initiate hydrogen plasma tests in TFTR.

FY 1982:

- Produce 1–10 Megajoule pulses of fusion energy TFTR.

REACTOR PROJECTS

Federal Energy RD&D Budget **($ Millions)**

Agency	FY 1975		FY 1976*		FY 1977	
	BA	BO	BA	BO	BA	BO
ERDA						
Operating Expenses	0	0	2.1	2.0	10.8	10.0
Plant and Capital Equipment	0	0	15.2	3.1	81.0	34.0
Total	0	0	17.3	5.1	91.8	44.0

* Does not include funds for FY 1976 Transition Quarter.

FUSION POWER R&D

Magnetic Fusion

DEVELOPMENT AND TECHNOLOGY

Technological Status and Problems

Status:

- The technologies required for reaching the program objectives on schedule appear to be achievable. Basic principles for the further development of neutral beams, superconducting magnets, tritium handling, etc., have already been established.

Problems:

- The requirements for neutral beams, superconducting magnets, and energy storage systems must be precisely defined so that effective and efficient hardware development can meet the experimental and power reactor goals.
- The technological basis for the engineering of future confinement experiments, fusion test facilities and fusion power reactors must be provided in the near-term.
- Engineering experience is required in the mid-term to design, construct and operate large-scale power reactors.
- Industrial experience and capability needs to be established for the design and fabrication of reactor components and complete reactor systems for the long-term.
- There is a need for long-term development of materials capable of performance adequate to allow the economic production of power from fusion reactors with acceptable environmental impact.

Program Implementation

The Development and Technology program consists of five functional activities or task areas: Plasma Engineering, Magnetic Systems, Materials and Radiation Effects, Fusion Systems Engineering, and Environment and Safety.

Plasma Engineering is directed toward the design and fabrication of the reactor subsystems that heat, fuel, and limit the impurities in the plasma. Neutral particle injection, resonant radio-frequency heating and direct energy conversion systems are under active study. Major emphasis now is on development and testing of high-energy, high-power neutral beams.

Magnetic Systems includes the development of superconductors, superconducting magnets, magnet technology, superconducting energy storage coils and switches, and homopolar energy storage machines. The immediate objectives are the construction and testing of large superconducting confinement magnets for both tokamaks and mirrors, and the fabrication and testing of inertial and inductive energy storage and transfer systems defined by the requirements for each fusion reactor approach.

Materials and Radiation Effects work is pointed toward providing economically and environmentally satisfactory materials that can be used in the fusion radiation environment. At present, this activity is subdivided into six comprehensive and interrelated areas: surface radiation effects; bulk radiation effects; neutron source development; materials selection and development; materials engineering; and dosimetry, damage analysis and simulation. Reactor material development is clearly recognized as a major long lead time effort critical to the ultimate success of the program. Work is underway to satisfy the differing needs of sequential fusion reactor facilities.

Fusion Systems Engineering is structured to integrate fusion reactor concepts and subsystems into composite total reactor designs which will support successive experimental steps leading to commercial fusion power. Now underway are design studies that

address the first experimental power reactor, reactor alternatives and economics, plasma modeling, blanket and shielding, tritium recovery and processing, and prototype reactor fueling and impurity control concepts.

Environment and Safety activities address the early identification and resolution of problems for facilities as they are conceived, designed, built, operated and decommissioned. This activity will continue to assess the environmental implications and the overall safety of all phases of the Fusion program to assure that not only the ultimate fusion power reactor, but also the facilities that will lead up to it, have minimum adverse safety and environmental effect.

Current activities in the Magnetic Fusion program include the preparation of environmental statements and a safety analysis report for each major facility (e.g., the Princeton TFTR and the Los Alamos Intense Neutron Source) and the performance of a comprehensive environmental analysis of the overall fusion program. Studies are also in progress at the National Laboratories and in industry to provide assurances that tritium and neutron activation products associated with fusion can be handled safely and contained with negligible impact on plant employees, the public and the environment. As part of a cooperative program, the ERDA Division of Biomedical and Environmental Research is conducting a $1.5 million per year environmental and safety research program in support of fusion. These studies include such topics as biological effects of magnetic fields and the environmental behavior and the toxicological and metabolic aspects of tritium and neutron activation products.

Following are major milestones projected for this subprogram:

FY 1976:

- Decide to build a superconducting Compact Torus for tokamak superconducting magnet testing.
- Provide 4 MW of neutral beam power on Princeton Large Torus.
- Approve Environmental Impact Statement for TFTR.

FY 1977:

- Operate the Eccentric Coil Test Facility for tokamak superconducting magnets.
- Decide whether to proceed with the construction of Technology Test Assembly for superconducting magnets.

FY 1978:

- Operate the Rotating Target Neutron Source for materials studies.
- Prepare environmental impact statement for Doublet III.
- Prepare environmeental impact statement for the first experimental power reactor.

FY 1979:

- Operate superconducting Compact Torus.

FY 1979–81:

- Initiate operation of Intense Neutron Source for materials testing.
- Decide to build the first experimental power reactor and select from competing alternative conceptual designs.
- Prepare Environmental Impact Statement for the Fusion Power RD&D Program.

FY 1980–81:

- Prove 50 MW of neutral beam power on TFTR.

FY 1985–2000:

- The technology base for reactor engineering will be extensively developed. Industry will have sufficient involvement in component development and reactor technology to be ready to supply subsystems as required for fusion power commercialization.

DEVELOPMENT AND TECHNOLOGY

Federal Energy RD&D Budget **($ Millions)**

Agency	FY 1975		FY 1976*		FY 1977	
	BA	BO	BA	BO	BA	BO
ERDA						
Operating Expenses	30.3	27.6	34.7	31.7	46.2	42.9
Plant and Capital Equipment	2.7	1.3	6.8	3.0	21.3	6.1
Total	33.0	28.9	41.5	34.7	67.5	49.0

* Does not include funds for FY 1976 Transition Quarter.

FUSION POWER R&D

Magnetic Fusion

APPLIED PLASMA PHYSICS

Technological Status and Problems

Status:

- Continuing developments in plasma theory and computer simulation of experiments are providing a greater understanding of existing experiments and a basis for new, larger experiments. The National Controlled Thermonuclear Research Computer Center became operational at Lawrence Livermore Laboratory in FY 1976. Research is continuing on a variety of exploratory concepts that appear to offer attractive potential fusion reactor characteristics.

Problems:

- More complete models of the behavior of plasmas in fusion systems to take into account multi-species, multi-dimensional effects must be developed.
- Advanced concepts must be explored and tested as possible backup and/or improvement over present concepts, or both.
- New diagnostic techniques and methods of plasma heating and production must be developed to meet the needs of future fusion systems.
- Further measurements of the cross sections and properties of atoms, molecules and nuclei are needed for better understanding of the properties of plasmas in fusion systems.

Program Implementation

Theoretical and experimental research is conducted to explore new methods of plasma production and heating; to determine atomic, molecular, and nuclear cross sections specific to the magnetic fusion program; to develop and demonstrate new diagnostic techniques; and to study novel fusion concepts. A substantial part of this work is conducted in universities where it provides a means of training the new scientists that the growth of the fusion program requires. A panel of experts representing all segments of the magnetic fusion program meets annually to identify the program's research needs and to recommend appropriate action plans. These studies are published widely.*

The National Controlled Thermonuclear Research Computer Center and associated user service centers are used for plasma simulations, theoretical calculations and engineering design codes. Ultimately the network will be used to predict operating characteristics of fusion power plants and major subsystems. A substantial increase in computational capability on expected plasma properties will be implemented for the design of further reactor experiments.

Close coordination will be maintained with research communities in government, industry and universities to ensure cross-transfer of results and to avoid unnecessary duplication of effort.

Milestones for Applied Plasma Physics activities follow:

FY 1976:

- Initiate operation of the network and five user service centers associated with the National Controlled Thermonuclear Research Computer Center.
- Decide whether or not to incorporate a Class VI computing capability on the computer network in 1978.
- Complete fabrication of a toroidal plasma de-

* The latest version is *The 1974 Review of the Research Program of the Division of Controlled Thermonuclear Research, ERDA-39,* January 1975, available from National Technical Information Service.

vice to investigate radio frequency and microwave interactions with plasmas at the harmonics of the cyclotron frequency and near the lower hybird frequency, respectively, and to determine the spatial location and relative rates of ion and electron heating.

FY 1977:

- Complete the development of a far infrared laser and detector system to measure ion temperature in high-temperature plasmas.
- Complete the measurements of charge exchange cross sections for carbon, nitrogen, iron, tungsten, and molybdenum for plasma cooling determinations.

FY 1978:

- Complete experimental testing of particle and energy flow into a divertor and refluxing back into the plasma using simulated divertor conditions in a quiescent plasma machine.

FY 1979:

- Complete initial development of a three-dimensional computer simulation capability for application of TFTR and experimental power reactor systems.

APPLIED PLASMA PHYSICS

Federal Energy RD&D Budget *($ Millions)*

Agency	FY 1975		FY 1976*		FY 1977	
	BA	BO	BA	BO	BA	BO
ERDA						
Operating Expenses	22.0	19.9	26.6	24.2	30.7	28.5
Plant and Capital Equipment	11.5	0.3	4.4	13.6	12.3	12.9
Total	33.5	20.2	31.0	37.8	43.0	41.4

* Does not include funds for FY 1976 Transition Quarter.

FUSION POWER R&D

Laser Fusion

Objectives

Near-Term:
(–1985)

- To develop technologies for illuminating nuclear fusion targets with high energy laser, electron, or ion beams.
- To accomplish research and testing needed to demonstrate scientific feasibility of fusion energy by inertial confinement techniques.

Mid-Term:
(–2000)

- To design and develop operating test systems, including critical materials, leading to construction of pilot facilities for net energy production.

Long-Term:
(Beyond 2000)

- To design and construct a demonstration plant to stimulate introduction of fusion technology by the commercial sector.

National Energy Technology Goals Supported

Primary

- Increase the use of essentially inexhaustible domestic energy resources

Secondary

- Perform basic and supporting research and technical services related to energy

Strategy

ERDA will demonstrate the feasibility of inertial confinement fusion by 1985 by demonstrating the scientific feasibility of laser, electron beam, or ion beam-driven fusion implosion. Input power sources will be developed and their suitability for repetitive, on-line operation in civilian power generation wil be determined. Also, input power source technology for application to weapons physics research and weapons effects simulation will be developed.

Inertial confinement fusion technology for commercialization by the year 2000 will be developed by including the development of materials and reactor technology for an experimental power facility, selecting the most suitable input power source among candidate technologies, and by performing system studies for applications engineering to meet economic, safety, and environmental requirements as a competitive energy technology.

Federal Role

Due to the complex interrelationship between the potential military and civilian applications, much of the research program has been conducted within the ERDA laboratories for national security reasons. Means are being devised to broaden the types and numbers of participants in the program and to expand the utilization of formerly classified data in energy research.

Other federal agencies involved:

- Department of Commerce (National Bureau of Standards): Broad laser research for various uses, some possibly applicable to laser fusion.
- Department of Defense (Naval Research Laboratory): Research on the detailed physics of various aspects of laser-matter interactions.

International Cooperation

International cooperation in laser fusion is conducted at an informal level. Nations and organizations involved include the United Kingdom, Germany, France, Italy, Belgium, the USSR, Japan, Australia, Israel, Euratom, IAEA, and IEA.

Technological Status and Problems

Status:

- Progress is being made toward the first goal of significant fusion burn. Consistent prediction of laser induced implosions for the 1.06 micron neodymium glass laser wavelength can be made. Experiments have confirmed theory as shown by the $\sim 5 \times 10^7$ neutrons produced from implosions of deuterium-tritium filled glass spheres. This is about 10^{-6} (one millionth) of scientific breakeven.
- Currently fusion materials being developed are assumed sufficient to satisfy needs until proof of concept is accomplished through the postulated operating test reactor phase, but qualified reactor-grade materials will pace development of the demonstration system.
- Both laser and electron beams have demonstrated capability to induce spherical compressions needed for inertial confinement.

Problems:

- Consistent theoretical models of laser induced implosion for all interesting wavelengths are not available.
- Not all necessary diagnostic instruments and methodology are available to measure and confirm the physical phenomena.
- The next generation of high power, short pulse lasers and multiple electron beam optics for newer electron beam systems with the required efficiency and necessary scalable parameters have not been identified.
- Systems designs for application of the energy available from laser fusion micro-explosions are not complete. Methodology and devices needed to be developed include: simulation facilities, test systems and engineering systems and subsystems.
- Qualified materials development is on the critical path of a demonstration reactor. The currently accepted time to qualify materials is seven to ten years once a multiple pulse test reactor facility is available.

Institutional Status and Problems

Status:

- Information has been declassified which has stimulated expansion of research in industry and universities and has increased exchange of technical information.
- Academia and industries are beginning to submit proposals for research on a cost-sharing basis.

Problems:

- The high risk and large investment required are deterrents to sustained industrial investments on a scale sufficient to carry laser fusion through the research phase of development.
- The interface of proprietary developments with government-funded research poses a management and coordination problem for development of the inertial confinement fusion technology.

Environmental Status and Problems

Status:

- A positive analysis program has begun and environmental protection requirements will be developed, on a required basis, as the technology progresses. Current ERDA procedures and requirements are satisfied due to the very low activation levels observed and envisioned for the next decade.

Problems:

- No major problems have been identified to date.

Program Implementation

Energy Research and Development Administration

Significant thermonuclear yield (one to ten percent of deuterium-tritium fuel in the pellet is consumed) is expected to be accomplished in the FY 1978–1979 period primarily with the Shiva facility. This facility, using neodymium glass elements, will be used to explore optimal target illumination and pellet systems so scaling parameters may be clarified.

A crucial R&D program to develop the laser system for achieving the scientific breakeven (SBE—energy output equals energy deposited on the target) and net energy gain (NEG—energy output exceeds total energy input to the system) milestones is being initiated. This element consists of further theory development followed by spectroscopy and scaling demonstration of candidate laser media.

The simplicity, efficiency, and comparatively low cost of relativistic electron beam generators make this concept promising for fusion application if significantly larger energy densities can be deposited on targets. The Electron Beam Fusion Facility to be completed in 1979 will provide the capability for proving the basic concepts of electron beam pellet compressions for obtaining fusion conditions.

Expanded suporting contracts for R&D in universities and private industry are yielding improved diagnostics, materials and components for the program.

Additional military applications will be developed as identified and defined by the basic research program.

LASER FUSION

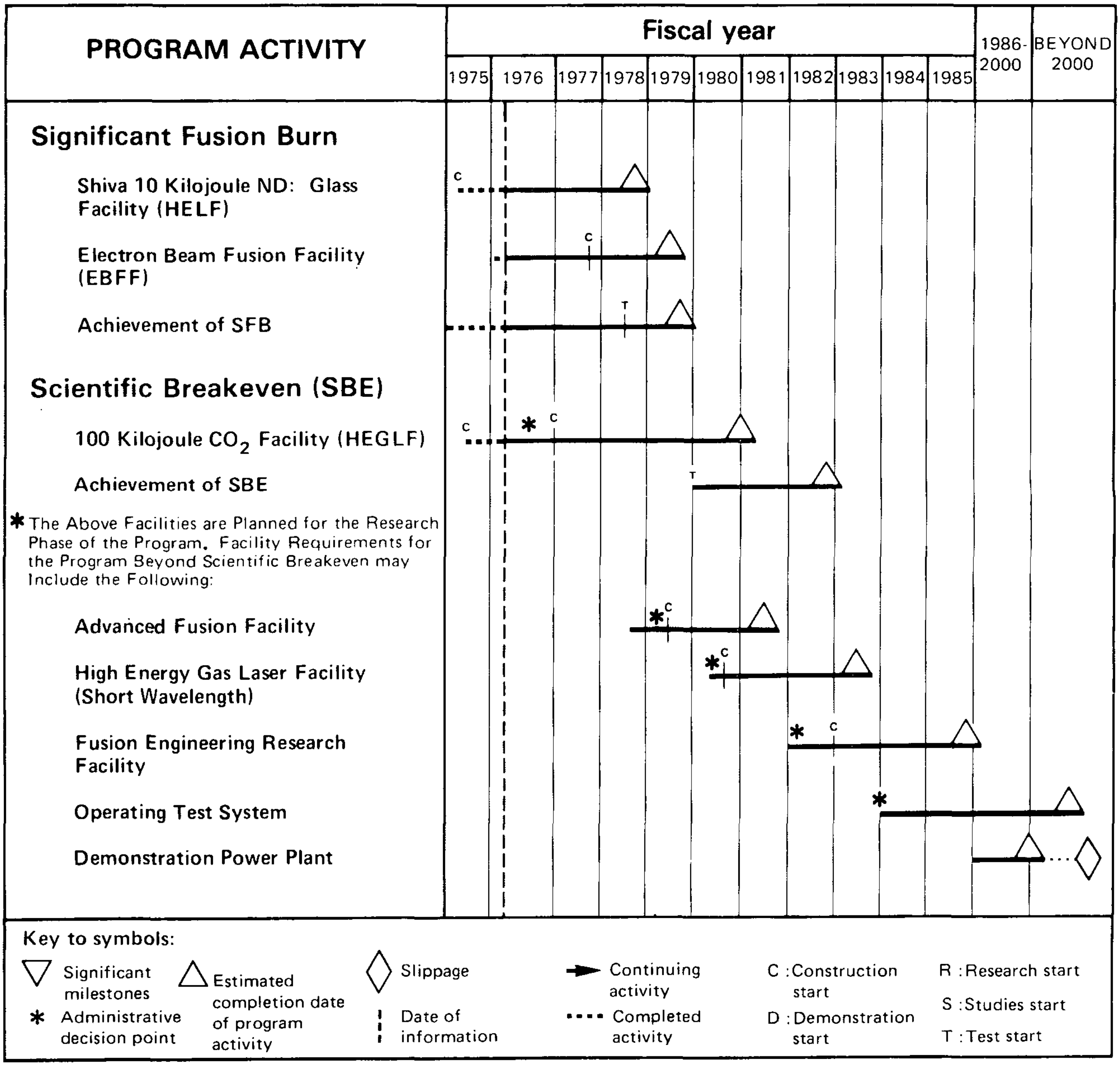
Federal Energy RD&D Budget **($ Millions)**

Agency	FY 1975		FY 1976*		FY 1977	
	BA	BO	BA	BO	BA	BO
ERDA						
Operating Expenses	45.6	43.4	65.5	59.5	71.4	69.3
Plant and Capital Equipment	19.5	12.5	18.1	19.6	29.6	21.2
Total	65.1	55.9	83.6	79.1	101.0	90.5

* Does not include funds for FY 1976 Transition Quarter.

ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION

LASER FUSION



NUCLEAR FUEL CYCLE R&D AND SAFEGUARDS EXECUTIVE SUMMARY

The Nuclear Fuel Cycle Research and Development and Safeguards effort consists of six major program activities: Uranium Resource Assessment; Support of Nuclear Fuel Cycle; Commercial Waste Management; Nuclear Materials Security and Safeguards; Uranium Enrichment Process Development; and Advanced Isotope Separation Technology. A continuing vigorous effort in these activities is required to assure an adequate supply of nuclear fuels, safe and economical reprocessing of spent fuels, acceptable methods for long-term storage of radioactive wastes, and cost-effective safeguards systems for the light water reactor and advanced fuel cycle systems.

The overall fuel cycle program has as its major objectives:

- Completing, as rapidly as possible, a comprehensive national assessment of domestic uranium resources and identifying favorable areas for private exploration to permit private industry to expand exploration and development of uranium resources on a timely schedule.
- Assisting industry, if necessary, in establishing a capability to reprocess and recycle spent fuels from nuclear reactors.
- Developing and demonstrating the required technology for safe and environmentally-sound processing, storage and management of radioactive wastes; and providing the facilities required for storage and permanent isolation of commercially-generated radioactive wastes when federal custody is required.
- Developing and demonstrating cost-effective safeguards systems for the LWR and advanced fuel cycle systems.
- Supporting and encouraging efforts to develop industry capability to enrich uranium in the nuclear fuel cycle.
- Developing advanced uranium enrichment technology for Cascade Improvement and Cascade Upgrading Programs and developing an advanced gas centrifuge technology to make it economically competitive with gaseous diffusion and a viable candidate for early use in expanding the domestic uranium enrichment industry.
- Investigating and developing isotope separation techniques, other than gaseous diffusion or gas centrifugation, which would have the potential of significantly reducing the costs of obtaining enriched materials for a variety of uses.

The primary specific actions which support the achievement of the program objectives are:

- Completing geological and related investigations to identify and assess the nation's uranium resources.
- Supporting the research and development of exploration, mining, and milling technology.
- Soliciting expressions of interest from the nuclear industry to define what incentives may have to be provided by the government and the role of government in assisting industry in establishing commercial light water reactor fuel reprocessing and recycling capabilities.
- Pursuing a broadly-based program of research and development of the chemical processes, systems, and components applicable to the reprocessing, recycling and waste management phases of the LWR fuel cycle.
- Designing, building and operating facilities required for storage and permanent isolation of commercially-generated radioactive wastes.
- Developing and demonstrating efficient and effective safeguards systems, procedures, and techniques for the protection of nuclear facilities and nuclear materials at facilities and during transport.
- Assure transfer to industry of the technology and capability for uranium enrichment through steps such as those in the proposed Nuclear Fuel Assurance Act.
- Continuing an aggressive gaseous diffusion process development effort.

- Incorporating advanced gaseous diffusion technology into Cascade Improvement Program (CIP) and Cascade Uprating Program (CUP) installations scheduled for the late 1970's and very early 1980's.
- Pursuing an aggressive gas centrifuge development, test, and demonstration program.
- Providing ERDA enrichment process development technology to U.S. private industry.
- Establishing the technical feasibility of laser techniques for uranium enrichment and plutonium isotope recovery including, if appropriate, designing, constructing, and operating pilot plants.
- Developing a base of expertise for laser enrichment in private industry.
- Establishing a base of expertise for application of laser techniques to reactor waste processing.

NUCLEAR FUEL CYCLE R&D AND SAFEGUARDS

Federal Energy RD&D Budget

($ Millions)

	FY 1975		FY 1976*		FY 1977	
Building Block	BA	BO	BA	BO	BA	BO
Uranium Resource Assessments	12.3	12.0	24.5	20.4	42.5	36.0
Support of Nuclear Fuel Cycle	17.9	15.5	39.3	34.7	69.5	61.8
Wate Management (Commercial)	11.0	9.8	14.8	13.3	82.3	64.2
Nuclear Materials Security and Safeguards	11.7	8.0	21.3	19.1	37.6	36.3
Uranium Enrichment Process Development	47.1	62.5	54.8	61.0	95.9	68.3
Advanced Isotope Separation Technology	24.0	18.5	32.6	27.6	43.8	39.2
Total	124.0	126.3	187.3	176.1	371.6	305.8

* Does not include funds for FY 1976 Transition Quarter.

NUCLEAR FUEL CYCLE R&D AND SAFEGUARDS

Uranium Resource Assessment

Objectives

Near-Term:
(–1985)

- To complete, as rapidly as possible, a comprehensive national assessment of U.S. uranium resources; to identify favorable areas for private exploration; and to develop improved exploration, resource assessment, and production technologies.
- To conduct geological research in order to aid the private sector in the discovery of uranium and thorium, and to develop and demonstrate mining technologies for the economical and environmentally-acceptable extraction of uranium from new ore types and low-grade deposits that are not economically recoverable by conventional mining methods.

Mid-Term:
(–2000)

- To define and characterize the U.S. nuclear fuel resource base for planning the nation's energy future; to assess the adequacy of nuclear fuel resources to meet demand projections consistent with the role of other energy sources and the breeder reactor; and to permit continuous prediction of the national nuclear energy fuel supply position.

Long-Term:
(Beyond 2000):

- To develop improved processes for economically recovering uranium from new ore types and low-grade domestic ores.

National Energy Technology Goals Supported

Primary

- Expand the domestic supply of economically recoverable energy-producing raw materials.

Secondary

- Perform basic and supporting research and technical services related to energy.

Strategy

The strategy is to develop a reliable estimate of the nation's uranium resources and to enhance the ability to find and produce uranium using several basic approaches which will be carried out concurrently.

An effort will be made to identify an increasing number of areas throughout the country which can be considered favorable for the occurrence of uranium through nationwide geologic, geophysical, geochemical and remote sensing evaluation programs. Supporting R&D will be carried out to improve exploration, mining and milling technologies in conjunction with industry. The program of collecting and analyzing uranium exploration and production data will be expanded to suport a continuing comprehensive resource and supply evaluation. Pertinent information will be made available to the private sector as it is developed.

ERDA will expand its program to assess uranium resources more completely. However, the full responsibility for assuring adequate investment in uranium mining and production capacity expansion is expected to lie with private industry.

There is a need to develop and demonstrate mining methods which promise reduced capital costs, less development time and reduced environmental disturbance and, therefore, offer potential for recovering uranium in currently uneconomic deposits. The strategy is to emphasize field demonstrations of these methods in cooperation with industry.

Federal Role

Government agencies will undertake the major role in uranium resource evaluation and a substantial R&D role in exploration in areas which may not be sufficiently attractive to industry at this time.

International Cooperation

There are currently no formal agreements with other countries for uranium resource development.

However, informal, bilateral cooperation and exchanges of information between ERDA and representatives of foreign governments have contributed to improved resource evaluation, exploration, mining and milling techniques in the U.S. and abroad. In addition, there is close cooperation and a contributing effort on ERDA's part with such organizations as the International Atomic Energy Agency, the European Nuclear Energy Agency, and the International Energy Agency. Joint programs are under consideration for the near future within the framework of one or more of these agencies and with individual countries.

Technological Status and Problems

Status:

- Currently estimated uranium resources available at relatively low cost are adequate to meet near-term requirements.
- Initial efforts are underway to develop and demonstrate new or improved mining and processing methods which are applicable to new ore types and lower-grade domestic ores that are not economically recoverable by current conventional mining methods.
- Technical constraints exist which inhibit the utilization of extensive but very low-grade deposits of uranium in geological formations such as shales and granites.

Problems:

- Additional uranium resources at reasonable costs are needed to meet mid-term requirements.
- Existing uranium resource data are inadequate for sound long-range planning and policy decisions on energy development options and strategies.
- Large areas of the country are inadequately explored and evaluated.
- More efficient and economic mining and processing methods are needed to recover uranium from new ore types and lower-grade domestic ores.
- A new technology is needed to mine and recover uranium efficiently from extremely large quantities of low-grade materials.

Institutional Status and Problems

Status:

- The current level of uranium industry exploration appears inadequate to identify resources which could supply mid-term and long-term demand projections.
- Federal action is currently oriented toward further withdrawal of public lands from mineral entry, thus further restricting lands available for uranium exploration and development.

Problems:

- The risks inherent in uranium exploration and production and the uncertain extent of the uranium market have served to limit the availability of private investment capital.
- The timing and impact of plutonium recycle and HTGR and LMFBR commercialization on uranium requirements are uncertain.
- Large areas of public lands are not available for private uranium exploration.

Environmental Status and Problems

Status:

- Industry is capable of meeting most of the present exploration, mine and mill environmental requirements concerning land disturbance, land rehabilitation, particulate emissions, radiation levels and water contamination.

Problems:

- Industry may encounter increased difficulties in meeting more stringent future mine and mill radiation and effluent standards.
- Major environmental constraints in land disturbance and reclamation, effluents, and solid waste disposal would exist in the mining and processing of extremely large quantities of low-grade materials, such as shales and granites.

Program Implementation

Energy Research and Development Administration

The central element of the ERDA resource effort is the National Uranium Resource Evaluation (NURE) program, a preliminary phase of which will be completed in FY 1976. Contributing and supporting activities include R&D on exploration concepts and technology, assessment technology, and mining and metallurgical methods, particularly those related to the recovery of uranium for new ore types and low-grade deposits. Coordination among government agencies and liaison with the private sector will be maintained to assure maximum availability and transfer of information.

A comprehensive national assessment of domestic uranium resources will be developed by FY

1981 based on aerial radiometric and magnetic surveys, water and stream sediment sampling, satellite imagery evaluation, surface geologic investigation of favorable areas, and drilling for subsurface geologic information in critical localities. Priority will be given to those areas of the country for which geological information indicates the greatest possibility of uranium. Information developed will be released as projects are completed in order to guide and facilitate private exploration. Industry exploration is an indispensable factor in arriving expeditiously at a more complete evaluation of the nation's uranium resource position.

Depending on the rate of resource development relative to projected uranium demand, the NURE program may need to be extended. Interim assessments of the U.S. uranium resource position will be issued as significant new information is developed.

Supporting technology R&D will provide more advanced uranium depositional concepts and geophysical and geochemical procedures and instrumentation which will expedite and enhance exploration and resource development. Utilization of extensive low-grade uranium deposits in geologic formations such as shales and granites will be investigated as alternative sources.

Department of the Interior

The Geological Survey will conduct basic geological studies and R&D on geophysical and geochemical exploration techniques in support of NURE and private exploration, and the Bureau of Mines, independently and jointly with ERDA and/or industry, will carry out R&D on improved uranium mining and processing technology.

Implementation of pilot and full-scale field demonstrations of in-situ and borehole hydraulic mining in cooperation with mining companies will be pursued to determine optimum techniques and demonstrate the technical and economic feasibility of the methods.

URANIUM RESOURCE ASSESSMENT

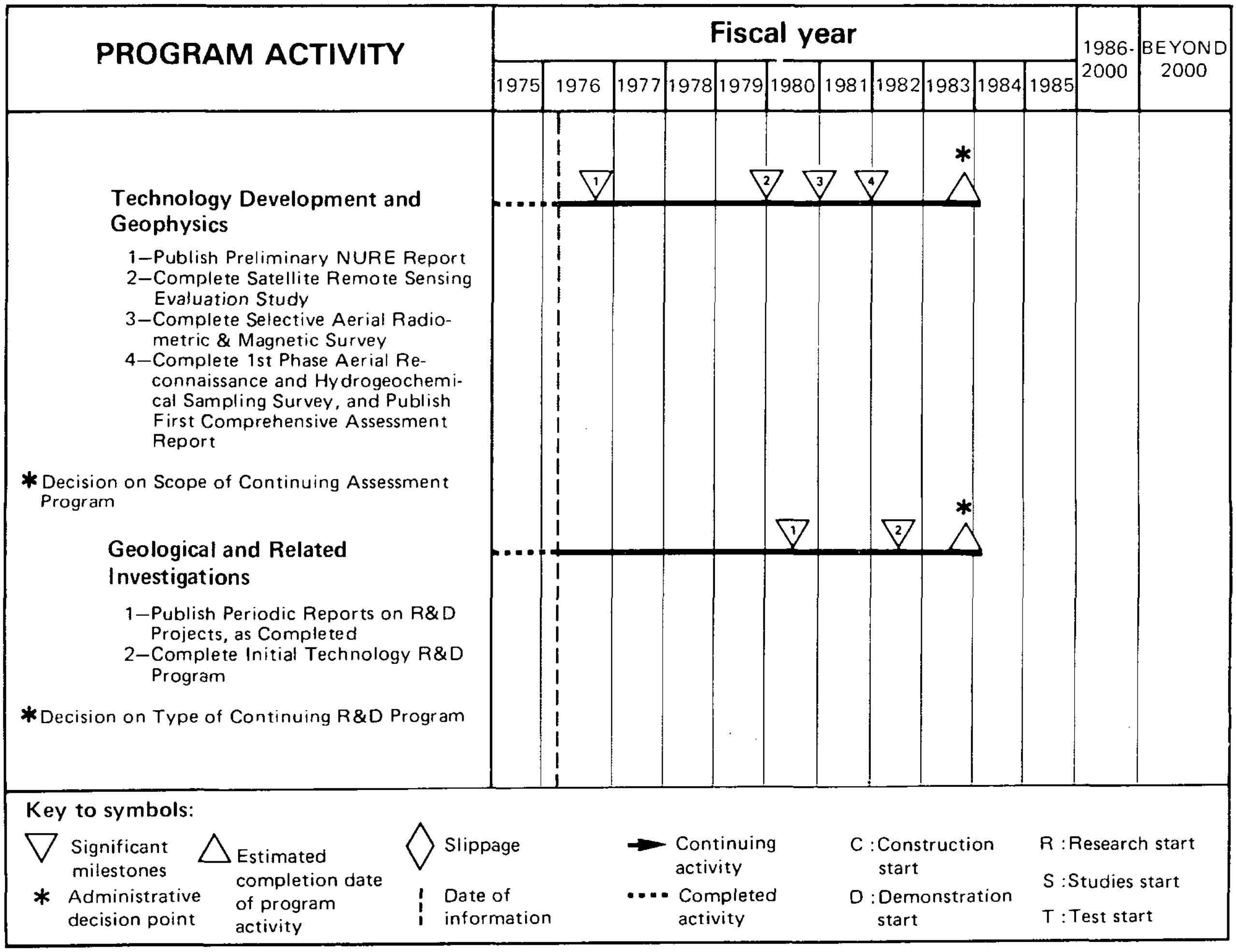
Federal Energy RD&D Budget — ($ Millions)

Agency	FY 1975		FY 1976*		FY 1977	
	BA	BO	BA	BO	BA	BO
ERDA						
Operating Expenses	6.4	6.4	16.8	14.0	31.3	27.0
Plant and Capital Equipment	0.6	0.4	2.1	0.9	5.2	3.1
Total	7.0	6.8	18.9	14.9	36.5	30.1
DOI	5.3	5.2	5.6	5.5	6.0	5.9
Total	12.3	12.0	24.5	20.4	42.5	36.0

* Does not include funds for FY 1976 Transition Quarter.

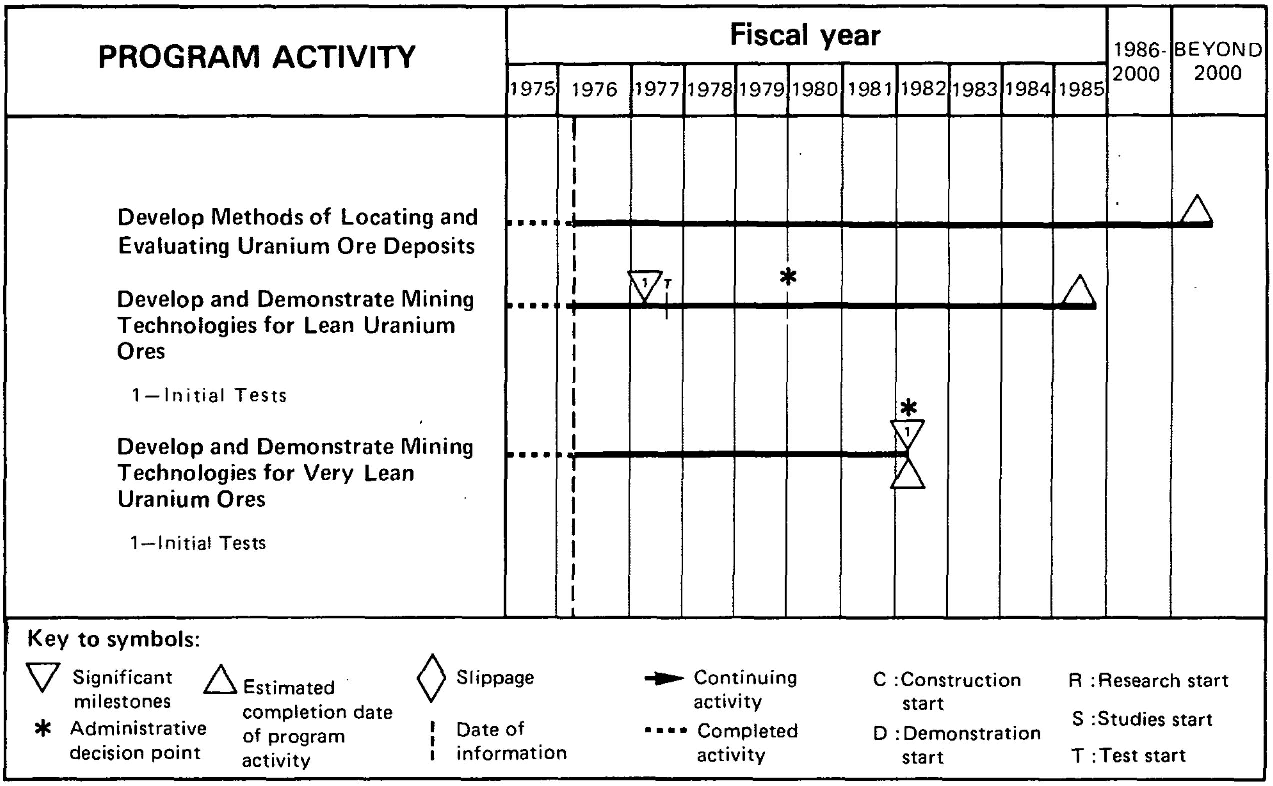
ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION

URANIUM RESOURCE ASSESSMENT



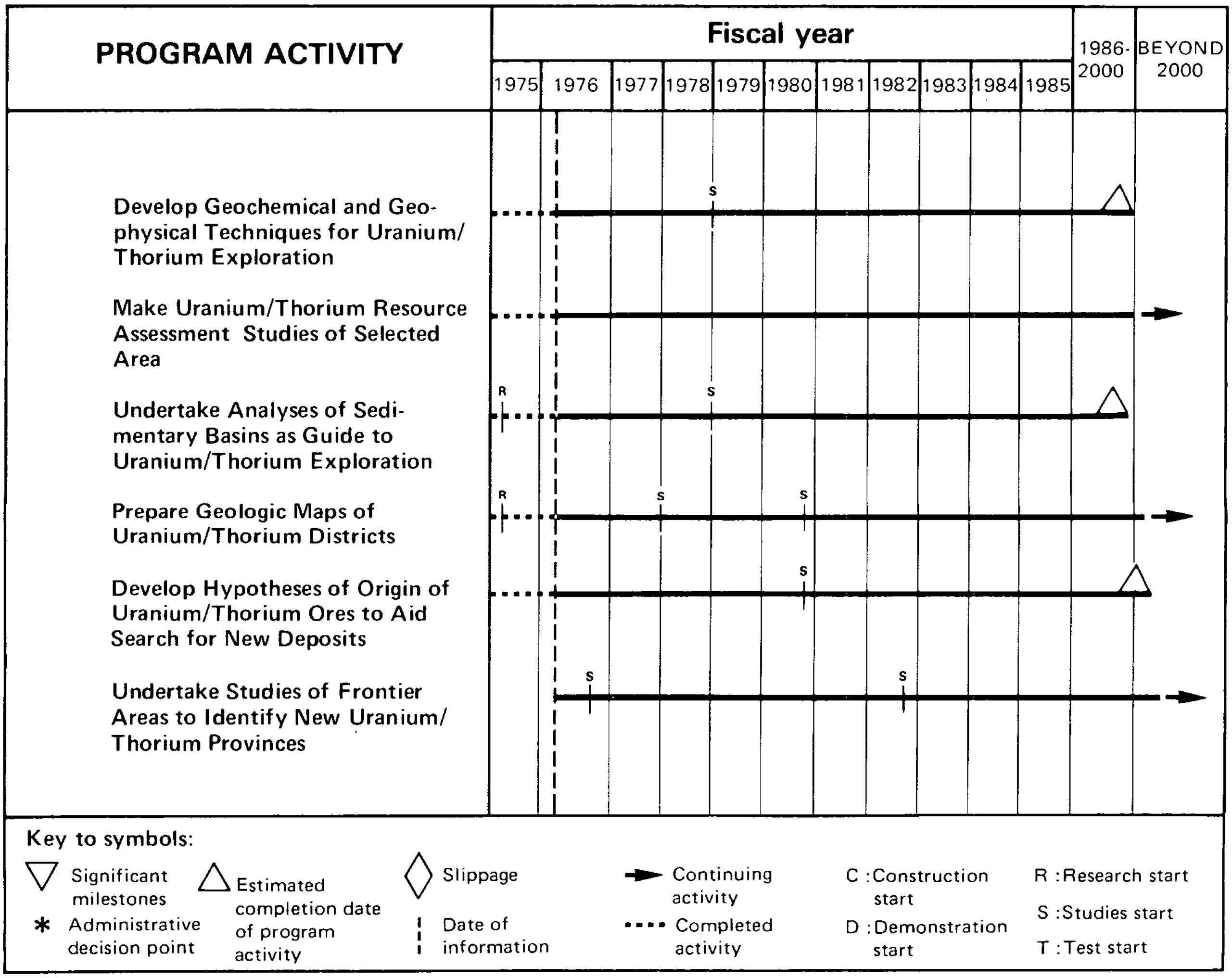
U.S. DEPARTMENT OF THE INTERIOR – BUREAU OF MINES

URANIUM RESOURCE ASSESSMENT



U.S. DEPARTMENT OF INTERIOR – U.S. GEOLOGICAL SURVEY

URANIUM RESOURCE ASSESSMENT



NUCLEAR FUEL CYCLE R&D AND SAFEGUARDS

Support of Nuclear Fuel Cycle

Objectives

Near-Term:
(–1985)

- To support industry in establishing the capability to recycle spent fuels from LWR's at the earliest feasible date.
- To provide a base technology, design studies, and pilot plants for LMFBR, HTGR (if necessary), and other advanced reactor fuel reprocessing and recycling to foster commercialization.
- To determine the ERDA role, if any, in assuring the growth of LWR fuel reprocessing and recycle facilities commensurate with LWR discharges and to maximize fuel recycling.
- To provide assurance of the safety of light water reactor (LWR) fuel cycle facilities. (NRC)

Mid-Term:
(–2000)

- To assist industry in establishing LMFBR fuel recycle.
- To assist industry to establish advanced reactor fuel recycle capability if necessary.
- To provide assurance of the safety of fuel cycle facilities for breeder and alternative converter reactors. (NRC)

Long-Term:
(Beyond 2000):

- To provide safety and control technologies associated with the decommissioning and decontamination of fuel cycle facilities. (NRC/ERDA)

National Energy Technology Goals Supported

Primary

- Increase the use of essentially inexhaustible domestic energy resources.

Secondary

- Increase the efficiency and reliability of the processes used in energy conversion and delivery systems.
- Protect and enhance the general health, safety, welfare, and environment related to energy.

The three fuel cycle support activities—Light Water Reactor, High Temperature Gas Cooled Reactor and Liquid Metal Fast Breeder Reactors—are discussed individually below.

LIGHT WATER REACTOR (LWR) FUEL CYCLE

Strategy

ERDA will recommend by the end of 1976 what, if any, government actions and types of assistance are appropriate in a program to demonstrate closing the fuel cycle (reprocessing and recycle facilities), which includes determining the appropriate means by which this can be accomplished. It is ERDA's intent to identify the minimum federal support required to provide for demonstration of all phases of reprocesing and recycling. ERDA options could include participation in and support for technology development, government guarantees of loans, insurance against extraordinary risks, etc.

NRC and ERDA are conducting necessary research to ensure that the licensing of fuel cycle facilities is founded on solidly-supported technical information. Initially, priority will be given to projects related to the light water reactor fuel cycle.

Federal Role

To assist in the initiation of commercial capabilities for: nuclear fuel reprocessing and recycling facilities, including facilities for spent fuel reprocessing; conversion of recovered uranyl nitrate to uranium hexafluroide; conversion of plutonium nitrate to solid form; fabrication of mixed oxide fuel assemblies; and treatment of high-level radioactive wastes prior to their delivery to the federal government.

Industry, universities and ERDA laboratories wil participate in the research and development effort required.

The ERDA effort will be coordinated with NRC, FEA, EPA, and DOT and other government agencies which interface with the ERDA program.

International Cooperation

No significant programs of international cooperation among domestic facilities and their foreign counterparts exist for the post-irradiation parts of the nuclear fuel cycle program. Technical liaison, to the extent possible, is maintained among the staffs at the ERDA National Laboratories and ERDA contractors and their counterparts in Great Britain, France, Belgium, Germany, Italy, Japan and India.

The NRC cooperates with the International Atomic Energy Agency, the International Standards Organization and other international organizations in nuclear safety and regulatory matters. The NRC has bilateral agreements with Denmark, Federal Republic of Germany, France, Italy, Japan, Spain, Sweden, Switzerland and the United Kingdom to exchange regulatory and safety information. Technical reports and visits by experts are exchanged with Federal Republic of Germany, France, Italy, Japan and Sweden.

Technological Status and Problems

Status:

- In the LWR fuel cycle there are currently no reprocessing and recycling facilities in operation. The Barnwell Nuclear Fuel Plant, being built by Allied-General Nuclear Services to reprocess 1500 MTU/yr, is undergoing licensing review and analysis at this time (a license may be granted during 1977). Nuclear Fuel Services is planning to modify its plant at West Valley, New York, to increase its capacity and upgrade the facility. However, it is not expected to be licensed and in operation for several years. General Electric does not consider the Midwest Fuel Reprocessing Plant to be operable in its current configuration.
- Lack of fuel recycle capability has resulted in increases in future requirements of uranium feed for enrichment and has discouraged some electric utilities from choosing the nuclear power option for new plant capacity. Additional storage space for spent LWR fuel will be required in the near-term.
- No commercial-scale capability for fabricating mixed oxide fuels using recycled plutonium is operable today. Pilot-scale operations, using "low exposure plutonium," have fabricated experimental quantities of mixed oxide fuel for demonstration of plutonium recycling in LWR'S.
- Facilities needed for the testing of accident probability models and control technologies are being evaluated and designed.

Problems:

- In the event of malfunction or failure of equipment located in areas of penetrating radiation, significant downtime to perform maintenance/replacement by contact maintenance methods may be required.
- The technology for the solidification of high-level wastes and the handling of other wastes from nuclear fuel recycling facilities is currently being developed for application to commercial utilization, but this technology has not been demonstrated on a large scale.
- The development and experimental verification of probabalistic models of fuel cycle processing accidents need to be done.
- Safety and control technologies associated with the decommissioning and decontamination of fuel cycle facilities need to be developed.

Institutional Status and Problems

Status:

- Regulatory decisions regarding the recycle of plutonium are still to be made.
- Presently, requirements and criteria for licensing are not sufficiently well defined to permit broad and timely application of LWR fuel cycle technology.

Problems:

- The capital equipment for commercial facilities are large and uncertain. The uncertainty in the performance of reprocessing facilities constitutes financial risks that are considered excessive in normal industrial practices at this time.
- Evolving technologies which result in changing regulations during the plant construction phase have had serious impact on the commercialization of fuel reprocessing and recycling technology.

Environmental Status and Problems

Status:

- The draft Generic Environmental Statement of Mixed Oxide Fuel (GESMO) recycle issues has been issued.
- The Nuclear Regulatory Commission has announced procedures for deciding, possibly by early 1977, whether to permit wide-scale use of plutonium mixed with uranium to fuel nuclear plants and the procedures for related interim licensing activities pending that decision.

Problems:

- The GESMO recycle issues (i.e., acceptabilities of the environmental impact, physical protection of fuel materials and facilities and accountability/control for mixed oxide fuel recycle) must be resolved by the Nuclear Regulatory Commission.
- Because of the uncertainty in the safeguard issue, the final GESMO will not be issued until 1977.

Program Implementation

- Provide assistance leading to the demonstration by industry of reprocessing LWR fuels to recover special nuclear materials and to recycle these materials in LWR reactors.
- Instigate a broadly based program of research and development in reprocessing and recycling technology in government and industrial laboratories.
- Coordinate effort with NRC, FEA, EPA, DOT and other appropriate government agencies.
- Solicit and evaluate industrial expressions of interest for ERDA assistance in the development of fuel reprocessing and recycling operations.
- Request proposals for government assistance in the design, construction, and operation of recycle facilities, as required.
- As warranted, select one or more proposals on the basis of the level of industry participation and contribution that would be made to achieving spent fuel recycle capabilities.

The major phases and timetable for carrying out the program strategy in the period 1976–1979 are:

1. In the remainder of FY 1976, ERDA will initiate, in government, industry, and university facilities, programs of research and development in processes, systems, and components associated with fuel recycle technology. Studies will be conducted to evaluate recycle economics, environmental effects, engineering concepts of recycle facilities, etc.
2. ERDA will solicit industrial expressions of interest for ERDA support for industrial projects for fuel recycle facilities and evaluate these expressions of interest to serve as a basis for formulating a "Request for Proposals (RFP)." If industry indicates, and ERDA agrees that ERDA support is needed, appropriate legislative action and identification of the program to the public will follow.
3. ERDA will solicit and evaluate the RFPs, develop an ERDA and industry plan, which may result in requesting funds from Congress to support the projects.
4. ERDA will cooperate and coordinate its planned R&D with NRC to assist NRC's development and reprocessing facilities.
5. A major effort is being placed on risk assessments for light water reactor fuel fabrication and reprocessing facilities. (NRC)
6. Analyses are in progress to identify the potential for and consequences of abnormal or accident situations during LWR fuel fabrication and reprocessing. (NRC)
7. Projects are to be conducted to identify and characterize normal plant effluents and to evaluate the effectiveness of proposed control technology. (NRC/ERDA)

In the period 1980 and beyond:

1. ERDA will continue to assess fuel reprocessing and recycling technology to determine areas of investigation which may arise through commercial application.
2. A joint program with industry which will result in design, construction, and operation of reprocessing and recycling facilities will be implemented as appropriate.
3. Consistent with the above, NRC will complete the licensing review process, publicly announce intent to issue an operating license, hold any hearings required, and issue an operating license.

HIGH TEMPERATURE GAS COOLED REACTOR (HTGR) FUEL CYCLE

Strategy

ERDA will support commercialization of steam cycle HTGR's and development of advanced gas cooled reactors, as a part of developing and demonstrating on a commercially-applicable scale, the technology needed to close the HTGR fuel cycle. The demonstration facility, in addition to providing technology to industry, will furnish early recycling services to HTGR's and, if feasible, will later be sold or leased to industry for expansion and continued operation. ERDA will make appropriate settlement for fissile materials contained in spent fuels with owners of these materials, and will make reverse settlement by returning these materials or their equivalent to the original owners.

Since the direction and timing of the HTGR steam cycle commercialization program is uncertain, the proposed fuel cycle program will remain flexible pending decisions on the future direction of the reactor program.

Key decision points and options available are:

To complete reassessment of the HTGR steam cycle commercialization schedule and prospects in late 1976. Options are to continue the program of providing a base technology to foster commercialization as provided herein or to modify it, if necessary.

To commit to demonstration facility architect-engineer design in late 1979. Options are to request construction funds or to postpone or eliminate the facility as HTGR commercialization prospects indicate.

To commit to demonstration facility construction (FY 1984 project) in late 1982. Options are to request construction funds or to postpone or eliminate the facility as HTGR commercialization prospects indicate.

To initiate actual construction of a demonstration facility in late 1983. Options are to initiate construction as scheduled, to postpone or modify project, or to rescind project funds as HTGR sales indicate.

NRC is to conduct research to ensure that the licensing of HTGR fuel cycle facilities is founded on solidly-supported technical information.

Federal Role

The necessity for federal participation arises from commercial uncertainties and financial risks associated with the new technology which has prevented any effective commercial involvement. Federal participation in HTGR recycle development encompasses all necessary efforts to develop recycle processes and components, to design, construct and operate a major demonstration facility, and to provide future settlement or recycle services up to an early stage of HTGR commercialization. Industry is expected to assume responsibility by purchasing or leasing the demonstration facility after about five years of operation, by expanding the facility to meet increasing fuel element discharges, and by providing follow-on facilities on a commercial basis as needed.

As technological success is realized in this program, it is expected to be reflected in a more favorable climate for HTGR commercialization and, in turn, a greater incentive on the part of industry to enter into recycle operations.

International Cooperation

Development of the HTGR and the HTGR fuel cycle is also being conducted by the Federal Republic of Germany (FRG). A bilateral exchange arrangement is in force with FRG, and discussions to extend the scope of this bilateral exchange are underway. Such an extension contemplates a cooperative program with both parties participating in the conduct and funding of program activities and both having access to the ERDA demonstration facility for the purpose of handling early recycle requirements.

Technological Status and Problems

Status:

- Process flowsheets have been established for fuel reprocessing and refabrication. Development of equipment components is underway.
- Conceptual design of pilot plant facilities has been completed and a cold reprocessing pilot line is being installed. Options are being evaluated on hot subsystems testing and demonstration facility requirements in terms of scope and timing.

Problems:

- The technology required for HTGR fuel cycle has not been demonstrated on any scale as an integrated system. Commercial scale demonstration of this technology is essential to commercialization of HTGR's. Demonstration requirements include remote process operation and equipment disposal of radioactive wastes, and nuclear material accountability and safeguards assurance.

- Technology for the treatment and disposal of high-level radioactive wastes from the process must be developed.
- Procedures and equipment must be developed by product analysis and inspection, quality assurance, and environmental protection.
- Acceptability and performance of recycle fuel must be established through a supporting fuel irradiation and evaluation program.

Institutional Status and Problem

Status:

- HTGR's are characterized by an uncertain prospect for steam cycle commercialization. This uncertainty directly affects the scope and timing of ERDA's activities toward HTGR fuel recycle demonstration.
- The current Chemical Processing Policy, for receipt and settlement of spent HTGR fuel until the time that recycle services are available, expires on December 31, 1983.

Problems:

- The Chemical Processing Policy needs to be extended beyond 1983 because recycle facilities will not be available until the early 1990's.

Environmental Status and Problems

Status:

- Environmental assessments of HTGR fuel recycle operations have been made, and impact statements have been approved and issued for hot fuel reprocessing and refabrication pilot plants assumed to be located at designated ERDA sites.
- Process designs have been carried to a point where basic feasibility is indicated. These evaluations and designs will serve as the basis for extrapolation to the environmental assessment of commercial-scale process demonstration recycle facilities.

Problems:

- Process technology development and demonstration of the environmental effectiveness of the processes in commercial-scale facilities needs to be accomplished.
- Safe disposal of C^{14} needs to be demonstrated.
- Long-term storage of waste needs to be demonstrated.

Program Implementation

Assuming affirmative decisions to proceed with the commercialization of the HTGR program have been made, the following program implementation schedule would be carried out.

Near-term: The government would conduct laboratory and cold prototype development through FY 1982; install and conduct component hot-cell tests through FY 1984; design an expandable HTGR Recycle Demonstration Facility (HRDF) through FY 1985; and construct HRDF 1984–1987.

Mid-Term: The government would conduct cold and hot checkout of HRDF in the 1988–1991 period; and carry out operation of HRDF in the 1991–1995 period. Industry would design and construct expansion of HRDF in the 1984–1994 period; buy or lease HRDF and continue operation from FY 1995 on; and provide follow-on recycle facilities in the late 1990's.

The anticipated output of this program includes solution of technical impediments, successful operation of a demonstration plant, and early provision of recycle services in accordance with the time-table shown above. Decision points exist through FY 1983 where options with regard to the demonstration plant can be followed depending upon the status of HTGR steam cycle commercialization. The point of active industrial participation begins in the mid-1980's with initiation of the design of demonstration plant expansion. Full industry participation is achieved in FY 1995 with industrial purchase or lease and continued operation of HRDF. The program is intended to provide the criteria and technology for safety evaluation and licensing by NRC.

LIQUID METAL FAST BREEDER REACTOR (LMFBR) FUEL CYCLE

Strategy

The government will carry the main burden of developing the base LMFBR reprocessing technology through the pilot plant stage. Industry participation in the base technology program, primarily for training professional staff, will be encouraged. As the program advances toward the demonstration phase of commercialization, the development will be shared with industry. Activities will be centered on large plant design studies, large-scale equipment component testing, development of equipment suppliers, development of safeguards procedures, and analysis of health and safety measures.

Federal Role

In view of the long lead time required for development of the LMFBR reprocessing technology prior to the time that commercial incentives exist, federal support is required for the base technology development through the small-scale pilot plant phase. The Oak Ridge National Laboratory (ORNL) has been the principal contributor to this phase of the development and will continue in this role through the pilot plant testing. Assistance from other National Laboratories and ERDA spent fuel reprocessing sites may be solicited in special areas. Industrial participation will be through study subcontracts and the assignment of industry personnel to the National Laboratory staff. Nuclear Regulatory Commission assistance will be sought in establishing the licensability of demonstration facilities where appropriate.

Industry expenditures are not expected to be significant until the large scale engineering development phase.

International Cooperation

Development activities related to breeder reactor fuel reprocessing are underway in France, Germany and England. Liaison is maintained with participating organizations in these countries.

Technological Status and Problems

Status:

- While a viable LWR reprocessing industry will provide vital technology and experience, the special characteristics of spent LMFBR fuels are such that several aspects of the established aqueous reprocessing technology must be significantly modified. Process and equipment concepts have been defined through studies and laboratory/bench scale/hot-cell experiments.

Problems:

- Successful performance of process and equipment concepts for LMFBR reprocessing requires extensive engineering development as well as testing on both a hot pilot plant and near commercial-scale.

Institutional Status and Problems

Status:

- There is no commercial interest in developing LMFBR fuel reprocessing at this time.

Problems:

- Until commercial interest emerges, definition of problems is premature.

Environmental Status and Problems

Status:

- An environmental impact assessment of a model commercial LMFBR reprocessing plant has been published as a part of the LMFBR program environmental impact statement.
- Backup data for environmental impact assessments are being obtained from the development program.

Problems:

- No major environmental problems are expected in the near- or mid-term developmental periods. For the long-term, public acceptance of safeguards procedures and effluent controls for the large quantities of plutonium involved in the LMFBR fuel cycle must be assured before commercialization of LMFBR reprocessing can materialize.

Program Implementation

A base technology for LMFBR reprocessing is being implemented through a laboratory process development program at the National Laboratories.

Authorization for a small-scale pilot plant (an FY 1981 construction project) to process the fuels discharges from the Fast Flux Test Reactor and Clinch River Breeder Reactor will be sought. The pilot plant is expected to be operational in FY 1988.

Industry participation will be sought in FY 1978 to conduct a conceptual large-scale plant study and to perform large-scale equipment component development. Industry investment in a facility for testing large-scale components will be sought in FY 1979, but industry funding of the test program is not expected. These combined activities will will provide data from which early projections of LMFBR fuel cycle economics and overall breeder power plant potential can be assessed.

The mid-term program objectives (–2000) are to be implemented through a progression of process development and demonstration activities, starting with the operation of a pilot plant in the 1988–1993 period, commercial plant prototype component development and testing during the period 1982–1990, and culminating in the design and construction of the first commercial-scale plant in the period 1990–1997.

Tasks are to be undertaken by NRC on the thorium and plutonium fuel cycle facilities for the decommissioning and decontamination of fuel cycle facilities, and those required to ensure that the licensing of such facilities will be founded upon solidly-supported technical information.

SUPPORT OF NUCLEAR FUEL CYCLE

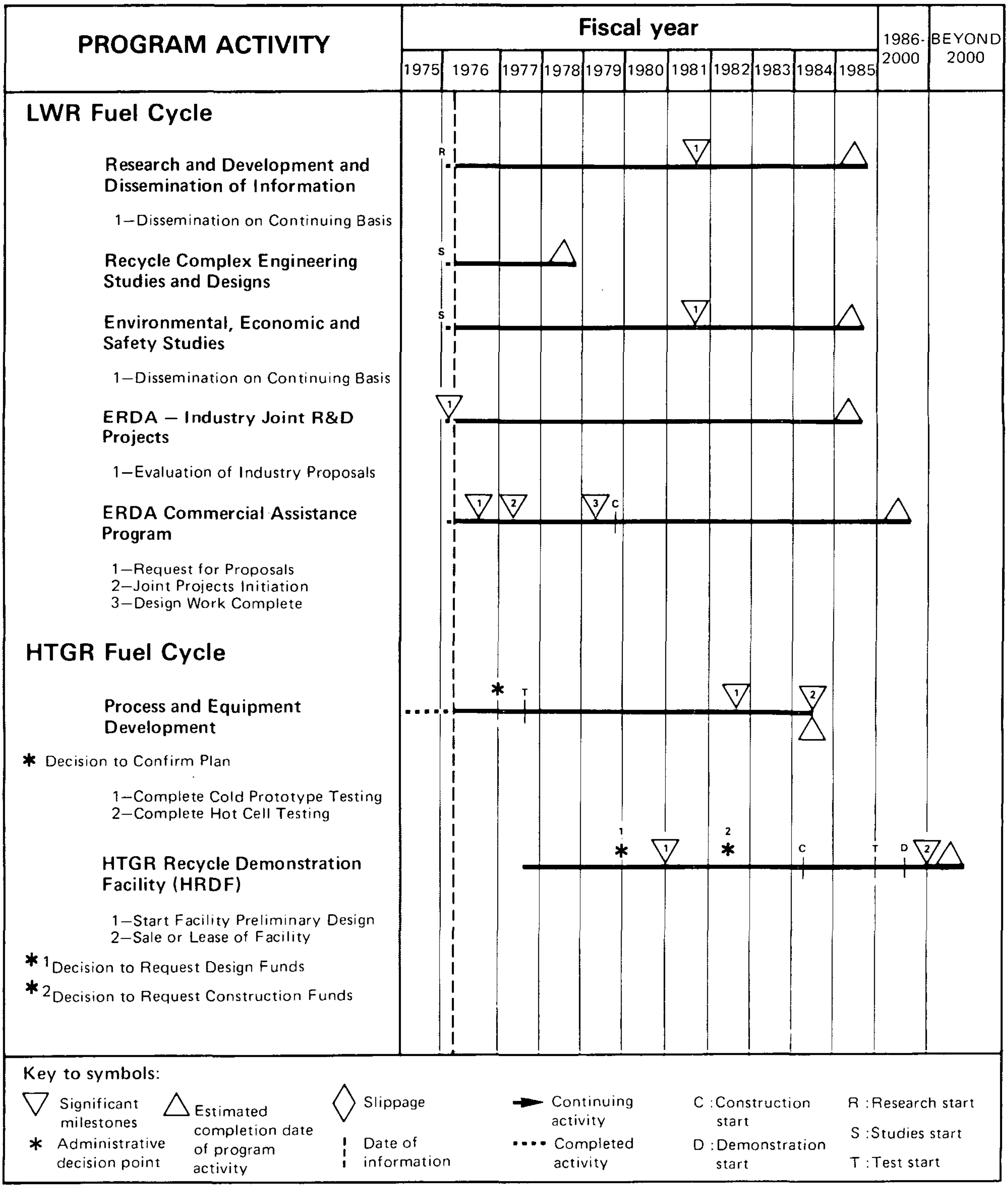
Federal Energy RD&D Budget **($ Millions)**

Agency	FY 1975		FY 1976*		FY 1977	
	BA	BO	BA	BO	BA	BO
ERDA						
Operating Expenses	17.1	15.1	35.5	31.1	56.7	51.8
Plant and Capital Equipment	0.8	0.4	0.9	0.9	4.8	2.4
Total	17.9	15.5	36.4	32.0	61.5	54.2
NRC	0	0	2.9	2.7	8.0	7.6
Total	17.9	15.5	39.3	34.7	69.5	61.8

* Does not include funds for FY 1976 Transition Quarter.

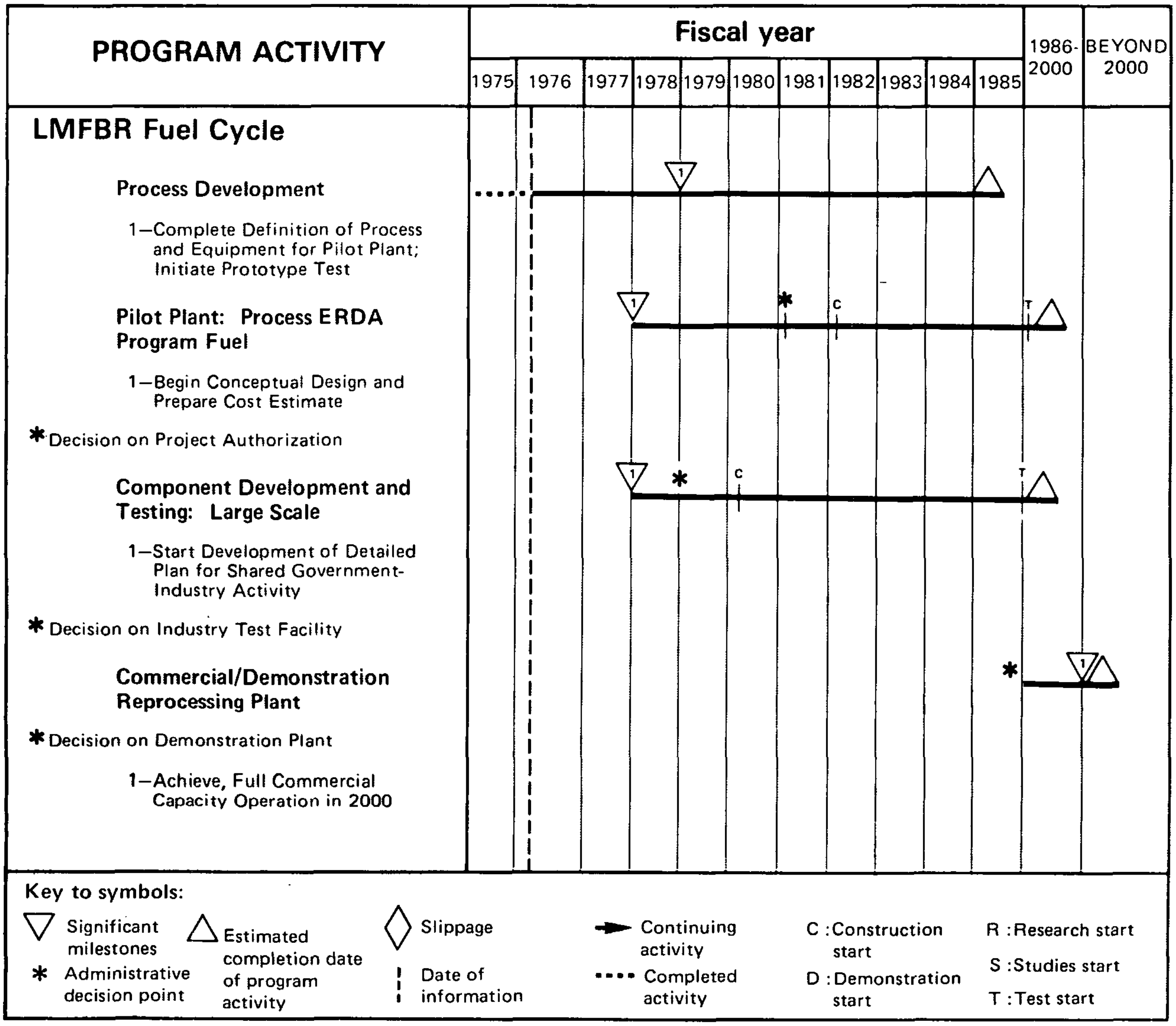
ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION

SUPPORT OF NUCLEAR FUEL CYCLE



ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION

SUPPORT OF NUCLEAR FUEL CYCLE (continued)



NUCLEAR FUEL CYCLE R&D AND SAFEGUARDS

Waste Management (Commercial)

Objectives

Near-Term:
(–1985)

- To demonstrate the technology required for processing, storage, and management of radioactive wastes as early as possible in order to assure the safe and environmentally sound expansion of nuclear power.
- To design, build, and operate the facilities required for storage and permanent isolation of commercially generated radioactive wastes where federal custody is required.
- To perform the necessary confirmatory research and development to provide a sound technical basis for regulation of the handling and disposition of wastes from the processing and use of nuclear fuels. (NRC)
- To evaluate the environmental geologic adequacy and integrity of land-fill sites for low-level radioactive waste disposal. (DOI)
- To determine mechanisms and methods of radioactive release and migration. (DOI)
- To develop geologic and environmental criteria and guidelines for low-level radioactive waste disposal methods. (DOI)

Mid-Term (–2000) and
Long-Term (Beyond 2000):

- To manage the long-term storage of radioactive wastes so that environmental and public health standards are met; to provide and operate the facilities required for the storage and permanent isolation of commercially-generated radioactive wastes where federal custody is required.

National Energy Technology Goals Supported

Primary

- Protect and enhance the general health, safety, welfare and environment related to energy.

Secondary

- Perform basic and supporting research and technical services related to energy.

Strategy

By use of basic geological science and established geological exploration technology, identify one or more sites for the permanent geological isolation of waste.

Evaluate the geohydrologic adequacy of the land-fill type of low-level solid radioactive waste disposal. (DOI)

Develop generic models to predict optimum hydrologic and geologic conditions for disposal of such wastes. (DOI)

Assess the potential for the disposal of low-level liquid radioactive wastes in the hydrologic environment. (DOI)

Working with industry as appropriate, develop various laboratory- and pilot-scale waste solidification and other treatment techniques to the point of full-scale industrial reliability.

Using available technology for handling large radioactive material inventories, establish one or more retrievable storage repositories if federal custody of commercial waste is required prior to the availability of permanent storage.

Federal Role

Government acceptance and storage of high-level radioactive wastes from commercial fuel reprocessors is required by *10/Code* of *Federal Regulations 50, Appendix F*. Proposed changes to *10 CFR 20* would require the government to accept virtually all fuel reprocessing radioactive wastes.

The federal government, through the NRC, is responsible for the licensing and verification of the safety in the handling, transport and disposition of materials from the nuclear fuel cycle.

The federal government, through the DOI, has a continuing program oriented toward the study of principles and process of groundwater movement.

International Cooperation

Technical liaison is maintained between ERDA and various international nuclear energy organizations (IAEA/UN, NEA, OECD, and IEA/OECD) with respect to current developments in waste management practices. This has been carried out primarily through visits and exchange of selected technical reports with the United Kingdom, France, Federal Republic of Germany, Canada, Russia, and Belgium.

The NRC cooperates with the International Atomic Energy Agency, the International Standards Organization and other international organizations in nuclear safety and regulatory matters. The NRC has bilateral agreements with Denmark, Federal Republic of Germany, France, Italy, Japan, Spain, Sweden, Switzerland and the United Kingdom to exchange regulatory and safety information. Technical reports and visits by experts are exchanged with Federal Republic of Germany, France, Italy, Japan, and Sweden.

Technological Status and Problems

Status:

- Adequate technology for retrievable storage of solidified high-level waste exists. The massive base of technology is documented in a comprehensive report entitled, "Alternatives for Managing Wastes from Reactors and Post-Fission Operations in the LWR Fuel Cycle" (ERDA 76-43).
- The only generic solution for maintenance-free management of such waste, which appears practical now, is placement in a stable geological formation at depths reachable by conventional mining methods.
- An interagency task force has been established to assure coordination of the activities which are being carried out by the responsible federal agencies toward having the needed disposal systems in operation by the mid-1980's when the first significant quantities of solidified high-level waste will be produced.
- Four field investigations of waste migration are underway at low-level, solid radioactive waste disposal sites. (DOI)
- Existing hydrologic data on the Nevada Test Site is being compiled. (DOI)
- A potential site for low-level liquid radioactive waste is being evaluated. (DOI)

Problems:

- Actual waste from commercial fuel reprocessing operations is not available since no reprocessing plants will be operating for the next several years.
- Immobilization of high-level waste to a solid form for handling transport and isolation operations requires high-temperature, fully remote operations not yet demonstrated on an extended basis with full-strength wastes.
- Specific sites for geologic isolation have not yet been idenitfied.
- Methods for fixation of iodine, noble gases and tritium in solid form will be needed should NRC regulations be changed to preclude their release to the environment.
- Improved methods for passivation of combustible contaminated wastes are needed to reduce volume and improve the margin of safety against radioactivity dispersion in case of fire.
- Models must be developed which simulate waste storage and transportation conditions and laboratory tests devised to confirm them. (NRC)
- A technology must be developed that leads to minimization of packaging required for waste storage and transport.
- A definition is needed of how to safely handle new materials from advanced reactor technologies, especially radioactive gases. (NRC)
- Technology and geological requirements for permanent storage of fuel cycle wastes must be established. (NRC)

Institutional Status and Problems

Status:

- NRC is responsible for licensing waste storage sites.

Problems:

- Government-industry cooperative arrangements are needed to demonstrate and promote adoption of required techniques of waste treatment.
- There are no detailed specifications for the characteristics of radioactive wastes or their packaging for delivery to the federal repositories.
- Public and local government acceptance of radioactive waste disposal concepts and opera-

tions, which is essential, is often difficult to achieve.

Environmental Status and Problems

Status:

- Site selections are now in progress for facilities for terminal storage of commercial radioactive wastes.
- Preparation of a generic Waste Management Environmental Impact Statement is underway.
- Current methods for the storage of radioactive wastes comply with environmental requirements.

Problems:

- Radioactive waste storage and/or isolation sites require careful site selection to prevent possible contamination and exposure of the population and the surrounding environment. Site specific environmental impact statements will have to be prepared to detail the likely impacts and how they differ at proposed sites.

Program Implementation

Studies to establish (or recommend to NRC) criteria for waste form and packaging are targeted for completion by 1978.

The planned sequence of development of permanent geological isolation of waste is: (1) review of available geological literature on the availability of several types of promising formations in the U.S.; (2) core drilling at a number (perhaps 20 to 25) of good potential areas; (3) in-situ inspection of about five of the best of these areas, perhaps requiring new excavation; (4) construction of one or more repositories for test emplacement of waste; and (5) conversion of repositories to permanent status contingent on successful completion of the test period. Expansion of this program in FY 1977 is targeted at beginning the test emplacement of waste by the mid-1980's.

Work on calcination vitrification techniques for high-level liquid waste is targeted for starting of industrial plant-scale testing by 1978.

Development work on incineration or other fixation of trans-uranium-contaminated waste is aimed at having a method or methods available for industry use by the late 1970's should such treatment be required or be advantageous from a volume reduction standpoint.

Development work on the removal and fixation of certain gaseous or volatile radionuclides from airborne effluents is aimed at having the technology ready for industry use by the late 1970's should new NRC regulations require such effluent clean-up.

Various storage options are being assessed with the objective of minimizing the space required for permanent storage. (NRC)

New field investigations are to be conducted at low-level radioactive waste disposal sites which have different geohydrological environments. (DOI)

Data on potential sites for low-level liquid radioactive waste storage are being evaluated to select a potential test injection site. (DOI)

WASTE MANAGEMENT (COMMERCIAL)

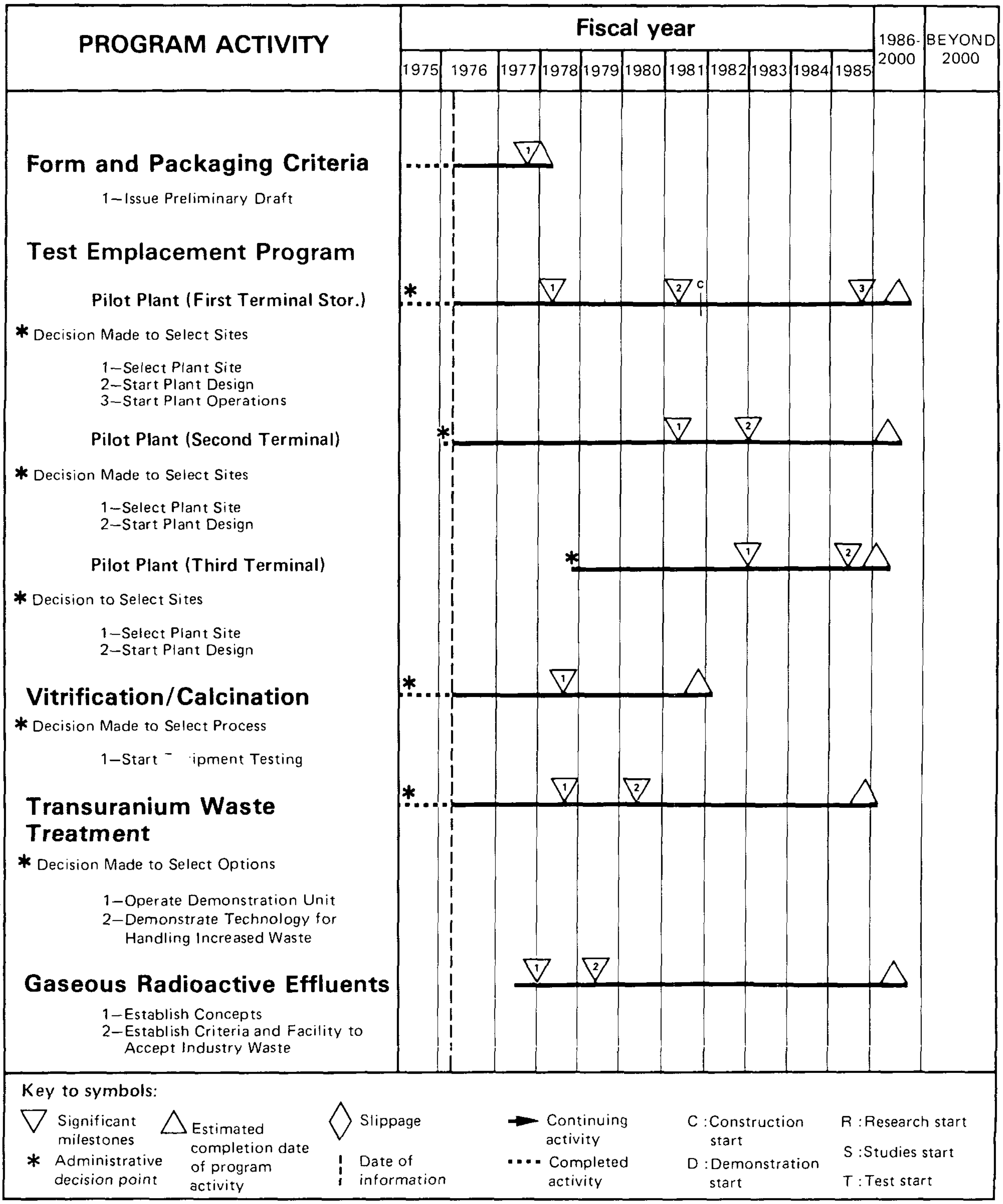
Federal Energy RD&D Budget ($ Millions)

Agency	FY 1975		FY 1976*		FY 1977	
	BA	BO	BA	BO	BA	BO
ERDA						
Operating Expenses	10.5	9.4	13.0	11.9	75.0	60.0
Plant and Capital Equipment	0.5	0.4	0.6	0.3	5.8	2.8
Total	11.0	9.8	13.6	12.2	80.8	62.8
NRC	0	0	1.2	1.1	1.5	1.4
Total	11.0	9.8	14.8	13.3	82.3	64.2

* Does not include funds for FY 1976 Transition Quarter.

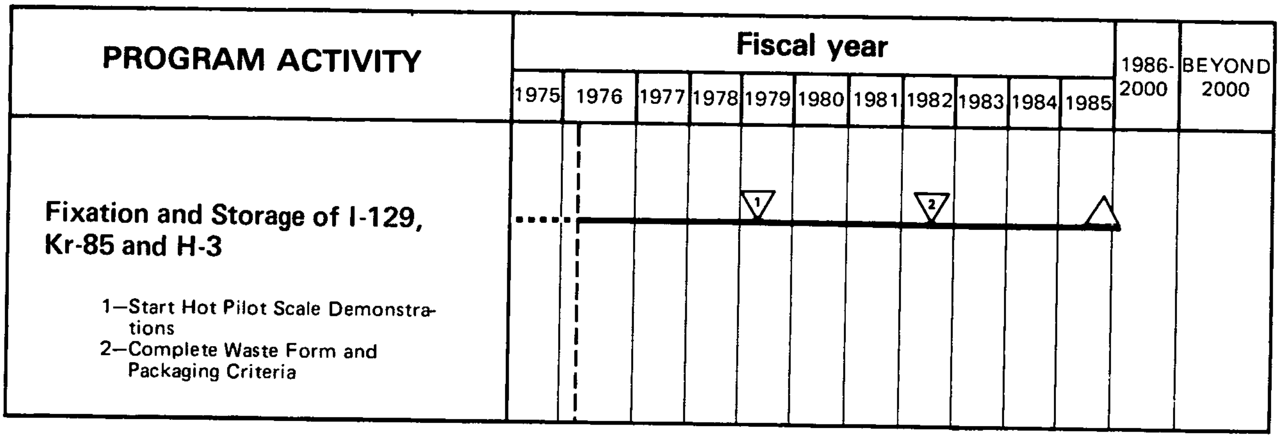
ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION

WASTE MANAGEMENT (Commercial)



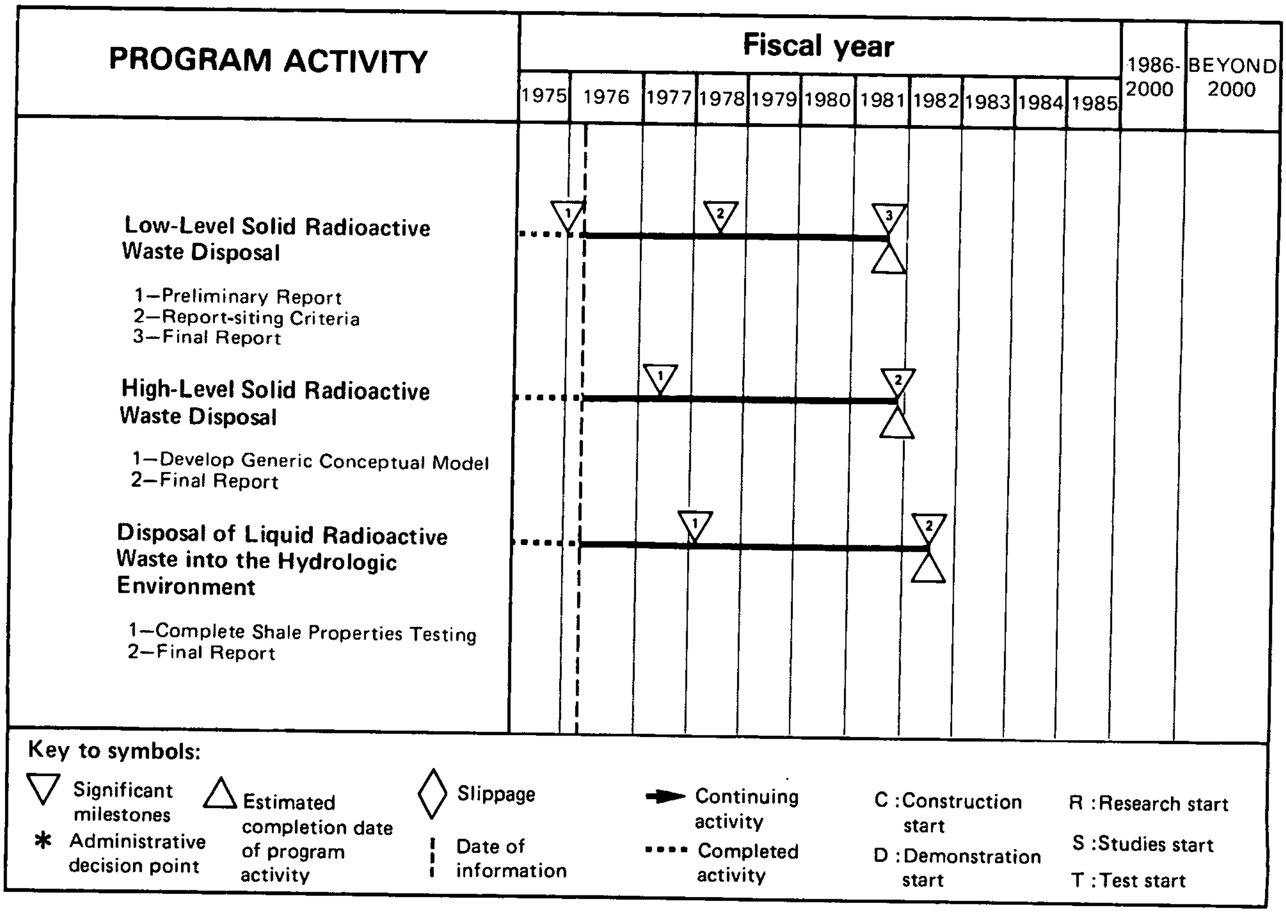
ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION

WASTE MANAGEMENT (Commercial) (continued)



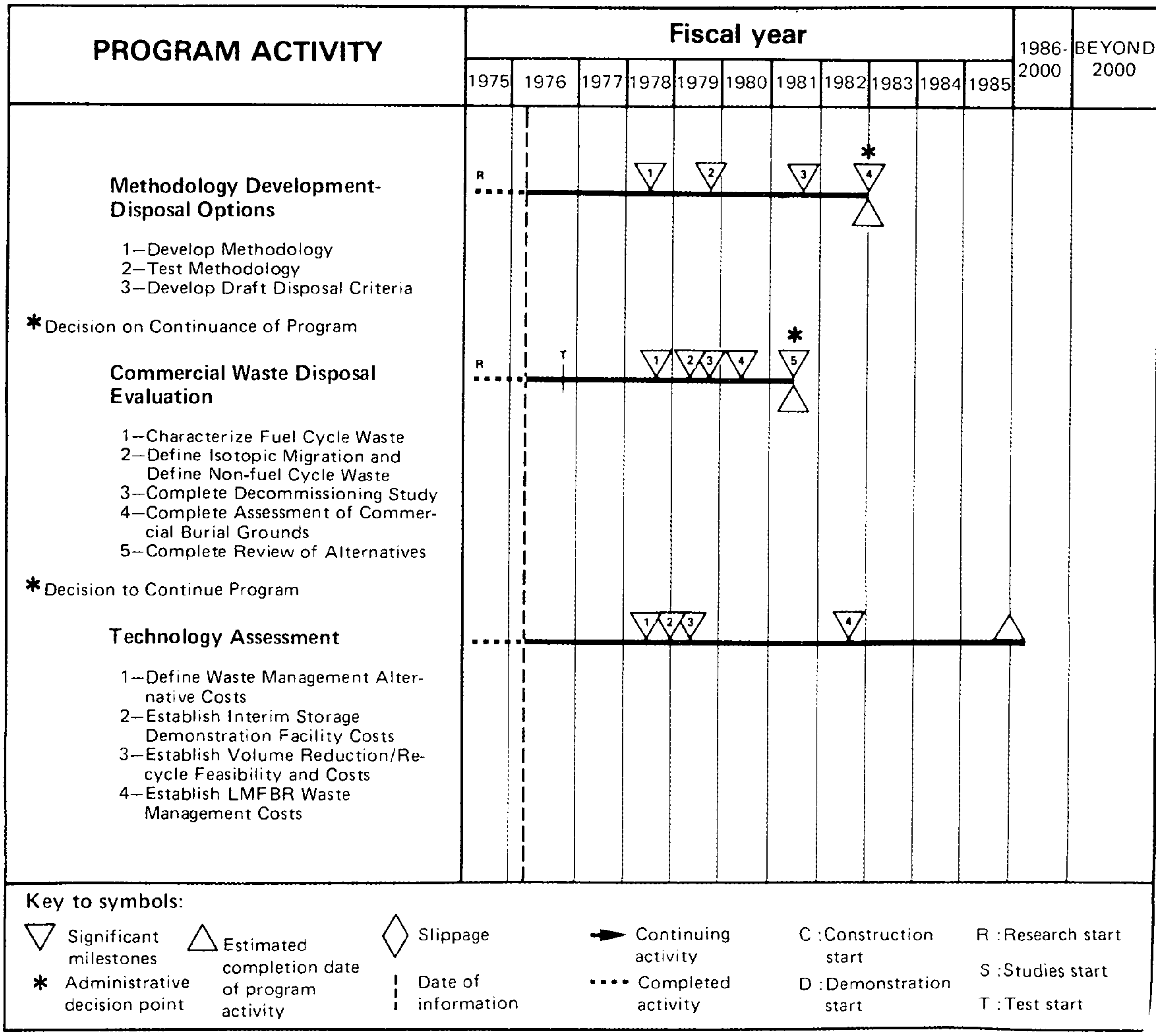
U.S. DEPARTMENT OF THE INTERIOR

WASTE MANAGEMENT (Commercial)



NUCLEAR REGULATORY COMMISSION

WASTE MANAGEMENT (Commercial)



NUCLEAR FUEL CYCLE R&D AND SAFEGUARDS

Nuclear Materials Security and Safeguards

Objectives

Near-Term (–1985), Mid-Term (–2000) and Long-Term (Beyond 2000):

- *Domestic*
  To protect the public against death, injury, or property damage from nuclear events produced by malevolent use of nuclear materials or sabotage of nuclear facilities. To develop, demonstrate, assess and assure the availability of effective safeguards systems.
- *International*
  To assist the International Atomic Energy Agency (IAEA) in its safeguards role in guarding against the proliferation of nuclear explosive devices and defining effective safeguards systems (internal control and physical protection) in conjunction with efforts of foreign nations for guarding against domestic threats to nuclear materials and facilities.

National Energy Technology Goals Supported

Primary

- Perform basic and supporting research and technical services related to energy.

Secondary

- Protect and enhance the general health, safety, welfare and environment related to energy.

Strategy

The analytical approach, rationale, and framework of the current safeguards program has been developed and detailed in ERDA–7 ("Societal Risk Approach to Safeguards Design and Evaluation," June 1975). From this approach, the following strategy has been developed to realistically achieve the safeguards program objectives.

- *Definition of Threat Situations Which Safeguards Systems Should Counter.* Define and assess credible threats to nuclear materials and facilities and develop a methodology to deal with these threats, recognizing the difficulties of quantifying potential human actions.
- *Development of the Capability to Evaluate Safeguards Measures and Systems.* Given a set of design threats and related adversary action sequences, develop systematic procedures needed to determine the effectiveness of a given safeguards system (e.g., for fixed facilities or during transportation) and a method to assess the cost-effectiveness and possible trade-off alternatives for any proposed safeguards changes (e.g., increased utilization of materials measurements techniques, redeployment of guards, increased reliance on physical protection measures, etc.).
- *Implementation of Safeguards for ERDA Materials in Facilities/Transit.* Budget for implementing previously identified required changes at ERDA facilities/transportation; complement additional needed changes identified as a result of effectiveness evaluations; conduct R&D on physical protection systems and hardware, material and personnel control systems and hardware, and search and recovery mechanisms; and develop an integrated information and control system. All mechanisms for application in the internal control system are being developed consistent with the need for safety and materials management.
- *Development of Safeguards Programs for Fuel Cycles.* Design, test, and evaluate balanced safeguards systems, using a cost effectiveness rationale, for application to existing and future commercial fuel cycles viewed in the long-term as an inexhaustible energy resource.
- *Cooperation with Others.* Ensure: a parity of safeguards among those agencies responsible for the security and safeguarding of nuclear materials; no duplication of safeguards R&D; and, that areas of responsibility are well defined

among those agencies concerned with the security and safeguarding of nuclear materials.

Federal Role

In resolving nuclear fuel cycle safeguards problems, the federal government is responsible for developing a system of safeguard measures, testing and evaluating that system in an operating commercial-scale plant in a cost effective manner, and enforcing requirements placed on commercial operations. Implementation of safeguards is to be performed by private industry and ERDA contractors. More specific areas of responsibility are defined below.

- *ERDA*. Responsible for RD&D of safeguards procedures and techniques applicable in the operating environment of existing and future fuel cycles; and for the promulgation and enforcement of requirements relating to nuclear material in the possession of contractors operating government-owned facilities within the ERDA complex.
- *Nuclear Regulatory Commission (NRC).* Responsible for conducting confirmatory safeguards research and the promulgation and enforcement of requirements for nuclear materials in the possession of licensed facilites. Licenses are responsible for requirement implementation.
- *Department of Defense (DOD).* Responsible for the promulgation and enforcement of requirements for all nuclear material in its possession (covered under section 91.b. of the Atomic Energy Act of 1954). This material is principally in the form of weapons and military reactor fuels.

International Cooperation

Three current international activities in this area are: (1) provision of U.S. consultants to Euratom and IAEA for improvement of its safeguards information system; (2) ERDA and Arms Control and Disarmament Agency (ACDA) sponsored R&D at ERDA facilities to support the International Atomic Energy Agency's (IAEA) activities, training of IAEA inspectors at LASL, and implementation of the President's offer to the IAEA for inspection of U.S. facilities as applicable under the Non-Proliferation Treaty; and, (3) physical protection appraisals by American teams of overseas facilities receiving special nuclear material and under U.S. export license granted by NRC.

Technological Problems and Status

Problem:

- Obtaining and understanding information concerning credible ranges of safeguards threats for protective systems design purposes.

Status:

- Sandia/Rand threat analysis study will be completed by the end of FY 77, resulting in a definition of the credible ranges of threats of safeguards concern. This study will be updated biannually to reflect social, economic and political changes.

Problem:

- Improving quantitative assessment of physical protection systems.

Status:

- As a tool to enhance inspection techniques, physical protection computer simulation models have been developed by Sandia and the Technical Support Organization (TSO) at BNL in FY 75–76. Operational assessments of ERDA facilities and model improvement will continue through FY 76–77. Operational implementation of the computer simulation model as a required inspection procedure is scheduled for FY 78.

Problem:

- Assessing effectiveness of facility internal control systems.

Status:

- A procedure has been developed by the National Bureau of Standards (NBS) for assessing the effectiveness of facility internal control systems and is currently under test at three Hanford facilities. Demonstration will be completed by the end of FY 77, with operational implementation to begin at other ERDA facilities in FY 77.

Problem:

- Rapid verification of nuclear materials inventories.

Status:

- A prototype automated on-line material balance system (DYMAC) developed by LASL is to be installed at the new LASL plutonium scrap recovery and processing plant beginning in mid FY 76. Another prototype system (DYMCAS) developed at Y–12 at ORNL and incorporating the DYMAC principles is to be installed in the Y–12 plant beginning in FY 77.

Problem:

- Marginal measurement capability relative to the uncertainties in closure of nuclear material balances.

Status:

- Equipment is being developed to reduce measurements uncertainties and costs for plutonium measurements (e.g., an automated calorimetry system and gamma-ray isotopic measurement system is being developed by Mound Laboratory).

Institutional Status and Problems

Problem:

- Ensuring a parity of criteria among those agencies responsible for establishing requirements for the safeguarding and security of non-weapons programs nuclear materials.

Status:

- The Division of Safeguards and Security (ERDA) and the Division of Safeguards (NRC) are enacting a working agreement to establish interagency procedures for: (1) assuring consultation and coordination in the development of NRC contingency plans for protecting nuclear materials and facilities against malevolent acts; (2) identifying necessary actions to maintain the policy of comparably effective safeguards systems; and, (3) affecting cooperation and consultation in specifications for safeguards research requirements, technical assistance studies, and technical support and operational implementation of international safeguards responsibilities.

Problem:

- Ensuring areas of responsibilities are well defined among those agencies concerned with the safeguarding and security of nuclear materials and facilities.

Status:

- Through the ERDA Emergency Action and Coordination Team (EACT) procedures have been established among ERDA, NRC, FBI, Department of State and other government agencies to facilitate a coordinated government response to threatened or actual malevolent acts involving nuclear materials or facilities. Formal agreement between ERDA and the FBI has been reached on the role of each in response to nuclear threat emergencies.

Environmental Status

- The purpose of the Nuclear Materials Security and Safeguards program is to protect the public against possible malevolent nuclear events which, if sucesssul, could result in serious environmental problems. Environmental problems resulting from possible malevolent use of nuclear materials, sabotage of nuclear facilities and nuclear accidents would be responded to by members of EACT, which has established procedures for handling such situations.

Program Implementation

Energy Research and Development Administration

The Nuclear Materials Security and Safeguards program objectives are being achieved by the sequential development and implementation of balanced effective security and safeguards procedures, techniques and mechanisms for the protection of nuclear facilities and nuclear materials of facilities and in transport. (See discussion in Strategy section.)

Credible threats will be defined and the capability developed to determine the effectiveness of a given safeguards system against a given credible threat. Current safeguards systems will be designed and demonstrated in pilot facilities and the technology made available to the private sector for application in meeting NAC requirements. International and other agency cooperation is also an on-going activity.

Definition of design threat studies began in FY 75 and will continue through FY 77. The operational data base resulting from these studies will be updated biannually.

Development of the capability to evaluate safeguards measures and systems, including development and application of physical protection and internal control assessment procedures, began prior to FY 75. Assessment procedures are tentatively scheduled for demonstration during FY 76 and for implementation by FY 78. These models will be applied to measure safeguards effectiveness on an ongoing basis at ERDA facilities in conjunction with other inspection activities.

Implementation of safeguards for ERDA materials in facilities/transit began prior to FY 76. Scheduled correction of previously identified deficiencies will continue into FY 78. Deficiencies identified as a result of the application of assessment models will be budgeted for correction control, and search and recovery mechanisms will be continued. Development of an integrated information and control system will result from implementation in late FY 77.

Development of safeguards for fuel cycles involves the design, test, and evaluation of safeguards systems, using existing technology, for application in pilot facilities from FY 76 to FY 81. Safeguards activity for the LWR fuel cycle demonstration program is scheduled for FY 76 to FY 83. Safeguards activity for the breeder reactor fuel cycle demonstration program is scheduled for FY 76 to FY 82.

Cooperation with others (U.S. government agencies, IAEA, Euratom, and other nations) is an on-going activity. Specific U.S. projects in support of effective IAEA safeguards (not previously mentioned under *International Cooperation*) scheduled for near-term completion are:

- Development of statistical and technical bases for IAEA inspection strategies.
- Perimeter safeguards study concerned with the unique and difficult problems of future international safeguards at isotopic separation plants.
- U.S. participation in IAEA safeguards inspection planning exercise at a low-enriched fuel fabrication plant to give the IAEA additional experience in and constructive criticism of their inspection-planning procedures for such facilities.
- U.S. contractor participation on the IAEA study and report on "Elements of a State's System of Accountability for and Control of Nuclear Material." The object of this report is to provide detailed guidance for other nations in establishing their domestic safeguards accountability and control (parallel to the IAEA's guidelines on physical security, "The Physical Protection of Nuclear Material," INFCIRC/ 225).

Nuclear Regulatory Commission

The primary focus of NRC's program is to develop methods, models and data in response to the following functional needs:

- A capability for assessing the effectiveness and socio-economic impact of safeguards policy options and alternative national strategies or procedures, including the choice of structure, objectives and performance criteria for the overall safeguards systems
- A capability for assessing alternative physical protection and materials control and accounting criteria in terms of the detailed requirements to be established in the regulations.
- A capability for assessing the effectiveness of license safeguards, as designs proposed in license applications (license review) and as operating systems (inspection).
- A capability for measuring the performance characteristics of subsystem components.

In addition, there will be activity to support the development of a central NRC safeguards information processing system. Contingency response capabilities will be developed as requirements are identified.

The primary objective of NRC safeguards research is to support the decision-making processes involved in rulemaking, licensing, and inspection by providing systematic methods for predicting and evaluating the performance of alternative safeguards strategies, systems and components. The payoff sought is the ability to demonstrate the relationship between objectives and effectiveness and between goals and achivements.

Systematic studies will be undertaken of what the potential adversary would or could do within the environment of the nuclear industry to perpetrate malevolent nuclear events in order to develop methods, models and data for predicting and evaluating the performance of safeguards systems designed to counter these actions.

Results from the NRC Safeguards Research program, new in FY 1976, are expected to emerge in FY 1977. The program is structured to provide preliminary results to support the Commission's schedule for rulemaking on LWR plutonium recycle. Iterative work will broaden the scope and deepen the detail of the research work.

Staff work is underway in the Office of Nuclear Regulatory Research to adapt the results of past AEC, ERDA and NRC research for application to current NRC operations. Examples of such work are: the physical protection simulation models developed by Brookhaven National Laboratory and by Sandia Corporation; and the Diversion Path Analysis technique developed by the National Bureau of Standards. The reactor sabotage vulnerability studies done by Sandia for the Division of Reactor Safety Research are being used to identify design criteria that might be the basis for new regulatory requirements.

The Safeguards Supplement to the Generic Environmental Impact Statement on the "Use of Mixed Oxide Fuel in Light Water Reactors (Plutonium Recycle)" provides a structure for the future safeguards regulations. It includes requirements for physical protection of facilities and materials in transit and requirements for materials control and accounting which emphasize containment and access controls. These requirements will be imposed within a general body of regulations which could influence the configuration of the nuclear industry, for example, through restrictions on the transport of certain forms of nuclear material.

NUCLEAR MATERIALS SECURITY AND SAFEGUARDS

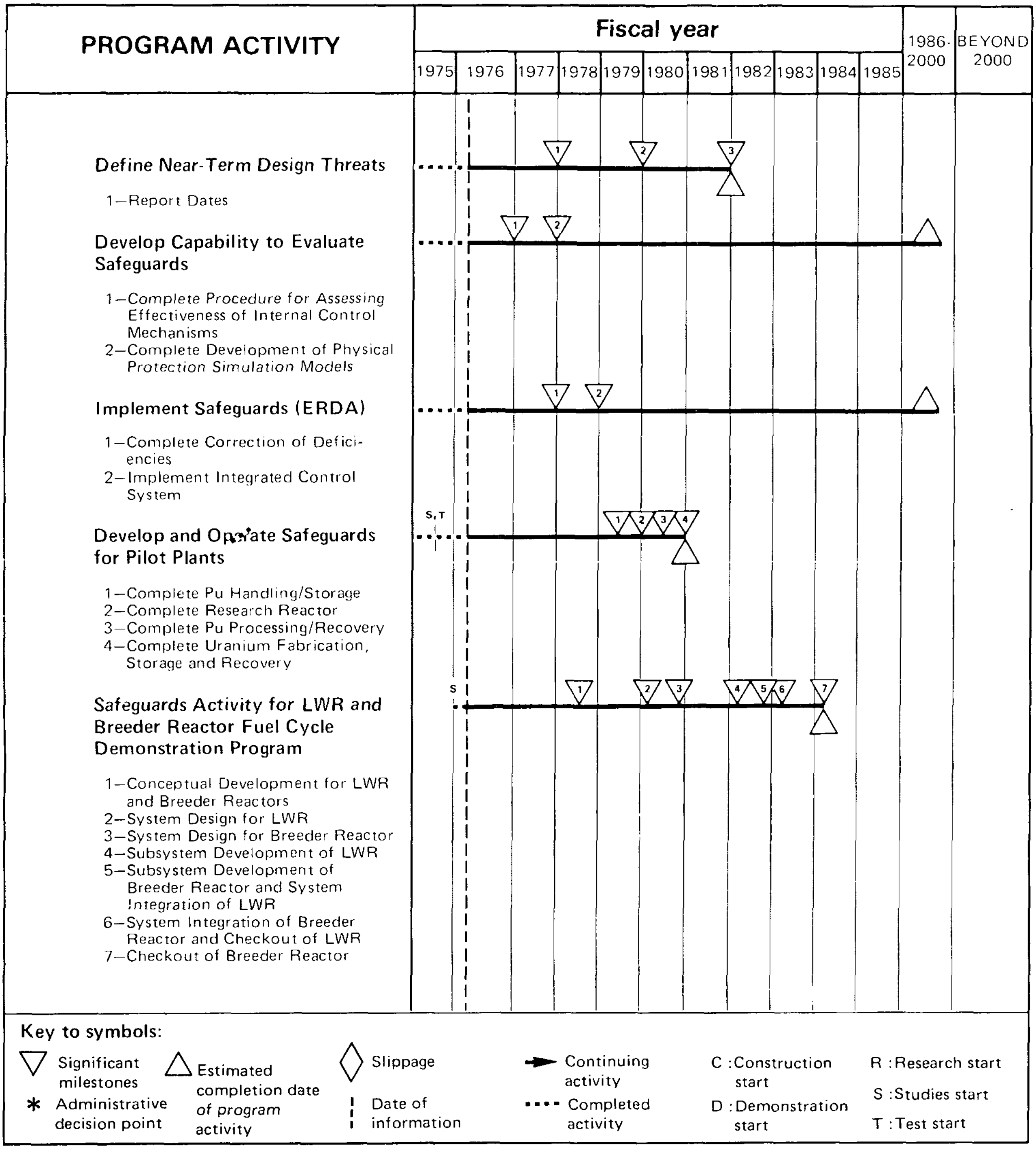
Federal Energy RD&D Budget **($ Millions)**

Agency	FY 1975		FY 1976*		FY 1977	
	BA	BO	BA	BO	BA	BO
ERDA						
Operating Expenses	6.2	5.8	13.6	12.0	25.7	22.3
Plant and Capital Equipment	4.2	1.1	3.0	2.7	2.4	5.0
Total	10.4	6.9	16.6	14.7	28.1	27.3
NRC	1.3	1.1	4.7	4.4	9.5	9.0
Total	11.7	8.0	21.3	19.1	37.6	36.3

* Does not include funds for FY 1976 Transition Quarter.

ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION

NUCLEAR MATERIALS SECURITY AND SAFEGUARDS



NUCLEAR FUEL CYCLE R&D AND SAFEGUARDS

Uranium Enrichment Process Development

Objectives

Near-Term:
(–1985)

- To maximize the production capability of the existing gaseous diffusion plants through continued development of advanced technology for cascade improvement (CIP) and cascade uprating (CUP) programs; to develop advanced gas centrifuge technology as a viable process for early application in a private uranium enrichment industry; to encourage the industrial sector to develop a competitive private enriching industry and to assume full responsibility for continuing technological development.

Mid-Term
(–2000) and Long-Term
(Beyond 2000):

- To minimize the role of ERDA in uranium enrichment process development as private industry assumes increasing responsibility for technological improvements.

National Energy Technology Goals Supported

Primary

- Efficiently transform fuel resources into more desirable forms.

Secondary

- Increase the efficiency and reliability of the processes used in the energy conversion and delivery systems.
- Perform basic and supporting research and technical services related to energy.

Strategy

ERDA has programs underway to improve the efficiency (Cascade Improvement Program—CIP) and to electrically uprate (Cascade Uprating Program—CUP) the existing gaseous diffusion plants. ERDA will pursue a gaseous diffusion process development program and incorporate advanced technology into CIP and CUP installations scheduled for the late 1970's and very early 1980's.

ERDA will pursue a gas centrifuge development, test and demonstration program on a schedule which would encourage consideration of the gas centrifuge process for early new plants.

ERDA will continue to share enrichment process development technology with U.S. private industry.

Federal Role

Originally, military usage of enriched uranium required that development in uranium enrichment be done under government contracts. With the evolution of a primarily electric power oriented demand, enriching technology, since the early 1970's, has been made available to U.S. companies which have been granted access under the government's industrial-participation programs.

Private industry is being encouraged to provide all new increments of enrichment capacity that will be required to meet the additional needs of the nuclear power industry. Under the President's proposed Nuclear Fuel Assurance Act (NFAA), ERDA would be authorized to negotiate and enter into contracts, each subject to Congressional approval, with private groups interested in building, owning, and operating gaseous diffusion and centrifuge enrichment plants. The continuation of federal technical development and assistance, until such time that industry can assume full responsibility, will likely be a condition for private investment in either enriching plants or enriching equipment manufacturing facilities.

International Cooperation

An agreement to maintain uniform classification policies in gas centrifuge technology is in effect between the United States and the Triparties (United Kingdom, West Germany and the Netherlands).

Foreign investment in private enrichment ventures will be encouraged, but control will remain, as required by law, with the U.S. participants. Foreign investors would not require or have access to classified information. Any proposals for sharing technology would be considered separately and would be subject to governmental review and approval.

Technological Status and Problems

Status:

- Although gaseous diffusion is a well-established and well-developed enriching process, there is a potential for further improvements.
- The gas centrifuge program has made significant progress and the technology has advanced to a state at which the centrifuge process is expected to be used in the expanding uranium enrichment industry. However, continued effort is required to develop advanced centrifuges, process systems, and manufacturing of a technology which is economically attractive relative to gaseous diffusion.

Problems:

- Long-term reliability of the existing gaseous diffusion plants to meet separative work commitments must be maintained.
- The mean time between failures and maintenance costs for advanced centrifuges is uncertain.
- Multistage centrifuge enriching process under typical plant operating conditions has not been demonstrated.

Program Implementation

Gaseous diffusion process development will be emphasized to assure that the CIP and CUP will provide an additional 6.0 million and 4.8 million separate work units per year, respectively.

The recently completed centrifuge process Component Preparation Laboratories (CPL's) provide the facilities needed to develop mass production techniques for building centrifuges. The CPL's will be modified to accommodate an advanced centrifuge model. The Component Test Facility (CTF), scheduled for operation in FY 1977, is a pilot plant for centrifuge operation under typical operating conditions to fully demonstrate the centrifuge enriching process. Reliability testing of advanced centrifuges will be conducted in the advanced equipment test facility (AETF), which is scheduled to be operational in FY 1978.

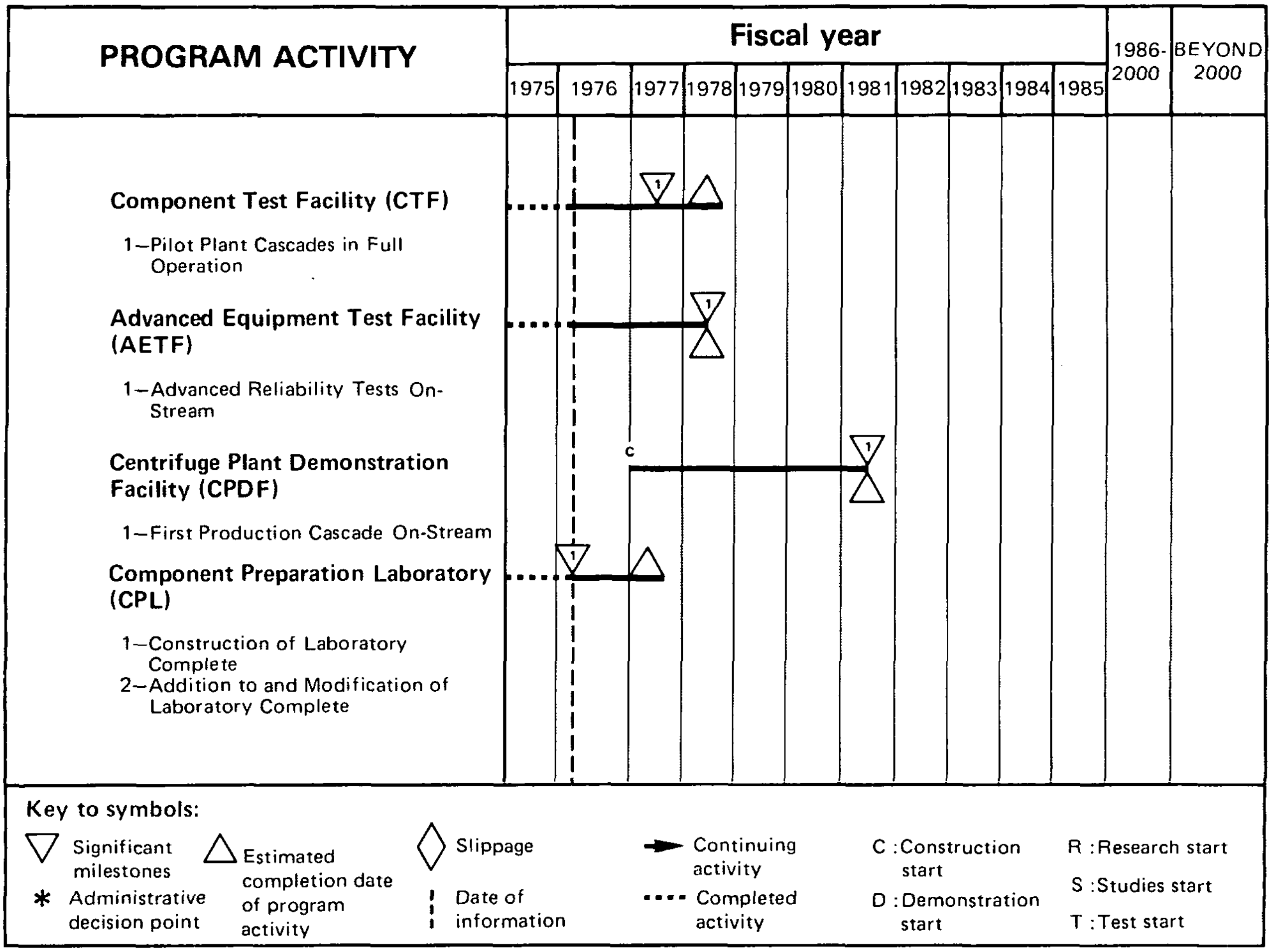
It is planned to start construction of a Centrifuge Plant Demonstration Facility (CPDF) in FY 1977 to test and demonstrate advanced centrifuge process concepts and auxiliary and support equipment. This facility is needed to gain operating and maintenance experience of a prototype module of an integrated gas centrifuge enrichment plant. Field operation of the first production cascade is scheduled for FY 1981.

ERDA has established test facilities in the Oak Ridge CPL for testing centrifuges by industrial participants. ERDA has also agreed to buy a limited number of industrial centrifuges for CFT installation in fiscal year 1977 and 1978. If development of the centrifuge enrichment process is successful, secondary environmental impacts would be expected to be significantly less than those from a gaseous diffusion plant.

Experience in gaseous diffusion operations, centrifuge enrichment plant operations and gas centrifuge manufacturing is being transferred to industry by ERDA. ERDA will also manufacture for industry key gaseous diffusion components (barrier and seals).

ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION

URANIUM ENRICHMENT PROCESS DEVELOPMENT



URANIUM ENRICHMENT PROCESS DEVELOPMENT

Federal Energy RD&D Budget **($ Millions)**

Agency	FY 1975 BA	FY 1975 BO	FY 1976* BA	FY 1976* BO	FY 1977 BA	FY 1977 BO
ERDA						
Operating Expenses	33.3	36.6	48.4	45.4	62.7	58.2
Plant and Capital Equipment	13.8	25.9	6.4	15.6	33.2	10.1
Total	47.1	62.5	54.8	61.0	95.9	68.3

* Does not include funds for FY 1976 Transition Quarter.

NUCLEAR FUEL CYCLE R&D AND SAFEGUARDS

Advanced Isotope Separation Technology

Objectives

Near-Term:
(–1985)

- Establish technical feasibility of advanced concepts, e.g., Laser Isotope Separation (LIS), for uranium enrichment. Validate LIS for plutonium isotope recovery.
- Develop technologies to significantly reduce the cost of uranium enrichment.
- Establish a base of expertise for advanced concepts.
- Transfer to industry U.S. Government-developed advanced technologies in uranium enrichment as rapidly as possible.
- Establish a base of expertise for applications to reactor waste reprocessing.

Mid-Term:
(–2000)

- Aid in the establishment of industrial production facilities for uranium and plutonium laser isotope separation and develop reactor waste applications.

National Energy Technology Goals Supported

Primary

- Efficiently transform fuel resources into more desirable forms.

Secondary

- Perform basic and supporting research and technical services related to energy.

Strategy

Continue a vigorous program of research and development on schemes of advanced isotope separation. The study of these methods should, during the period 1976-1978, allow ERDA to reach a decision in late FY 1978 to decide which process should be scaled-up towards a pilot plant in the early 1980's. Following the decision, a pilot plant for advanced uranium and plutonium separation may be designed and constructed. Technology transfer to industry would occur throughout. The prosecution of broad-based R&D programs involving ERDA laboratories and the private sector in laser induced chemistry and laser development and other advanced concepts will continue. During the mid-term period full-scale enrichment should become operational with the transfer of technology to the industrial participants. Program emphasis will change in the mid-term to reactor waste applications.

Federal Role

An overriding national interest exists to maintain the U.S. lead in uranium enrichment for (1) economic production of nuclear fuels to meet projected U.S. requirements and foreign competition and (2) supporting non-proliferation policy.

Investment in advanced technology is viewed as high risk, but with a potentially high payoff.

Other federal agencies involved in this program include:

- Department of Commerce (NBS)—Fundamental research in photochemistry and photophysics.
- Department of Defense (DARPA)—Research on tunable lasers.
- Nuclear Regulatory Commission—Determine licensability of private enrichment facilities.

Encourage additional involvement of the laser industry as the laser requirements become better defined.

Encourage involvement of the enrichment industry in the near future through the Industrial Participation Program.

International Cooperation

No international program exists. Exchange of basic scientific data is not possible because of security classification and non-proliferation reasons.

Technological Status and Problems

Status:

- Although data now exist in spectroscopy and basic physics of uranium and uranium compounds, it is not adequate for optimum designs.
- Lasers for laboratory use now exist at wavelengths previously not available. These allow a refinement of earlier spectroscopic data and a greater flexibility in separation experiments.
- Uranium enrichment demonstrations for non-laser advanced concepts should occur in FY 1977.

Problems:

- An adequate base of physical, chemical and spectroscopic data on uranium and plutonium and their compounds sufficient to allow technical evaluation of laser isotope separation processes does not exist.
- Commercial high power, stable, narrow-line lasers of adequate power do not exist at wavelengths needed for laser separation applications.
- New technology is required for handling large quantities of material in forms necessary for laser isotope separation using uranium metal vapor and uranium plasmas for the ion cyclotron resonance separation process.
- Accurate assessment of costs for advanced concepts separation of uranium and other elements is dependent on progress in the above areas.

Institutional Status and Problems

Status:

- Jersey Nuclear-Avco Isotopes, Inc. (JNAI) has developed LIS methods and has committed to build a LIS pilot plant.
- Policy for industrial access and participating in government-sponsored advanced concepts research and development is being formulated.
- Critical elements of the ERDA program will remain classified in order to insure protection against nuclear proliferation.

Problems:

- Current ERDA patient policies, by demanding background rights, present a barrier to full usage of industrial laser expertise and are under review.
- Ability of the private sector to perform RD&D on plutonium separation is limited by the need for costly and highly specialized facilities.
- A satisfactory means of minimizing unnecessary duplication of government sponsored research with that of the private sector is being developed.

Environmental Status and Problems

Status:

- Due to the early stage of technological development and lack of relevant data, environmental impacts of advanced concepts have not been specifically studied. However, it is anticipated that the major environmental impacts would be associated with off-site power production.

Problems:

- LIS plant operations would probably require chemical processing in mirror etching, uranium recovery, and laser dye recycling. The effluents from these operations would be subject to meeting EPA standards.
- Non-laser concepts would involve uranium recovery operations, uranium plasma generation, chemical processing and solvent reclamation. The effluents from these operations would be subject to meeting EPA standards.
- No major environmental problems have been identified to date.

Program Implementation

The ERDA LIS program is centered in the multi-program ERDA laboratories at Livermore, California, and Los Alamos, New Mexico, and the Union Carbide Y-12 plant and the Gaseous Diffusion Plant at Oak Ridge, Tennessee. A significant level of laser research is supported in universities and industrial concerns.

The Advanced Concepts Program, not using lasers and having identified processes, is growing and presently involves Mound, Argonne, and Oak Ridge National Laboratories, and TRW in the private sector.

Los Alamos Scientific Laboratory—Molecular Process

Development of lasers at LASL, several universities, and industrial research laboratories.

Run experimental separation systems.

Use of high-resolution spectorscopy to explore the use of different wavelengths and refine laser requirements.

Operation of a test bed at the Oak Ridge Gaseous Diffusion Plant to develop collection techniques and production-scale equipment.

Equipping a new laboratory to examine the entire 0.2-20 wavelength range.

Lawrence Livermore Laboratory (LLL)—Metal Vapor Process

Have enriched milligram quantities of uranium.

Visible plus a readily available infrared laser are now in progress.

Continuing detailed spectroscopy to improve extraction.

Techniques for materials handling, both in product collection and in fuel preparation, are under study at LLL and in large scale at the Oak Ridge Y-12 Plant.

Mound Laboratory—Chemical Exchange

Have measured an enrichment factor for a two phase liquid-liquid extraction method.

Scientific feasibility expected to be completed in early FY 1977.

Argonne Laboratory—Chemi-ionization

Separation device will begin check out operations in early FY 1977.

Uranium enrichment demonstration expected in mid-FY 1977.

Ion Cyclotron Resonance Separation Process

Concept demonstration of process for potassium has been completed.

Concept demonstration of process for uranium is expected in early FY 1977.

Overall ERDA Program

A substantial industrial program will be started in FY 1977 to design and fabricate lasers for process applications.

Due to similarity of technological interests, close coordination with DoD laser development efforts exist through panel participation with groups from the DoD community.

Process cost models for all concepts are being developed and will be continually refined as the technology develops and the data and cost bases are established.

U.S. Government technology will be continually transferred to industry after expansion of the Industrial Participation Program, which now transfers gaseous diffusion and gas centrifuge technology, to include advanced concepts.

Plutonium isotope recovery development will rely heavily on data and techniques developed for uranium.

The technology now under development for uranium and plutonium should be applicable to reactor waste reprocessing.

ADVANCED ISOTOPE SEPARATION TECHNOLOGY

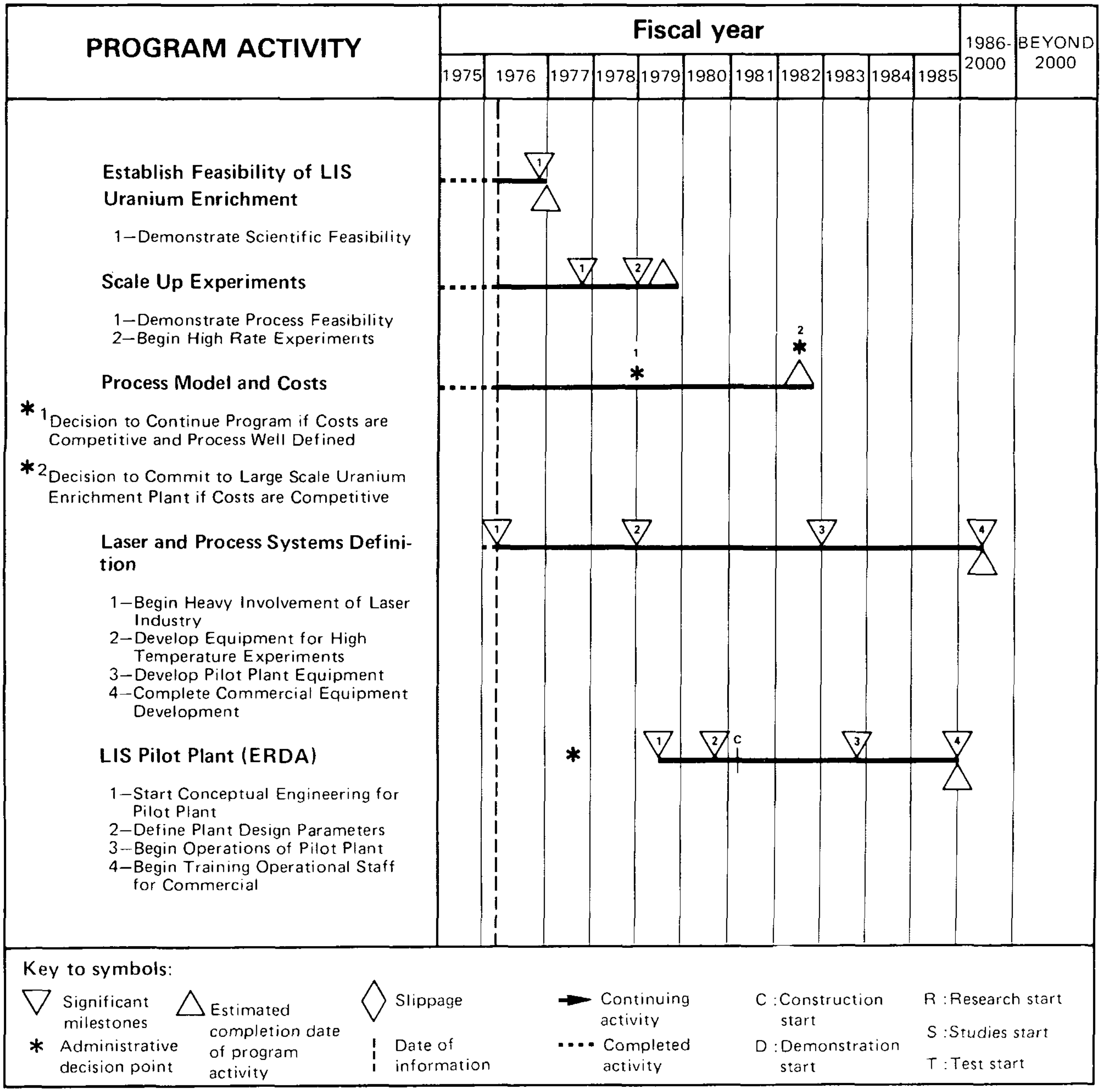
Federal Energy RD&D Budget **($ Millions)**

Agency	FY 1975		FY 1976*		FY 1977	
	BA	BO	BA	BO	BA	BO
ERDA						
Operating Expenses	21.1	16.6	29.4	25.0	36.8	34.0
Plant and Capital Equipment	2.9	1.9	3.2	2.6	7.0	5.2
Total	24.0	18.5	32.6	27.6	43.8	39.2

* Does not include funds for FY 1976 Transition Quarter.

ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION

ADVANCED ISOTOPE SEPARATION TECHNOLOGY PROGRAM



FISSION POWER EXECUTIVE SUMMARY

Fission Power effort consists of six major program activities: Liquid Metal Fast Breeder Reactor, Water Cooled Breeder Reactor, Gas Cooled Reactors, Light Water Reactor Technology, Supporting Activities and Reactor Safety Facilities. Major emphasis is being placed on the Liquid Metal Fast Breeder Reactor Program including innovative government/industry cooperative management concepts aimed at expediting the ultimate commercial deployment of the breeder.

The major objectives of the reactor efforts include:

- Developing the broad technological, engineering, and industrial base necessary for establishing the Liquid Metal Fast Breeder Reactor (LMFBR) as a safe, reliable and economical nuclear energy source.
- Demonstrating on a commercially applicable basis the design, licensing, construction, and operation of the Clinch River Breeder Reactor (CRBR) as part of a utility system.
- Confirming the capability of breeding in a light water reactor (LWR) using a thorium-uranium-233 cycle, and providing technology to assist industry in the evaluation and application of the concept.
- Evaluating a gas-cooled reactor (GCR) as an alternate fast breeder with the potential of an increased breeding rate relative to the Liquid Metal Fast Breeder.
- Developing technology to assist private industry in the design, construction, and operation of high efficiency, high temperature gas-cooled thermal reactors for electric power and process heat application.
- Supporting the Nuclear Regulatory Commission (NRC) in the conduct of its reactor safety research effort.
- Assisting private industry through a cooperative program, aimed at increasing the productivity of existing light water reactors and developing technology to reduce the time and cost of constructing new light water reactors.
- Conducting studies and other activities in support of current and potential reactor development efforts.

The primary specific actions proposed which would support the achievement of the program activities are:

- Building a sound technological base in support of the demonstration and potential commercialization of LMFBRs.
- Participating in a cooperative program with industry to design, license, build and operate the 380 MWe Gross Clinch River Breeder Reactor as part of a utility system.
- Developing a broad reactor safety technology base that will permit greater flexibility in reactor design and operations.
- Improving LMFBR fuel performance through the use of advanced materials and designs.
- Conducting a research, development, design, and fabrication of a LWBR core for operation in light water reactors, and developing and disseminating the technology necessary for industry to evaluate the commercial potential of this reactor concept.
- Continuing the evaluation of the ultimate potential of gas-cooled reactors and adjusting the program activities depending on the results of the analysis and the actions taken in the commercial marketplace.
- Providing the requisite engineering and safety technology which is needed to support an industrially organized effort potentially leading to the construction and operation of a gas cooled fast breeder reactor (GCFR) demonstration plant in the late 1980's.
- Testing and developing improved LWR base technologies in order to improve plant components which are significant contributors to plant outages.

- Developing new technologies wihch will shorten construction time and reduce the cost of LWRs.
- Construct highly specialized experimental facilities for the Nuclear Regulatory Commission's reactor safety research program.

FISSION POWER

Federal Energy RD&D Budget

($ Millions)

Building Block	FY 1975 BA	FY 1975 BO	FY 1976* BA	FY 1976* BO	FY 1977 BA	FY 1977 BO
LMFBR Base Program R & D	356.8	349.6	313.3	310.4	343.3	333.3
Clinch River Breeder Reactor Plant Project	62.8	60.0	107.0	57.0	237.6	171.0
LMFBR Reactor Safety	47.4	42.6	55.0	51.2	70.2	66.7
Advanced Fuels	17.8	13.6	15.1	14.8	16.2	15.6
Water Cooled Breeder Reactor	36.3	37.5	42.1	43.9	48.8	39.6
Thermal Reactors (HTGR & VHTR)	14.2	12.3	15.3	14.3	16.2	16.3
Fast Breeder Reactor (GCFR)	6.8	5.5	6.3	6.1	8.1	7.5
Gas Cooled Reactor Safety	6.5	5.5	8.1	7.6	9.3	8.8
Light Water Technology	51.4	45.2	73.4	62.7	82.1	75.7
Supporting Activities	13.2	8.8	17.4	14.7	20.1	21.3
Reactor Safety Facilities	(1)	(1)	(1)	(1)	33.3	24.7
Sub-Total	613.2	580.6	653.0	582.7	885.2	780.5
Other Capital Equipment (2)	4.3	3.4	24.4	3.4	27.7	8.8
Molten Salt Breeder Reactor (3)	7.2	4.5	3.6	4.1	0	0
Total	624.7	588.5	681.0	590.2	912.9	789.3

(1) This activity was funded by the AEC until January 18, 1975 and then by NRC through FY 1976. The BA and BO amounts for both years were identical: $22.3 million. ERDA assumes budgeting function in FY 1977.
(2) These items are not associated with any specific BB within the Fission Program.
(3) This program is being terminated, and no funds have been requested for FY 1977. It is not described in this report.
* Does not include funds for FY 1976 Transition Quarter.

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FISSION POWER

Liquid Metal Fast Breeder Reactors

The overall LMFBR program is broken down in this Plan into four separate activities: (1) Base program research; (2) Clinch River Breeding Reactor Plan Project; (3) Reactor safety; and (4) Advanced fuels research. These four activities are discussed separately.

BASE PROGRAM RESEARCH AND DEVELOPMENT

Objectives

Near-Term:
(–1985)

- To provide the basic information, including engineering data and engineering design and analytical methods, to support the design, construction, operation and maintenance of LMFBRs; to develop and demonstrate engineering capability and industrial technology and to provide a means for incorporating technological advances into hardware for the demonstration and prototype LMFBRs.
- To provide and operate a reactor complex (Fast Flux Test Facility) specifically designed for testing LMFBR fuels and materials under irradiation conditions prototypic of large fast breeder plants.

Mid-Term:
(–2000)

- To build upon the near-term achievements to establish a technological basis for commercialization of the LMFBR concept, thus providing an essentially inexhaustible long-term (beyond 2000) energy resource option.
- To continue to provide a technology base support for fuels and materials development, component development and safety in concert with industrial suppliers and utilities to improve reliability, safety, and economics of commercial plants, and, in the case of components, to provide the hardware and experience required to build large LMFBRs.

National Energy Technology Goals Supported

Primary

- Increase the use of essentially inexhaustible domestic energy resources.

Secondary

- Efficiently transform fuel resources into more desirable forms.
- Increase the efficiency and reliability of the processes used in the energy conversion and delivery systems.
- Perform basic and supporting research and technical services related to energy.

Strategy

The strategy for the LMFBR base program is to provide a strong technology base in support of the demonstration and potential commericalization of LMFBRs. This requires developmental research including analytical and experimental effort in reactor physics, component development, engineering methods, nuclear fuel systems, materials, and fuel fabrication technology. The program currently provides support for LMFBR project activities and also provides the advanced technology necessary to assure the viability of the Liquid Metal Fast Breeder Reactor as an energy option. The program utilizes the technical competence of the National Laboratories, industrial contractors and universities. Industry participation in base program research centered at National Laboratories and ERDA facilities is generally encouraged in order to assure the orderly transfer of the technology to industrial organizations.

The reprocessing of LMFBR fuels will be undertaken on the schedule required to have a commercial reprocessing capability in place when it is needed to accommodate utility-owned LMFBR electric generating plants.

Federal Role

The Federal role is to provide assistance to industry by developing those LMFBR technologies that industry is unable to support due to the long time required for new technology development and the corresponding financial burden and risk associated with such development. The federal role includes construction, operation, and maintenance of costly central facilities of a type not affordable by private industry, e.g., Fast Flux Test Facility, Experimental Breeder Reactor-II, critical physics experimental facilities, and test facilities at the Liquid Metal Engineering Center, Hanford Engineering Development Laboratory, Argonne National Laboratory, and Oak Ridge National Laboratory. Cooperative industry participation in this program is encouraged and many cooperative programs have been effected.

Greater industry financial involvement can be assumed as the technology advances through the operation of pilot plants and a prototype demonstration reactor. By the year 1990, industry-based funding can be expected to exceed the federal contribution.

International Cooperation

The United States is a member of the International Atomic Energy Agency (IAEA) and participates in working groups and seminars supported by the IAEA to exchange information on LMFBR technology.

The United States is also a member of the Organization of Economic Cooperation and Development (OECD). A cooperative arrangement with the Nuclear Energy Agency (NEA), an agency of OECD provides for computer codes exchange and participation in specialist meetings.

The United States also has an arrangement with the International Energy Agency (IEA), another agency of OECD for participation in nuclear Energy research and development. The latter arrangement allows for multi-lateral agreements related to nuclear research.

Bilateral arrangements also exist with the United Kingdom, Japan, and the USSR on LMFBR technical exchange. Similar arrangements with West Germany and France are currently being negotiated. A more limited agreement is also being negotiated with Italy.

Technical exchange programs with the United Kingdom, West Germany, and Japan have been operative for a number of years. The exchange with West Germany has been on the basis of ad hoc agreements originating from the now expired EURATOM agreement.

Technological Status and Problems

Status:

- The base program is divided into the following subprograms:

Physics	Systems
Fuels	Components
Materials	Fast Flux Test Facility (FFTF)
Chemistry	

- The LMBR Physics program activities are utilizing critical experiments being conducted in support of the Clinch River Breeder Reactor Plant Project (CRBRP) to provide a realistic test of the validity of data and methodology being developed for use in the testing of future breeder reactors. Critical experiment facilities are being enlarged to accommodate experiments with larger reactor cores.
- The LMFBR Reference Fuels program continues to provide engineering test data and fabrication technology to support the design and operational application of FFTF and CRBRP fuel assemblies. The effort is concentrated on mixed plutonium-uranium oxide fuel and uranium oxide blanket elements, boron carbide control elements and 20 percent cold worked stainless steel cladding.
- The LMFBR Materials program is directed to provide basic materials data and engineering information pertinent to the emphasis on the characterization of the reference steam generator alloy, and the necessary fabrication and inspection technology. Structural design methods are being developed for use in designing reactor system components for high temperature service. The technology being developed will be verified by application in the CRBRP and the prototype large breeder reactor (PLBR).
- The LMFBR Chemistry program activity is concentrated on sodium chemistry, component cleaning and decontamination and the transport of radioactive materials by sodium.

- The LMFBR Systems program includes the prototype reactor design effort. Design contracts have been awarded to three industrial teams of reactor manufacturers and architect-engineers.
- Instrumentation and control efforts are currently directed to the development of a number of promising new sensors and surveillance systems which will be demonstrated in the PLBR. Techniques are being developed for predicting thermal hydraulics and vibrational behavior of the LMFBR cores and major components. Important research associated with steam generator development includes studies of steam generator flow stability, leak detection, and sodium/water reactions.
- The LMFBR Component program has successfully provided a wide variety of reactor components. The evaluation of major component conceptual designs, selection of designs for detailing, fabrication and test of large plant-size prototype units is continuing.
- The construction of the FFTF was 55 percent complete as of December 31, 1975 and about 92 percent of the major equipment has been shipped to the site.

Problems:

- Uncertainties in important physical parameters such as breeding gain, reactivity requirements, shielding design, and the sodium void coefficient need to be reduced.
- Low cost mechanized and automated production methods for producing mixed oxide LMFBR fuel in quantities required to meet projected demands must be demonstrated. Current total U.S. industrial capacity based on a batch type manual operation is less than three tons per year and would not meet projected requirements.
- Fuel examination facilities must be expanded to accommodate anticipated FFTF irradiated fuel material.
- Alternate LMFBR surveillance systems for the continuous monitoring of structural, component, and coolant conditions during plant operations should be developed.
- An on-line monitoring system for the detection and location of failed fuel and steam generator leaks needs to be developed.

Institutional Status and Problems

Status:

- Industrial and utility participation is being encouraged to help ensure acceptance of the LMFBR by the private sector.
- Some regulations for the safeguarding of nuclear fuel and radioactive materials throughout the fuel cycle and management of nuclear wastes have been issued to provide for the future protection of the public and to promote public acceptance of the LMFBR.

Problems:

- Procedures for the safeguarding of nuclear fuel and radioactive materials throughout the fuel cycle and management of nuclear wastes need to be further domonstrated to ensure licensability and public acceptance.
- The present projected capital cost of LMFBR power plants coupled with the long construction time of all nuclear power plants means that any economic uncertainties associated with the LMFBR need to be clearly resolved to permit the large private financing required several years before the benefits begin to accrue from LMFBR plant operation.

Environmental Status and Problems

Status:

- A Final Environmental Impact Statement for the LMFBR Program (*ERDA 1535*) has been approved by the ERDA Administrator and issued.
- ERDA and NRC are both proceeding with programs to improve safeguards for the nuclear fuel cycle.
- Research on the health effects of transuranics has been underway for many years. Specific programs are being directed to minimize the release of radionuclides such as krypton-85, tritium, carbon-14, iodine-129, and the transuranics by the LMFBR fuel cycle.

Problems:

- LMFBR Plant safety standards and regulations have to be developed to the point where they will be accepted by the public and the various regulatory agencies.
- An acceptable safeguards program, in conjunction with the NRC, must be implemented.
- Additional information, and corresponding procedures, and controls must be developed relative to plutonium and other transuranic nuclide hazards.
- LMFBR Program environmental issues must be adequately identified and resolved.

Program Implementation

The LMFBR Technology Program is planned to continue through the year 1995. It is assumed that industry will accept responsibility for many aspects of these technologies by 1990. Instrumentation and control, low induced vibration analysis and certain aspects of fuel fabrication technology development are programmed through 1995. The FFTF is expected to be operational through 1995.

Implementation details are shown on the milestone chart.

BASE PROGRAM RESEARCH AND DEVELOPMENT

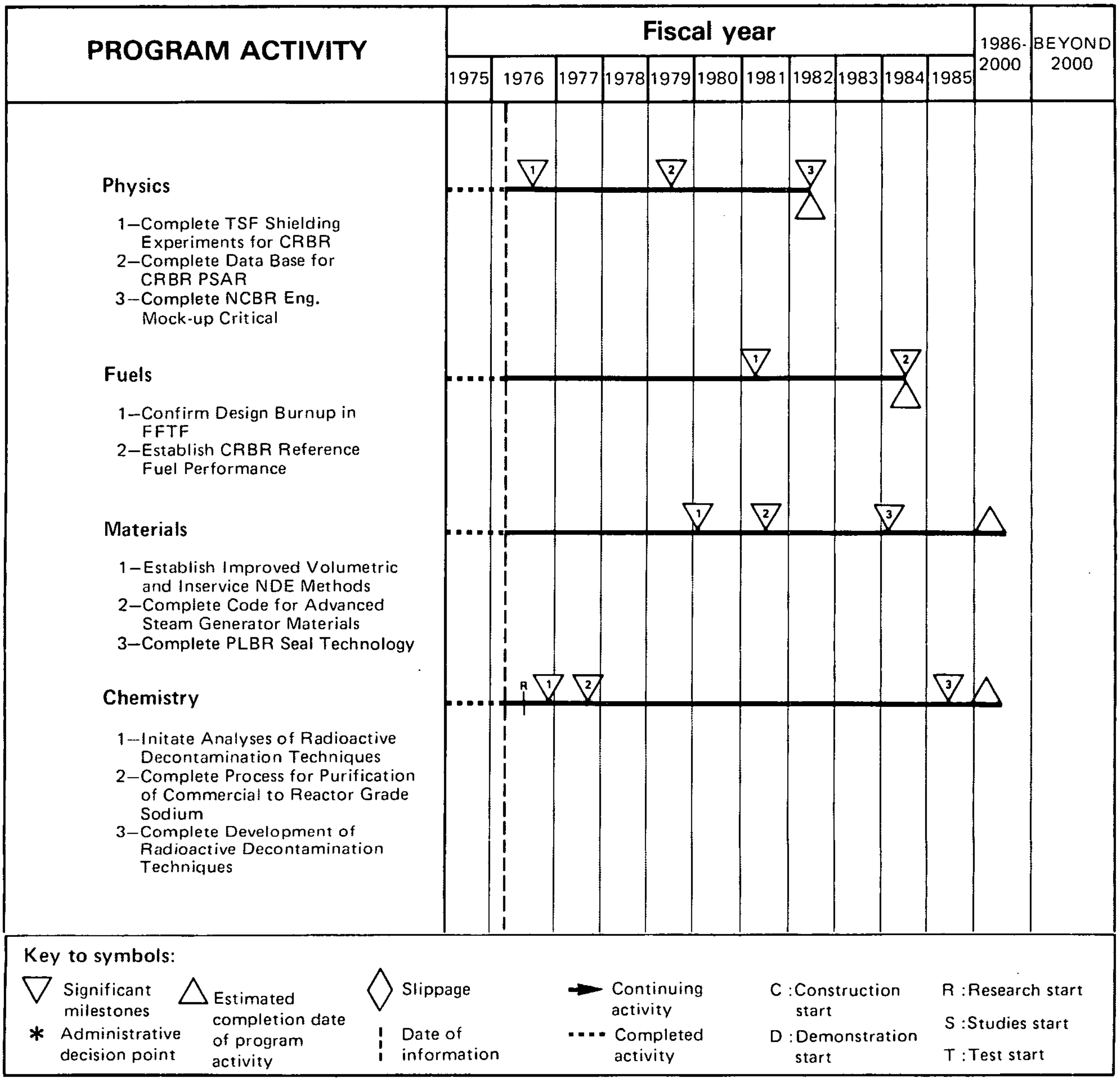
Federal Energy RD&D Budget **($ Millions)**

Agency	FY 1975		FY 1976*		FY 1977	
	BA	BO	BA	BO	BA	BO
ERDA						
Operating Expenses	189.3	204.7	191.0	188.7	227.2	217.0
Plant & Capital Equipment	167.5	144.9	122.3	121.7	116.1	116.3
Total	356.8	349.6	313.3	310.4	343.3	333.3

* Does not include funds for FY 1976 Transition Quarter.

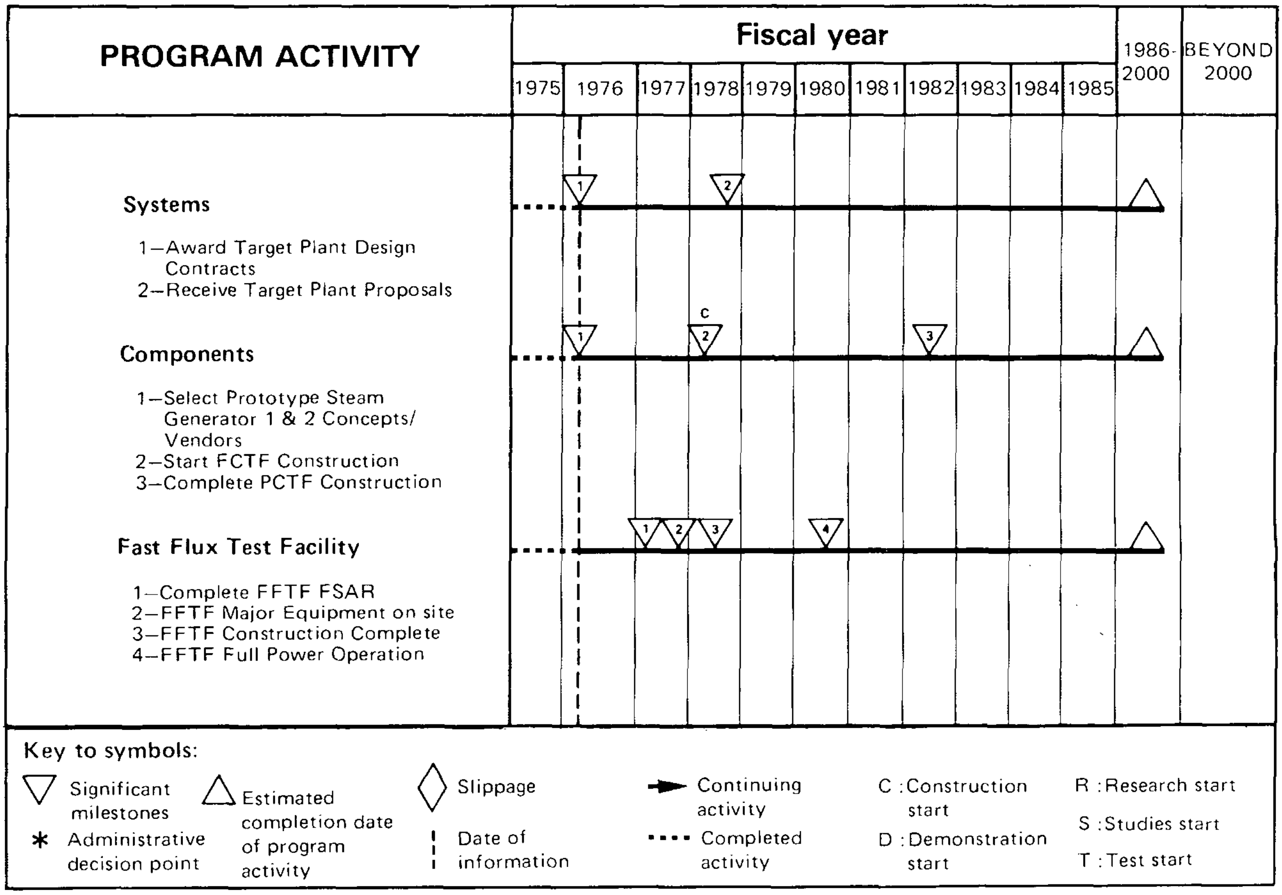
ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION

BASE PROGRAM R & D



ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION

BASE PROGRAM R & D (continued)



FISSION POWER

Liquid Metal Fast Breeder Reactors

CLINCH RIVER BREEDER REACTOR PLANT PROJECT

Objective

Near-Term:
(–1985)

- Design, license, build, and operate a 380 MWe Gross liquid metal fast breeder reactor power plant as a part of a utility system.

National Energy Technology Goals Supported

Primary

- Increase the use of essentially inexhaustible domestic energy resources.

Secondary

- Expand the domestic supply of economically recoverable energy-producing raw materials.
- Increase the efficiency and reliability of the processes used in energy conversion and delivery systems.

Strategy

In cooperation with industry, ERDA will design, license, build and operate a 380 MWe Gross plant, which is an appropriate scale-up between the LMFBR test reactor (FFTF) with prototype primary system components and that anticipated for commercial size LMFBR's.

Elements of the strategy include:

- Distribute the component design and procurement effort throughout the nuclear components industry to build and strengthen a competitive capability for LMFBRs within the United States and within the electric power industry.
- Pursue the licensing, safety, and environmental requirements for the CRBRP that are required for any commercial utility facility. In the process inform the public about the safety of the installation.
- Provide for operation of this plant by a utility in a utility power grid for five years under the direction of the LMFBR program and then indefinitely at the option of the utility.
- Reduce the identified key uncertainties through the conduct of supporting research and development.

Federal Role

In the CRBRP project the relationship of the federal role to the industrial participants is contractually fixed. Financially, the electric utilities industry and the major manufacturers combined are providing approximately $260 million of the project's resources.

Using the FFTF and other test facilities, ERDA will play a lead role in the development of fuels, materials, and component technology necessary to support the construction and operation of this plant.

Using various safety research facilities, ERDA will develop realistic safety technology that will support the licensability of the plant, and will provide technical support to NRC as required in the resolution of problems associated with the safety and environmental aspects of this plant.

International Cooperation

There is no international program specifically concerned with the project.

Since the United States is a member of the International Atomic Energy Agency (IAEA), there is a constant information exchange and the potential for technical cooperation on this project with other members.

Technological Status and Problems

Status:

- A reference design for the Clinch River Fast Breeder Reactor has been completed.
- Most of the conceptual design and much of the detailed designs for the overall plant have been completed. Component design and procurement is well underway. The stated objective for maximum participation throughout the nuclear component industry is being achieved.
- Initial drafts of most of the System Design descriptions have been issued.
- Cost and schedule projections are being met.

Problems:

- Although development and testing of plant safety and component design features are underway, none affects the feasibility of the plant design.
- Resolving the intensity of the seismic event for design problem purposes needs to be accomplished. Resolution of this problem will involve ERDA, NRC, and USGS.

Institutional Status and Problems

Status:

- All NRC questions on the CRBRP Environmental Report have been answered and there appear to be no outstanding environmental issues that would delay licensing, construction, or operation of the CRBRP. NRC questions on the CRBRP Preliminary Safety Analysis Report (PSAR) are being answered.
- Component design and development is drawing heavily upon industrial capability. Utility participation involves about 700 utilities, including TVA in whose system the plant will operate.
- The Draft Environmental Statement (DES) for the CRBRP was issued by NRC on February 12, 1976.

Problems:

- Public acceptance of the safety of the breeder reactor, including materials safeguards, must be achieved.

Environmental Status and Problems

Status:

- The Environmental Impact Statement (EIS) for the overall LMFBR program has been approved and issued by ERDA.

Problems:

- No major, unacceptable environmental impacts have been identified.

Program Implementation

Implementation of this project covers two major phases: construction of the plant to achieve criticality in October 1983, and a subsequent five-year operating program to be completed in January 1989. Successful operation for three years (ending 1986) is an essential criterion for a commercialization decision, which is scheduled to be made in 1986.

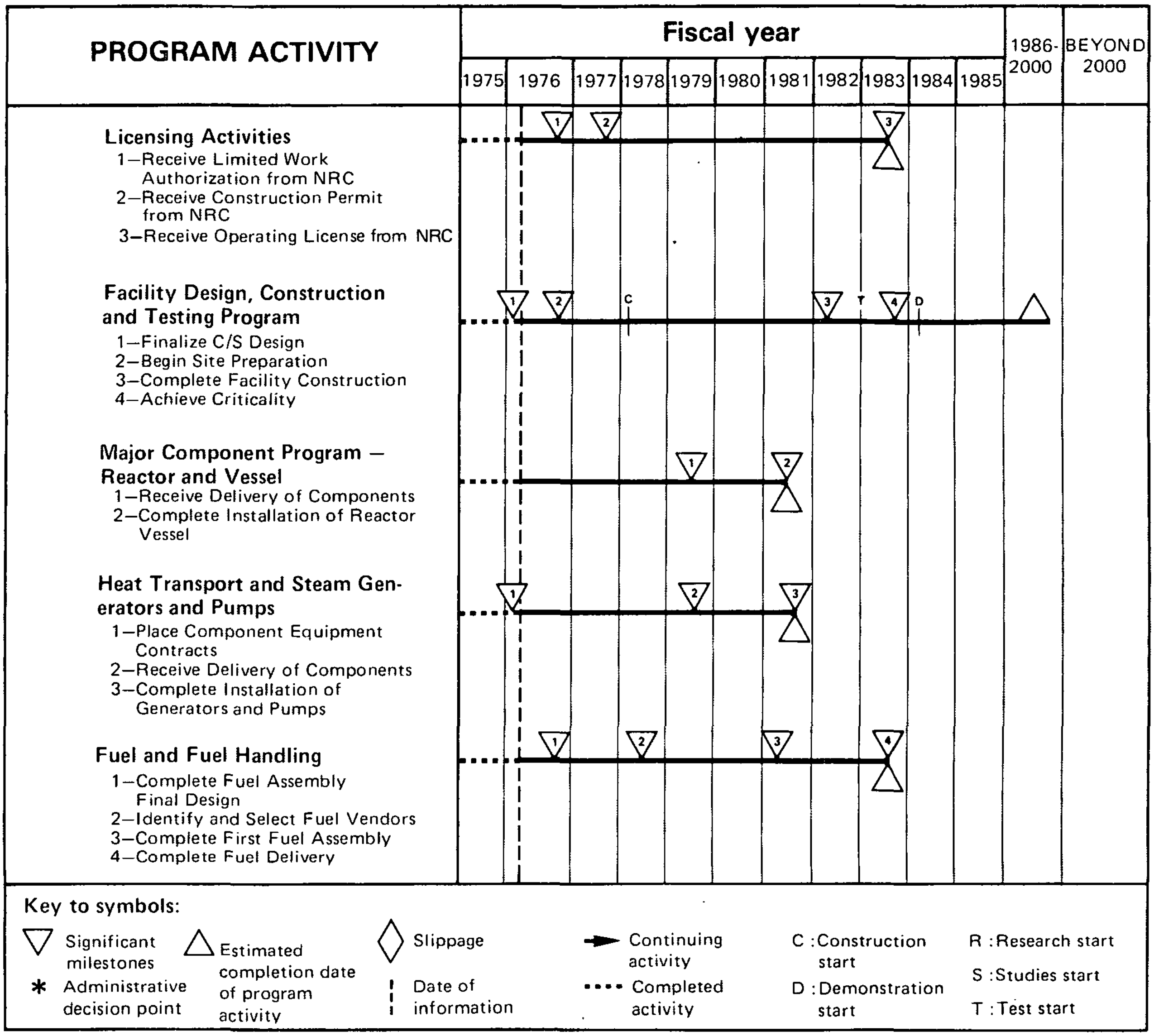
Licensing, environmental and safety-related activities are also well underway. The first fruition of these efforts will be in the anticpated receipt of a Limited Work Authorization and the consequent initiation of site work in November 1976. Receipt of a Construction Permit is anticipated well in advance of the time to initiate construction in February 1978. With the planned completion of construction in December 1982, the receipt of an Operating License in May 1983 is anticipated, followed by the achievement of criticality in October 1983. The licensing proceeding will include the usual public hearings which will give the public the opportunity to participate in the NRC decisions related to the CRBR.

The five-year operating program will demonstrate and document the reliability, maintainability, availability, and operating economy of a breeder reactor on a utility grid. It will demonstrate the safety and evironmental desirability of a breeder reactor so important to the public acceptability of the LMFBR. Operation of CRBRP will also yield the first large-scale measure of breeding ratio and doubling time. Capability to demonstrate reductions in doubling time and increases in breeding ratio during operation will be provided by utilization of improved fuel assembly and core designs in subsequent fuel loadings. Finally, it will contribute to the advanced fuels testing program of the overall LMFBR effort.

TVA is making some of its facilities available to the CRBRP project, is performing supportive work, and will operate the plant.

ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION

CLINCH RIVER BREEDER REACTOR PROJECT



CLINCH RIVER BREEDER REACTOR PLANT PROJECT

Federal Energy RD&D Budget **($ Millions)**

Agency	FY 1975		FY 1976*		FY 1977	
	BA	BO	BA	BO	BA	BO
ERDA						
Operating Expenses	62.8	60.0	107.0	57.0	237.6	171.0
Plant and Capital Equipment	0	0	0	0	0	0
Total	62.8	60.0	107.0	57.0	237.6	171.0

* Does not include funds for FY 1976 Transition Quarter.

FISSION POWER

Liquid Metal Fast Breeder Reactors

REACTOR SAFETY

Objectives

Near-Term:
(–1985)

- To resolve major safety issues to assure that commercial LMFBRs can be designated, constructed, licensed, and operated without undue risk to the public.
- To provide a safety technology base that will permit greater flexibility in LMFBR design and operation which may yield economic benefits.

Mid-Term:
(–2000)

- To resolve major safety issues that may arise.

Long-Term:
(Beyond 2000)

- To perform the necessary confirmatory research to provide adequate assurance of fast breeder reactor safety. (NRC)

National Energy Technology Goals Supported

Primary

- Protect and enhance the general health, safety, welfare, and environment related to energy.

Secondary

- Increase the use of essentially inexhaustible domestic energy resources.
- Efficiently transform fuel resources into more desirable forms.

Strategy

The program approach is to establish four lines of assurance that the hazardous material associated with the fission process in an LMFBR will not be released into the environment. These lines are:

1. Prevent accidents
2. Limit core damage
3. Contain accidents in primary system
4. Attenuate radiological products.

The first line of assurance will be established in as strong a fashion as is possible with available resources. A priority effort will continue within the third line to eliminate energetic recriticality as a concern. Work on establishing the second and fourth lines will be conducted in parallel; the elimination of energetic recriticality is a significant consideration in making the second and fourth lines viable lines of assurance.

A research program will also be conducted to provide an independent assessment of the technology and methodology proposed to resolve the principal safety questions affecting the LMFBR design (NRC).

At such time as the LMFBR becomes fully commercial, it is anticipated that the majority of the responsibility for conducting LMFBR safety R&D will be assumed by the reactor manufacturers. The extent and nature of ERDA involvement at that time will be governed by factors which are now difficult to predict with certainty. However, it is not likely that any large-scale experiments would continue to be conducted by ERDA.

Federal Role

The Energy Reorganization Act of 1974 charges ERDA with the responsibility for the development of nuclear power concepts. Because the potential for public risk is fundamentally and specifically affected by design, this requires the development of a base technology for use in the design and operation of commercial reactors. Ultimately, the primary effort in safety R&D will be the responsibility of private industry.

The Nuclear Regulatory Commission is also sponsoring LMFBR safety R&D as part of its confirmatory research activities. This work is supplementary to ERDA efforts with close liaison being maintained to avoid unnecessary duplication while maintaining NRC's independence. A description of current and planned reactor safety research sponsored by NRC is available as NUREG–75/058

International Cooperation

ERDA has proposed cooperation in some aspects of its fast breeder reactor safety program and it is currently under examination by IAEA members.

The NRC cooperates with the International Atomic Energy Agency, the International Standards Organization and other international organizations in nuclear safety and regulatory matters. The NRC has bilateral agreements with Denmark, Federal Republic of Germany, France, Italy, Japan, Spain, Sweden, Switzerland and the United Kingdom to exchange regulatory and safety information. Technical reports and visits of experts are exchanged with Federal Republic of Germany, France, Italy, Japan, and Sweden.

Technological Status and Problems

Status:

- Analytical models and experimental data are available or are being obtained as required to support present plant commitments (FFTF and CRBRP).
- Within the first line of assurance, the questions of Doppler coefficient and sodium superheat have been resolved to the extent required. The questions of effect of large blockage and pin-to-pin propogation of fuel failures are nearing resolution.
- Within the second line of assurance, work on fuel sweepout is in an early phase.
- Within the third line of asurance, analytical methods of determining mechanical deformation are nearing acceptance. Work on demonstrating the absence of energetic recriticality is in an early stage.
- Within the fourth line of assurance, aerosol and sodium fire models are preliminary defined.
- During FY 77 a decision will be made on whether the Safety Research Experiment Facility (SAREF) should be initiated in FY 78.
- Safety assessments required for the licensing of fast breeder reactors are being developed.

Problems:

- Within the first line of assurance, work remains to be performed on addressing sodium void effects on large cores, establishing quantitative reliability data, and other areas.
- Within the second line of assurance, work remains to be performed on establishing a model for fuel failure and assessing fuel coolant interactions.
- Within the third line of assurance, work remains to be done on post accident heat removal.
- Within the fourth line of assurance, aerosol and sodium fire models must be refined and applied.
- Methodologies need to be developed for utilizing additional data in making safety assessments. (NRC)
- Experimental verification is required of the validity of models and of the values of critical parameters used in determining LMFBR safety. (NRC)

Institutional Status and Problems

Status:

- The Nuclear Regulatory Commission is currently conducting independent activities required to provide a basis for licensing and regulation of LMFBR's.

Problems:

- The development of technology leading to more effective regulatory requirements is needed.
- The development of information, including assessments of public risk, needs to be undertaken so that informed public judgments can be made.

Environmental Status and Problems

Status:

- Confirmatory research activities have been defined to furnish data which are fundamental to the safety assessments required for licensing commercial plants. (NRC)

Problems:

- Facilities and additional experimental data are needed for the assessment of the environmental safety of commercial LMFBR plants. (NRC)

Program Implementation

Energy Research and Development Administration

The end product of the LMFBR safety program is a family of analytical models, computer codes and analytical and experimental data all appropriately documented in available form for use by interested parties in analyzing, designing, licensing, and operating LMFBRs.

The technical basis for project Safety Analysis Reports will be established primarily using current facilities. The Safety Research Experiment Facility (SAREF) if initiated in 1978 is projected to become operational in 1983. The facility would provide integration of separate effects data and extrapolation of data to larger scale.

Within the first line of assurance a high priority is assigned to developing quantitative reliability data. These data will be used in the conduct of a probabalistic risk assessment analogous to those reported in *WASH 1400.*

The use of probabilistic risk assessments will be extended into the full spectrum of LMFBR accident scenarios as a supplement to currently acceptable safety analysis approaches.

The information needed to develop a second line of assurance is currently being developed through small scale out-of-pile tests as well as in-pile tests in existing facilities such as the Transient Reactor Test Facility (TREAT) and Engineering Test Reactor (ETR).

A major question within the third line of assurance concerns the possible energetic recriticality of LMFBR fuel in the case of a postulated accident. Although it does not appear that the required arrangement of fuels could be obtained in an LMFBR, there is the possibility that a large-scale test may be desirable. This possibility is now being investigated.

The approach within the fourth line of assurance is aimed at scoping the area to determine which large-scale experimental programs, if any, should be undertaken.

With the basic approach and methods developed to establish a licensability case, responsibility for licensing of specific designs is a manufacturer responsibility. This concept is being demonstrated by the separation of responsibility for CRBRP, with the base program providing the technology and the project undertaking the licensing activity.

Simplified design approaches, data bases, and supporting technology will provide the broadest flexibility for design approaches, but the selection and specific defense of any design will be done by the designer.

Nuclear Regulatory Commission

To obtain the needed data for evaluation of models, the following technical program is being carried out by NRC:

- Study the interaction between sodium coolant and nuclear fuel in the case of a core disruptive accident.
- Investigate the potential for fuel recriticality in the event of core rupture and fuel melt down.
- Construct a facility for studying rapid transients in fast breeder cores to verify models of this type of potential accident.
- Study post accident heat removal proceduers.

LMFBR REACTOR SAFETY

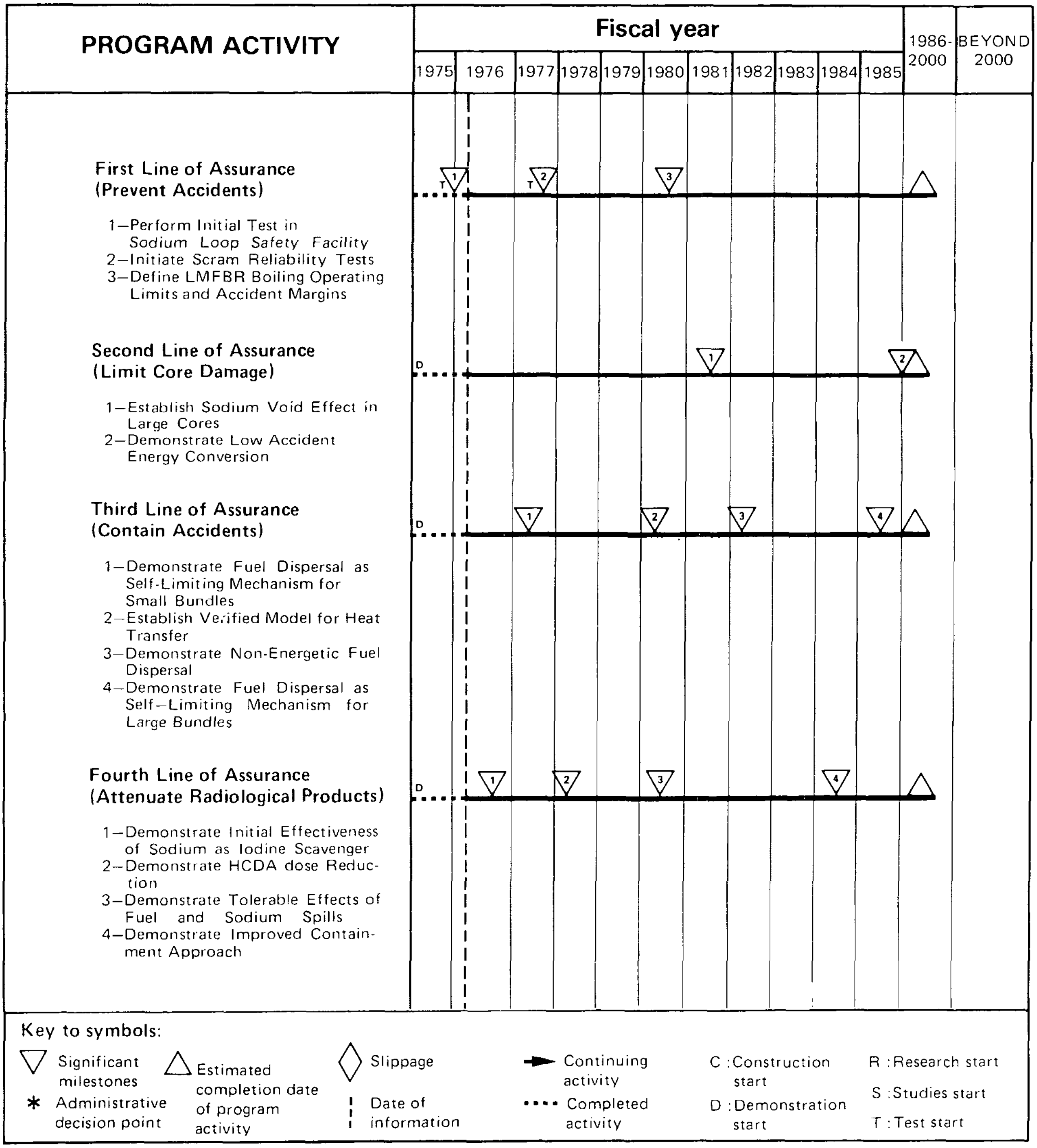
Federal Energy RD&D Budget **($ Millions)**

Agency	FY 1975		FY 1976*		FY 1977	
	BA	BO	BA	BO	BA	BO
ERDA						
Operating Expenses	39.4	36.8	46.0	44.0	54.5	52.2
Plant and Capital Equipment	4.7	2.9	3.4	1.8	3.9	3.4
Total	44.1	39.7	49.4	45.8	58.4	55.6
NRC	3.3	2.9	5.6	5.4	11.8	11.1
Total	47.4	42.6	55.0	51.2	70.2	66.7

* Does not include funds for FY 1976 Transition Quarter.

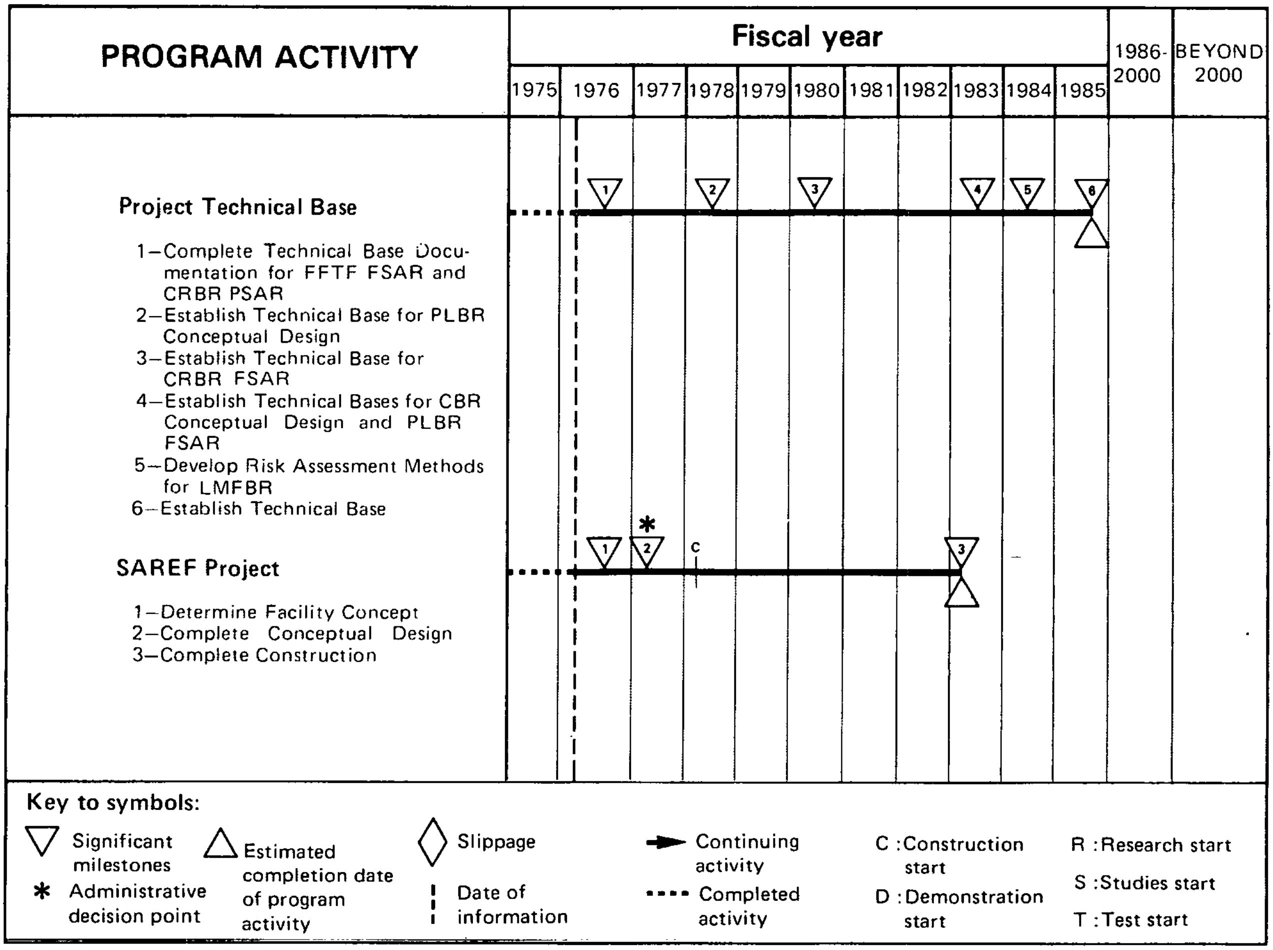
ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION

LMFBR REACTOR SAFETY



ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION

LMFBR REACTOR SAFETY (continued)



FISSION POWER

Liquid Metal Fast Breeder Reactors

ADVANCED FUELS

Objectives

Near-Term:
(–1985)

- To develop advanced cladding alloys which can withstand operating conditions to be encouraged in commercial LMFBRs, e.g., exposure to high temperature sodium and fast neutrons for periods of time consistent with fluences of at least 2.5×10^{23} neutrons/cm^2 ($E > .1$ Mev) with total swelling less than five percent and in-reactor creep less than one percent.
- To develop an economical advanced high breeding gain oxide fuel element as an extension of the established reference oxide fuel element technology.
- To develop advanced carbide and nitride fuel elements that are capable of achieving breeding gains that are at least twice that of the reference oxide fuel element system with the low cycle cost associated with fuel burnups of 150,000 MWD/T.

Mid-Term:
(–2000)

- To provide for commercial advanced LMFBR core designs; to assure technology transfer and improved methods to permit the commercialization of economical high breeding-gain LMFBRs.

National Energy Technology Goals Supported

Primary

- Increase the use of essentially inexhaustible domestic energy resources.

Secondary

- Efficiently transform fuel resources into more desirable forms.
- Increase the efficiency and reliability of the processes used in the energy conversion and delivery systems.

Strategy

The required testing period is long in comparison to program schedule requirements; therefore, it is not possible to evaluate materials and design concepts sequentially. An intensive screening phase will be conducted for the next few years in order to bring forward the best candidate designs. Screening will be based on irradiation testing in EBR-II, fabrication experience, and system design studies. This early phase is supported by activity in the National Laboratories, universities, and the commercial sector. Some commercial funding is also provided, mainly through the establishment of experimental fuel production facilities, and the development and provision of nuclear safeguards systems. Following the screening phase, a selected advanced fuel design will be evaluated on a statistical basis by making partial core loadings in FFTF and CRBR. At that stage the fuel fabrication will be done by the commercial participants in the program. Thus, experience will be gained on fuel element performance in-core, fuel fabrication, and core design optimization, as well on reprocessing and core safety aspects provided by support areas. This experience provides the basis for selecting an advanced design for the commercial LMFBR in the middle 1980's.

Federal Role

Since development of an advanced LMFBR fuel assembly technology involves a long lead time and large capital investments coupled with substantial uncertainty, federal involvement is necessary. For the near-term, the development tasks are carried out with federal funding in numerous national laboratories, universities, and commercial laboratories. However, the commercial organizations (Westinghouse ARD, Atomics International, and Battelle Memorial Institute) supply the fuel fabrication plant and capital equipment. This funding arrangement is planned to continue until the middle 1980's. At that time it is likely that a strong commercial interest will assume a greater proportion of the support. Before the year 2000, the commercial funding base should be dominant.

International Cooperation

A broad bilateral LMFBR agreement involving fuel development exists with the United Kingdom. Two additional bilateral agreements, one with the German-Benelux group and one with France, are now being negotiated. All three call for an exchange of technical information. Exchanges of technical experts and special test materials are also included. Preliminary technical inforamtion exchange meetings on advanced fuel development have been held successfully with the United Kingdom, France, and the German-Benelux group.

Technological Status and Problems

Status:

- Systems design studies, performance modeling, fabrication, irradiation testing, and materials properties determinations are underway. Candidate materials and designs have been selected and are being evaluated in order to select the more viable choices. This will provide the data base for design of full-size fuel assemblies to be tested in the FFTF and CRBR.

Problems:

- Advanced fuels which can maintain the characteristics of total swelling of less than five percent and in-reactor creep of less than one percent after encountering extended exposure to high temperature sodium and fast neutrons have not been developed.
- Advanced carbide and nitride fuels which are capable of achieving significantly higher breeding gains and lower fuel costs have not been developed.

Institutional Status and Problems

Status:

- A government-industry cooperative program is in existence.

Problems:

- A private, competitive fuel industry needs to be developed.

Environmental Status and Problems

Status:

- Laboratory environmental controls are in effect.
- Environmental controls for a private, competitive fuel industry need to be developed.

Program Implementation

Energy Research and Development Administration

The Advanced LMFBR Fuel Development Program objectives will be achieved by implementation in three phases that are closely related to the overall LMFBR development plan.

- During the screening phase, fuel element and structural alloy candidates will be evaluated via ex-reactor studies, fabrication experience, and in-reactor testing. By 1978 there will be enough information to permit selection of the best fuel system concepts and elimination of unpromising concepts. Parallel efforts in supporting programs will establish the incremental reactor safety and reprocessing technology that is unique to advanced fuel systems. Parallel efforts in supporting programs will continue.
- During the 1978–1983 period the selected advanced fuel system will be subjected to intensive testing in EBR-II and in FFTF (including a partial core loading of FFTF in 1983). These will lead to a partial core loading of CRBR in 1985. Parallel efforts in supporting programs will continue.
- In 1985 the option to select an advanced fuel assembly design for commercial advanced LMFBRs will be available.

LMFBR ADVANCED FUELS

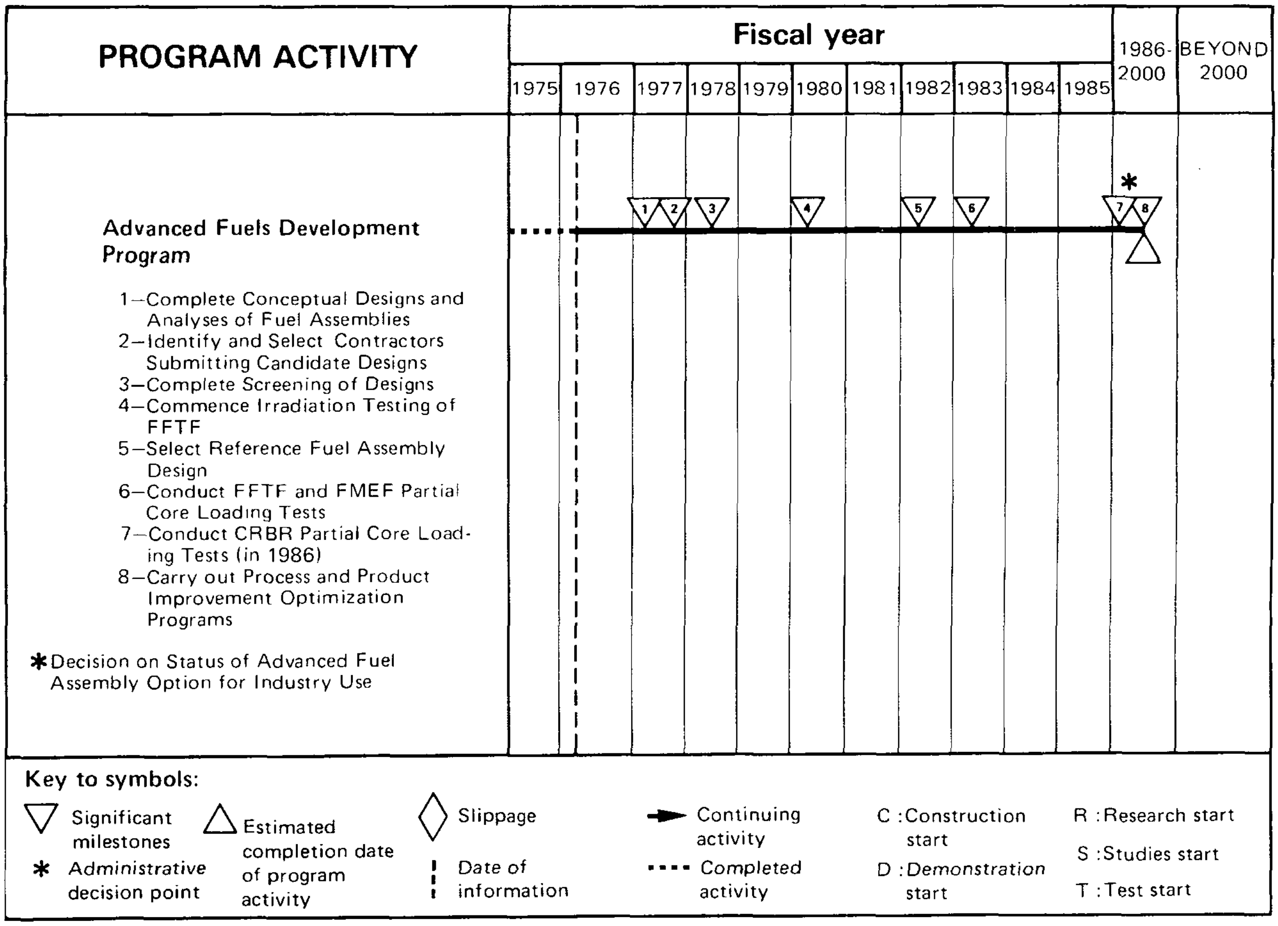
Federal Energy RD&D Budget **($ Millions)**

Agency	FY 1975		FY 1976*		FY 1977	
	BA	BO	BA	BO	BA	BO
ERDA						
Operating Expenses	17.3	13.3	14.5	14.4	15.5	15.0
Plant and Capital Equipment	0.5	0.3	0.6	0.4	0.7	0.6
Total	17.8	13.6	15.1	14.8	16.2	15.6

* Does not include funds for FY 1976 Transition Quarter.

ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION

LMFBR ADVANCED FUELS



FISSION POWER

Water Cooled Breeder Reactor Program

Objectives

Near-Term:
(–1985)

- To confirm the capability of breeding in a pressurized water reactor.
- To develop and disseminate the technology necessary for commercial application of the thorium-uranium breeder concept to light water reactors.

National Energy Technology Goals Supported

Primary

- Increase the use of essentially inexhaustible domestic energy resources.

Secondary

- Expand the domestic supply of economically recoverable energy-producing raw materials.
- Efficiently transform fuel resources into more desirable forms.
- Increase the efficiency and reliability of processes used in energy conversion and delivery systems.

Strategy

This program provides for the research, development, design, fabrication and operation of a Light Water Breeder Reactor (LWBR) core to confirm that breeding can be achieved in existing and future light water reactor systems using the thorium-uranium-233 fuel system. Successful operation of this LWBR core in a light water reactor will provide the basic technology which would make available for power production about 50 percent of the energy in the thorium reserves, a source of energy many times greater than known fossil fuel reserves. The LWBR concept is the only known approach for increasing the fuel utilization of the light water thermal reactors significantly beyond the one or two percent achievable with present types of light water reactors. Since the LWBR concept is based on the proven technology of the pressurized light water system, successful operation of the LWBR core will show that it is feasible to install breeder cores in existing and future pressurized water reactor plants and will provide the basic technology which can be used directly in large-scale light water breeder applications.

The program also supports the Advanced Water Breeder Applications (AWBA) project which is directed toward assisting U.S. industry in the evaluation and application of the technology developed and confirmed in the Light Water Breeder Reactor (LWBR) program to existing and future water reactor plans.

Federal Role

Federal funds are required to support the Water Cooled Breeder Reactor effort due to the commercial uncertainties and financial risk associated with new technologies and the need to accelerate progress beyond normal commercial capability. This federal effort includes both the research, development, design, fabrication and operation of an LWBR core and dissemination of LWBR technical information to U.S. industries. The AWBA project has been initiated to assist vendors, utilities and other interested organizations in evaluating the technology developed and confirmed in the LWBR project and to determine the degree to which they desire to apply the LWBR technology to their own programs.

Technological Status and Problems

Status:

- Fabrication of the Shippingport LWBR core is well underway, the reactor vessel closure head is nearing completion, and the control drive mechanisms and core barrel have been delivered.

Problems:

- Testing with the seed-blanket LWBR must be conducted to evaluate performance, measure the breeding ratio, and confirm the technology.
- Determination must be made of how to most efficiently produce U–233 for light water breeder cores while producing useful power.
- The physics, thermal and fuel performance characteristics of large light water pre-breeder and breeder cores must be established.

Institutional Status and Problems

Status:

- The LWBR concept is an extension of the light water reactor technology which is well established today. This permits concentration of the development effort on the breeding technology without the uncertainties and cost of developing a new kind of power plant.

Problems:

- A development effort is underway to determine whether breeding can be attained in a light water reactor using the thorium cycle. Proof of breeding will not be established until the early 1980's. Information is being developed under the Advanced Water Breeder Applications Program that is necessary for industry to evaluate and apply the LWBR concept. This information when developed will allow industry to decide if economic considerations warrant commercialization of the concept.
- Commercial applicability of the LWBR must be assessed by industry based on the technology being developed in the LWBR and AWBA programs.
- Industry has to establish a thorium and fuel recycle capability.

Environmental Status and Problems

Status:

- A draft Environmental Statement in support of the operating of the Shippingport LWBR core and subsequent LWBR development work has been issued. Public comments on the draft have been received and a public hearing in Pittsburgh has been held. The final Environmental Statement is under preparation.

Problems:

- Except for reduced requirements for mining and the enrichment of uranium, the environmental problems associated with LWBR's are similar in nature to those associated with LWR's.

Program Implementation

The research, development, design, fabrication and operation of the LWBR core in the Shippingport Atomic Power Station is being sponsored by ERDA.

It is planned that the LWBR core will be installed in the Shippingport reactor plant during 1976. The core will be operated for about three years. Subsequent to operation the core will be removed and an end-of-life proof-of-breeding core evaluation program will be performed.

Technical information relating to the development of the LWBR core is being carefully documented, published, and made available to U.S. industry. This is the same procedure used to promulgate the technology developed for the Shippingport Atomic Power Station (the first commercial nuclear powered central power station in the United States) which demonstrated the feasibility of pressurized water reactors and zircaloy clad oxide fuel rods. The technology is currently widely used by the nuclear industry.

WATER COOLED BREEDER REACTOR PROGRAM

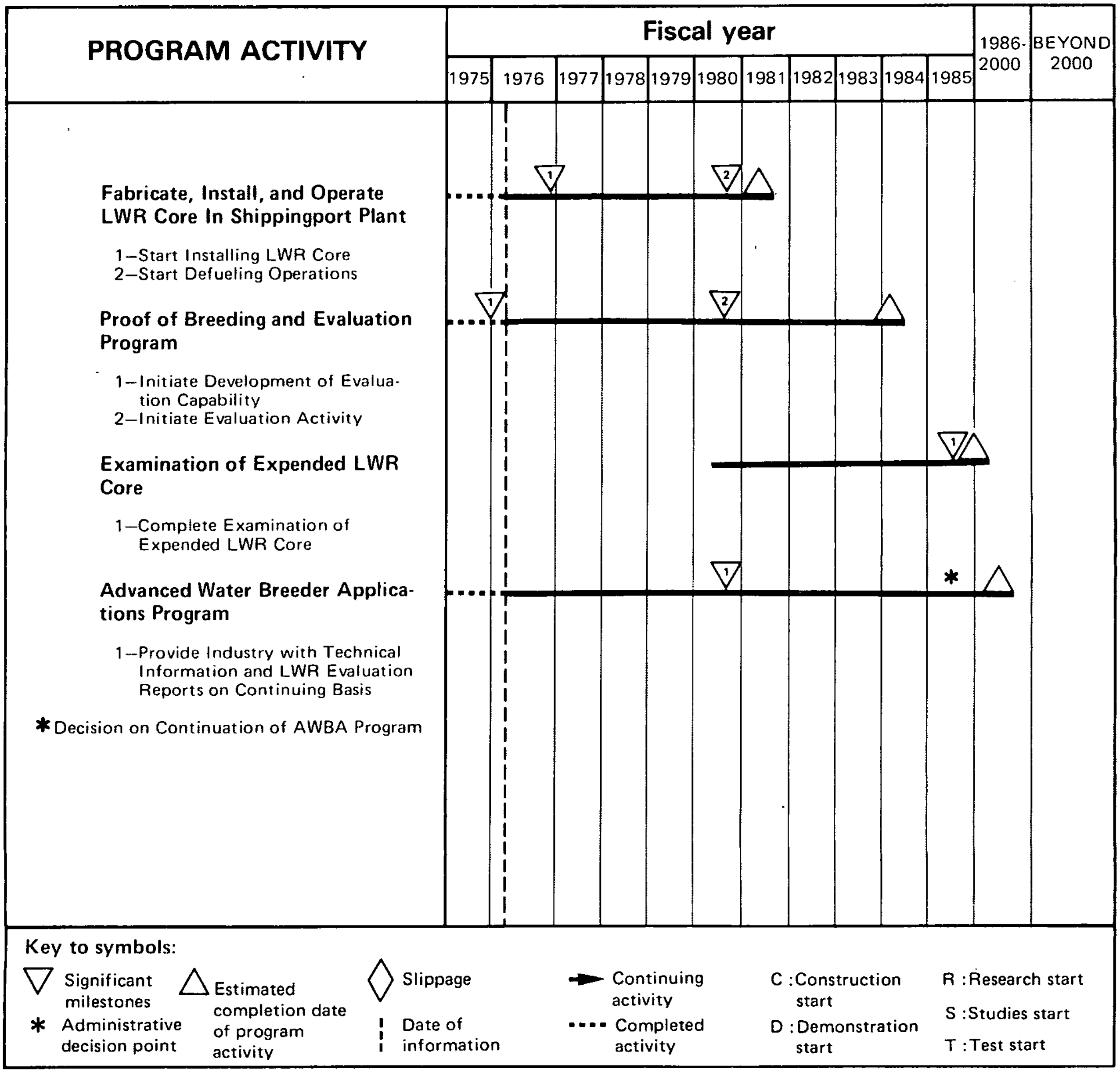
Federal Energy RD&D Budget **($ Millions)**

Agency	FY 1975		FY 1976*		FY 1977	
	BA	BO	BA	BO	BA	BO
ERDA						
Operating Expenses	31.2	30.3	39.4	37.9	37.0	35.7
Plant and Capital Equipment	5.1	7.2	2.7	6.0	11.8	3.9
Total	36.3	37.5	42.1	43.9	48.8	39.6

* Does not include funds for FY 1976 Transition Quarter.

ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION

WATER COOLED BREEDER REACTOR PROGRAM



FISSION POWER

Gas Cooled Reactors

THERMAL REACTORS (HTGR AND VHTR)

Objectives

Near-Term:
(–1985)

- To establish a technology base for the variety of high temperature gas cooled thermal reactors (HTGRs) and assist industry in the completion, design, and initiation of construction of a large power plant.

Near-Term:
(–2000)

- To assist industry, if and as appropriate, in the commercial development and deployment of high temperature gas cooled thermal reactors (HTGRs and VHTRs) capable of improved resource utilization, reduced environmental effects, and improved siting flexibility as compared to light water (LWR) types.

National Energy Technology Goals Supported

Primary

- Increase the efficiency and reliability of the processes used in energy conversion and delivery systems.

Secondary

- Expand the domestic supply of economically recoverable energy producing raw materials.
- Protect and enhance the general health, safety, welfare and environment related to energy.

Strategy

During 1976 industry and ERDA will complete studies of the technical, economic, and business factors associated with introducing the steam cycle HTGR and to decide whether to continue with commercialization and how to do so. If commercialization proceeds, an expanded component development and qualification program beginning in FY 1977 will be required by ERDA to reduce the technical uncertainties, and utility support will be needed for a lead plant. As part of this program, ERDA would complete the technology and engineering for selected components of a Rankine cycle HTGR by 1985 and would develop the technology for recycle of HTGR fuels using the thorium-uranium-233 fuel cycle by early 1990's; support would be provided for first-of-a-kind components in a lead plant project sponsored by industry and the utilities.

In addition, ERDA, in conjunction with industry, would: (1) develop the technology and engineering for selected components of an HTGR-type direct cycle reactor in support of an industrial program to develop this concept for initial commercial operation in the 1990's; (2) determine the program and resources required to develop Very High Temperature Gas Cooled Reactor (VHTR) systems capable of operating with helium outlet temperature above 1500° F for use as heat sources in high temperature processes; and (3) carry out those development programs which are justified on the basis of the assessed benefits.

An alternative strategy in the event of a major perturbation causing the commercialization of the steam cycle to be abandoned by industry for other than technical reasons is to develop advanced gas cooled reactors without the benefit of the steam cycle HTGR. Such a development program would probably be largely ERDA-funded and would lead to direct cycle and VHTR demonstration plants in the early 1990's.

Federal Role

Support basic research and development, provide test facilities for components and systems for advanced concepts, and participate in demonstration projects. Federal participation is necessary because economic incentives are inadequate in the near-term and risks too high to induce sufficient non-federal support.

The HTGR development program is closely coordinated with the General Atomic Company (GA) privately-funded programs in fuel, graphite, and other reactor components for the steam cycle plant. The Oak Ridge National Laboratory (ORNL) also conducts R&D in support of this program.

ERDA has underway an HTGR fuel recycle program and is beginning programs for handling HTGR radioactive wastes. Accountability technology is expected to be developed cooperatively with NRC.

Privately-funded work (principally GA and utilities) is supplemented by the ERDA Direct Cycle and VHTR Development Programs. VHTR conceptual designs funded in part by ERDA have been developed and studies on the potential for industrial processes used are in progress. NASA is funding several studies of hydrogen production, including use of nuclear process heat. The American Iron and Steel Institute is conducting studies of nuclear heat for making reducing gas for steelmaking with ERDA technical support.

International Cooperation

Agreements are in effect with the Nuclear Energy Agency Dragon Project and with the Federal Republic of Germany for exchange of information on fuel, graphite, fission product behavior and materials. Materials are being tested in out-of-pile loops in Oslo, Norway, under the Dragon Agreement. In the area of VHTR development, both the Federal Republic of Germany and the Japanese Atomic Energy Institute are performing studies and experimental work, but cooperation on these programs has not yet been implemented. Expanded cooperation with Germany and France for development of the steam cycle HTGR is being considered. An agreement is being negotiated with the Federal Republic of Germany to expand cooperation in the steam cycle HTGR, fuel recycle, the direct cycle HTGR, and the process heat VHTR.

Technological Status and Problems

Status:

- The 330 MWe Ft. St. Vrain demonstration plant is currently undergoing startup testing with full power expected by mid 1976. Industry is currently reviewing its plans for continuing the designing, licensing, and testing for larger versions of the HTGR. The on-going ERDA program is concentrated on completing the technology base for the fuel, the thermal barrier, the Pre-Stressed Concrete Reactor Vessel, establishing the technology for fuel recycle, and developing technology for advanced HTGRs. ERDA is performing an independent assessment of the gas-cooled reactor program to determine its future course in view of the industry situation.

Problems:

- Lack of operating experience of 330 MWe Ft. St. Vrain Reactor.
- Reliable operation of scale-up reactor components must be demonstrated.
- Development and qualification of initial, make-up, and recycle fuels and graphites remain to be demonstrated.
- Large-scale closed cycle turbomachinergy, heat exchangers and valves need to be developed for the direct cycle reactor.
- High temperature materials suitable for long-term operation in helium for process heat exchangers and other components must be developed.
- Adequate seismic damage assessment capability for the core and components does not exist.

Institutional Status and Problems

Status:

- Initial attempts by industry to commercialize the steam cycle HTGR have been unsuccessful and have resulted in large financial losses. Industry is unwilling to proceed without a reduction in technical and financial risks. No commercial HTGRs are on order at this time. No substantial industrial or Government commitments have been made to support advanced HTGRs.

Problems:

- If the technology is to be adopted, industry and Government must cooperate to establish the commercial potential of the steam cycle HTGR to justify continued heavy private and Government investment.
- Arrangements must be made to provide financing for the first-of-a-kind costs and for accepting the financial risk of the first large HTGR.

- ERDA must commit to close the fuel cycle at the appropriate time if the HTGR concept is to be viable.
- Government support of the direct cycle HTGR prototype development and testing must be provided.
- Simultaneous production and marketing of heat and electrical power from a single plant requires institutional, managerial and regulatory arrangements.

Environmental Status and Problems

Status:

- Relative to light water reactors, gas cooled thermal reactors are environmentally more attractive. The HTGRs have about 40 percent efficiency as compared to about 33 percent for light water reactors and thus have less thermal discharge and lower cooling water requirements. An HTGR would use 25 to 50 percent less uranium ore during its lifetime than an LWR. Direct cycle HTGRs have the potential for about 50 percent in thermal efficiency and significantly lower environmental effects; their economical use of dry cooling towers can provide greater siting flexibility. In process heat applications, the VHTR has potential for reducing air pollution relative to fossil-fuel systems as well as mining and land reclamation requirements.

Problems:

- The environmental problems associated with gas cooled thermal reactors are the same in nature but of less severity than other nuclear reactors.

Program Implementation

Energy Research and Development Administration

The lack of satisfactory commercial activity has led to a major program review and evaluation by industry and determine by mid-1976 the proper course of the plan. At present, the principal HTGR activities are aimed at completing by the mid 1980's the technology base necessary for construction and operation of large commercial HTGRs. This technology is demonstrated in the Ft. St. Vrain reactor which is expected to begin commercial operation by mid-1976.

The direct cycle HTGR program will continue in a Conceptual Design phase during FY 1976 and 1977 with the short-term objective of developing a design with a plant capital cost at least 20 percent lower than current LWRs, with high potential reliability and maintainability, and with a thermal efficiency of 50 to 55 percent. Development plans will be prepared and certain long lead and key feasibility tests will be done. This work will be coordinated closely with the German HHT project.

Near-Term:

Begin commercial operation of the 330 MWe Ft. St. Vrain demonstration plant.

Make decision on commercialization of steam cycle HTGR.

Complete studies of development alternatives and prepare a development plan for a direct cycle HTGR program.

Initiate steam cycle HTGR lead plant project design and construction.

Develop and test materials and component technologies for the VHTR and HTGR.

Complete large HTGR steam cycle component development. Complete construction of steam cycle HTGR lead plant. Industry to initiate construction of commercial steam cycle HTGRs.

Test prototype HTGR gas turbine components.

Begin construction of first large HTGR gas turbine power plant.

Begin construction of first VHTR demonstration plant.

Mid-Term:

Commercial steam cycle HTGRs come into operation.

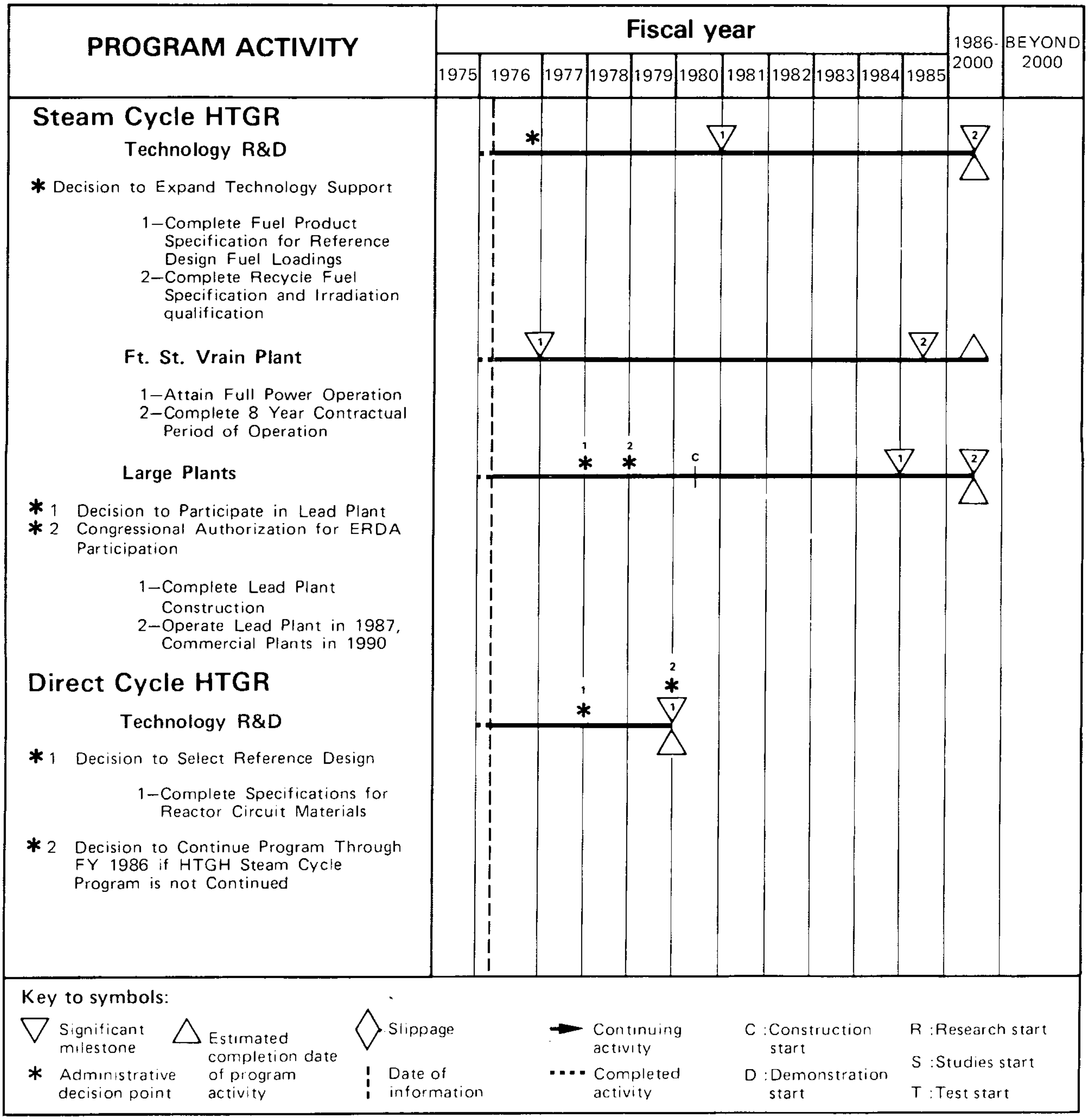
Complete construction and start up the first large HTGR gas turbine plant.

Complete fuel and materials technology program and components and systems testing for VHTR.

Complete construction and start up first VHTR demonstration plant.

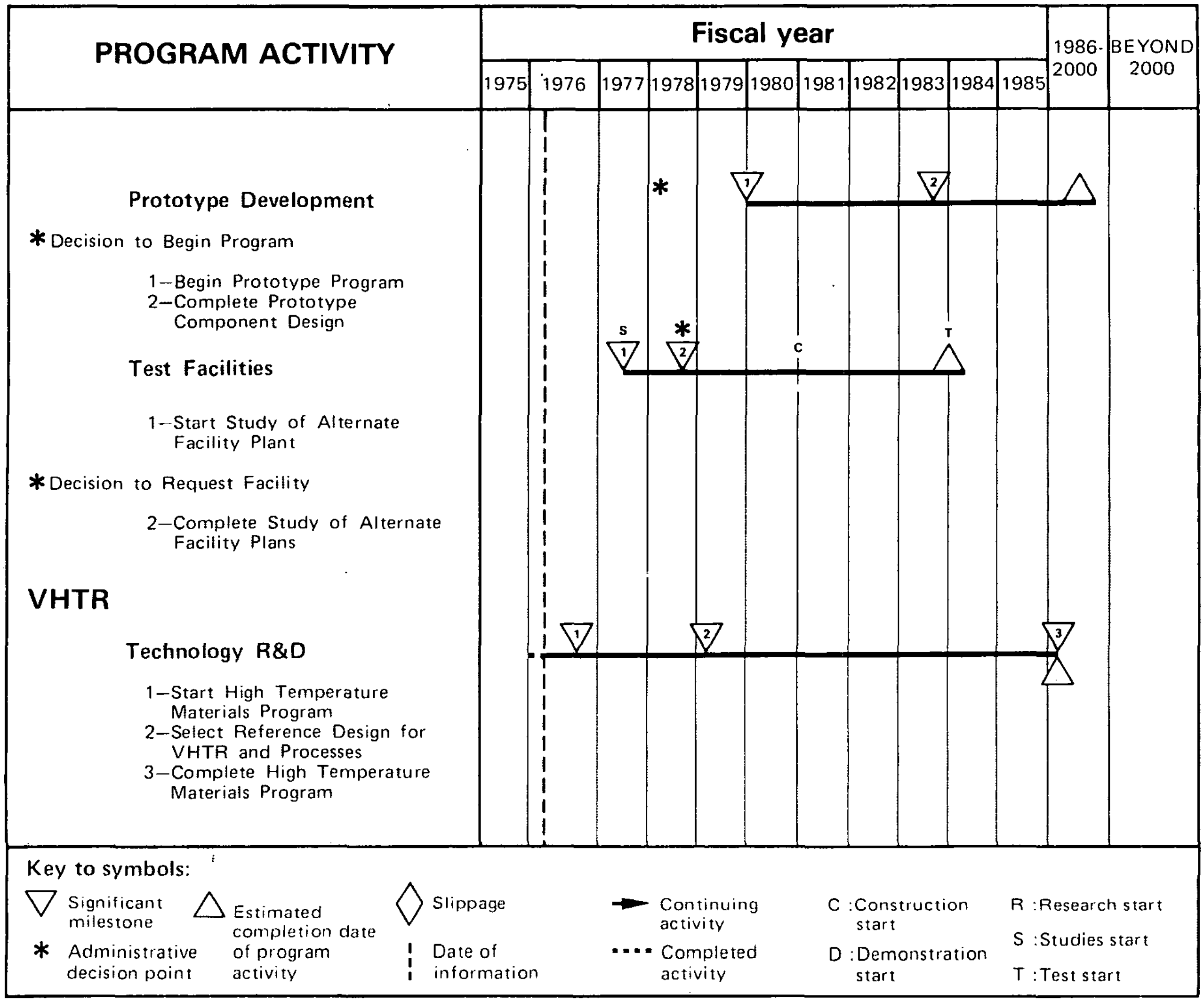
ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION

THERMAL REACTORS



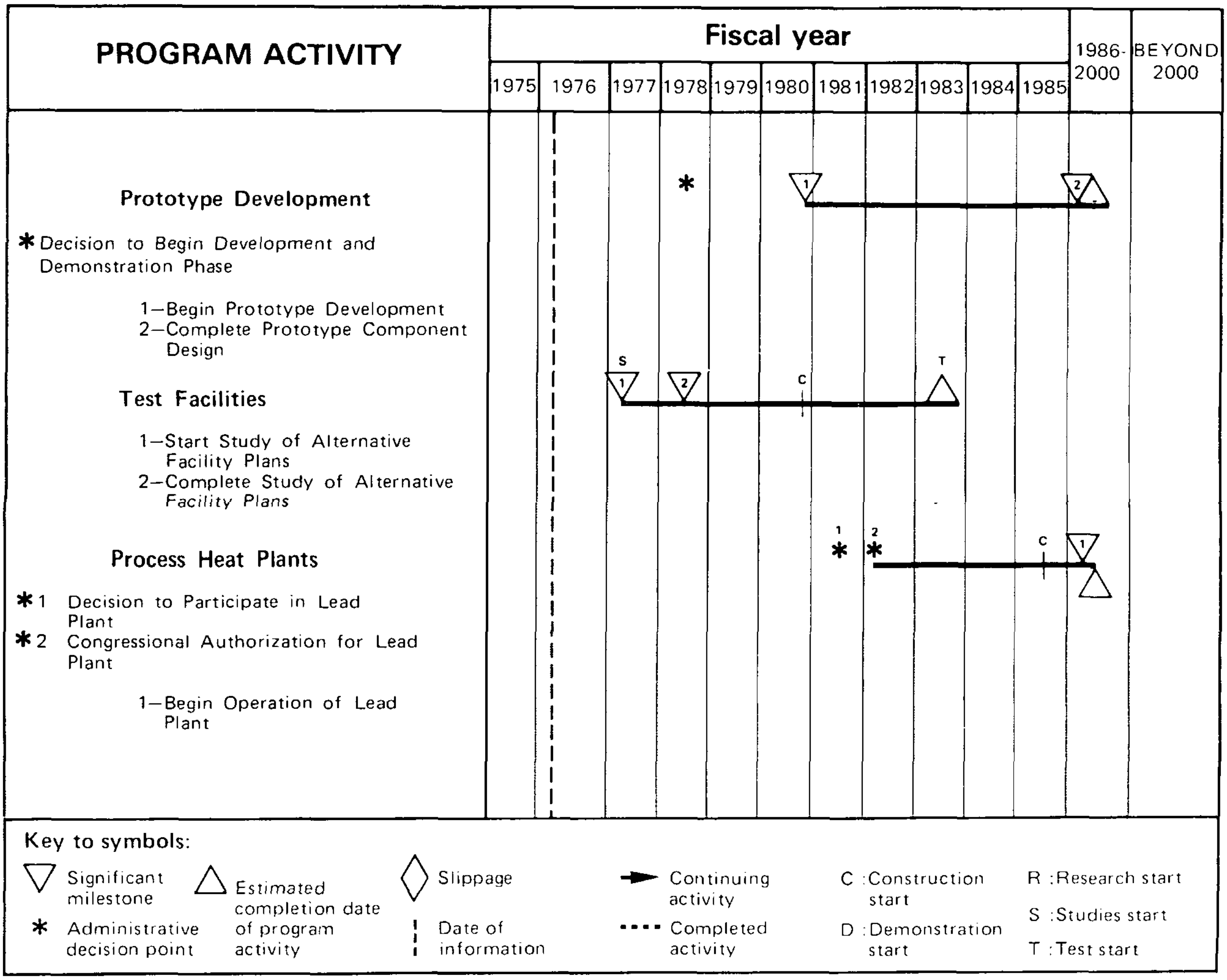
ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION

THERMAL REACTORS (continued)



ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION

THERMAL REACTORS (continued)



THERMAL REACTORS

Federal Energy RD&D Budget **($ Millions)**

Agency	FY 1975 BA	FY 1975 BO	FY 1976* BA	FY 1976* BO	FY 1977 BA	FY 1977 BO
ERDA						
Operating Expenses	13.7	12.0	14.8	14.1	15.6	15.4
Plant and Capital Equipment	0.5	0.3	0.5	0.2	0.6	0.9
Total	14.2	12.3	15.3	14.3	16.2	16.3

* Does not include funds for FY 1976 Transition Quarter.

FISSION POWER

Gas Cooled Reactors

FAST BREEDER REACTORS

Objectives

Near-Term:
(–1985)

- To provide engineering and safety technology needed to support an industrially-organized effort potentially leading to construction of a GCFR demonstration plant and operation in the late 1980's.

Mid-Term:
(–2000)

- Assuming that a decision is made to construct a GCFR demonstration plant, develop this concept for commercial use before the year 2000.

National Energy Technology Goals Supported

Primary

- Increase the use of essentially inexhaustible domestic energy resources.

Secondary

- Expand the domestic supply of economically recoverable energy raw materials.
- Increase the efficiency and reliability of the processes used in energy conversion and delivery systems.

Strategy

Near-Term:

The GCFR program expects to rely on the current technology for uranium-plutonium oxide fuels with stainless steel claddings and part of the existing technology for HTGR components, thereby substanially reducing development costs. The ERDA program is aimed at evaluated and testing the unique features of the GCFR design to demonstrate their feasibility and provide data for a demonstration plant design. ERDA expects that industry will submit a proposal for a cooperative demonstration plant project. A decision on ERDA participation will be made after review and negotiation of the technical, financial, and management aspects of the proposal, and after completion of an environmental impact statement.

Mid-Term:

Plans for the commercial deployment of the GCFR will be made subsequent to a decision to begin a demonstration plant project. The necessary fuel cycle development will be initiated subsequent to this decision.

Federal Role

Federal participation is initially necessary because economic incentives are inadequate in the near-term and risks too high to induce sufficient non-federal support. This participation takes the form of supporting basic research and development, providing test facilities for components and systems, and participating in a demonstration project if program priorities and funding permit.

ERDA and private utility funds support the ongoing GCFR development work. General Atomic serves as the industrial contractor, providing the overall coordination of the program and the design of the demonstration plant. ANL functions as a supporting laboratory for fuels, physics, and safety analyses and test data. ORNL functions as a supporting laboratory, providing some of the required pressure vessel and shielding analyses and test data. ORNL will also conduct thermal hydraulic and structural testing of core elements in the Core Flow Test Loop.

International Cooperation

No U.S. government exchange agreements exist at this time. However, the General Atomic Company has private cooperative information exchange and experimental program agreements with the Swiss Federal Institute for Reactor Research; Kraftwork Union and the national laboratories, KFA-Julich and GFK-Karlsruhe, in West Germany; the multinational Gas Breeder Reactor Associates (GBR); and the IEA in Brazil.

Technological Status and Problems

Status:

- The GCFR is in the technology development phase. There are no unresolved feasibility questions, but engineering data are needed to provide an improved design basis.
- Prototype irradiation of GCFR fuel is underway to verify the pressure equalization system (venting).
- Reference design for a 300 MWe demonstration plant has been prepared.
- Development plans for key components for the GCFR demonstration plant have been prepared.
- A preliminary Safety Information Document has been submitted and is undergoing review by the NRC.
- Initial critical experiments have been completed to verify basic core physics calculations.

Problems:

- The thermal hydraulic behavior of GCFR fuel assemblies remains to be verified under both steady-state and transient conditions.
- Adequate testing is required to demonstrate that the practical engineering details of the fuel pin pressure equalization system are feasible.
- The development and testing of large-scale GCFR components and systems (e.g., helium circulator, steam generator, and fuel handling machine) must be accomplished during a demonstration plant project.

Institutional Status and Problems

Status:

- The GCFR technology development program is a joint U.S. Government, foreign governments, and private industry effort directed toward construction of a cooperative GCFR demonstration plant.
- The Southwestern Public Service Company has announced its interest in taking the lead role in construction of the first GCFR, and in contributing $100 million to the plant project.
- The decision for wide-scale development of the breeder has not yet been made by ERDA.

Problems:

- Arrangements must be made to provide financing for the first-of-a-kind costs and for accepting the financial risk of the GCFR demonstration plant.

Environmental Status and Problems

Status:

- In 1974, the AEC Directorate of Licensing requested that the Preliminary Environmental Impact Report be submitted for the GCFR. This report is now undergoing review by NRC. The report indicated that the environmental impact of the GCFR is expected to be similar to that of the LMFBR.

Problems:

- These environmental impacts include construction and land use, heat dissipation, discharge of chemicals, release of radioactive materials, and waste disposal.

Program Implementation

Energy Research and Development Administration

The GCFR demonstration plant program can be separated into two phases: first, a Program Definition Phase which includes program planning, preliminary design, and technology development, all leading to a decision point in 1979 regarding proceeding with a demonstration plant; and second, a Development and Demonstration Phase which includes construction, plant startup and operational testing extending into the early 1990's.

Near-Term:

Work on the Core Flow Test Loop (CFTL) will be initiated during this phase so that data on the thermal and mechanical behavior of multipin fuel assemblies cooled by high pressure helium will be available for detailed fuel design during the Development and Demonstration Phase. Because design of the fuel appears to be a pacing item for the GCFR demonstration plant, early construction and operation of the CFTL to verify basic core design assumptions is required.

Assuming a favorable decision to proceed with a demonstration plant, a utility would be expected to take a lead role in constructing the demonstration plant. Other participants would probably include ERDA and national laboratories for technology development and first-of-a-kind support, an architect-engineer for plant design and construction, and possible foreign participants.

Mid-Term:

The major milestones scheduled for the mid-term would be the GCFR demonstration plant startup and full power operation.

Following sucessful operation of the demonstration p!ant, commercial orders would be expected. Work on the commercial plants would be expected to be funded and carried out by private industry.

Long-Term:

Full-scale commercialization of the GCFR during this time period would be expected. A competitive LMFBR-GCFR breeder economy would be expected to develop during this time.

FAST BREEDER REACTOR

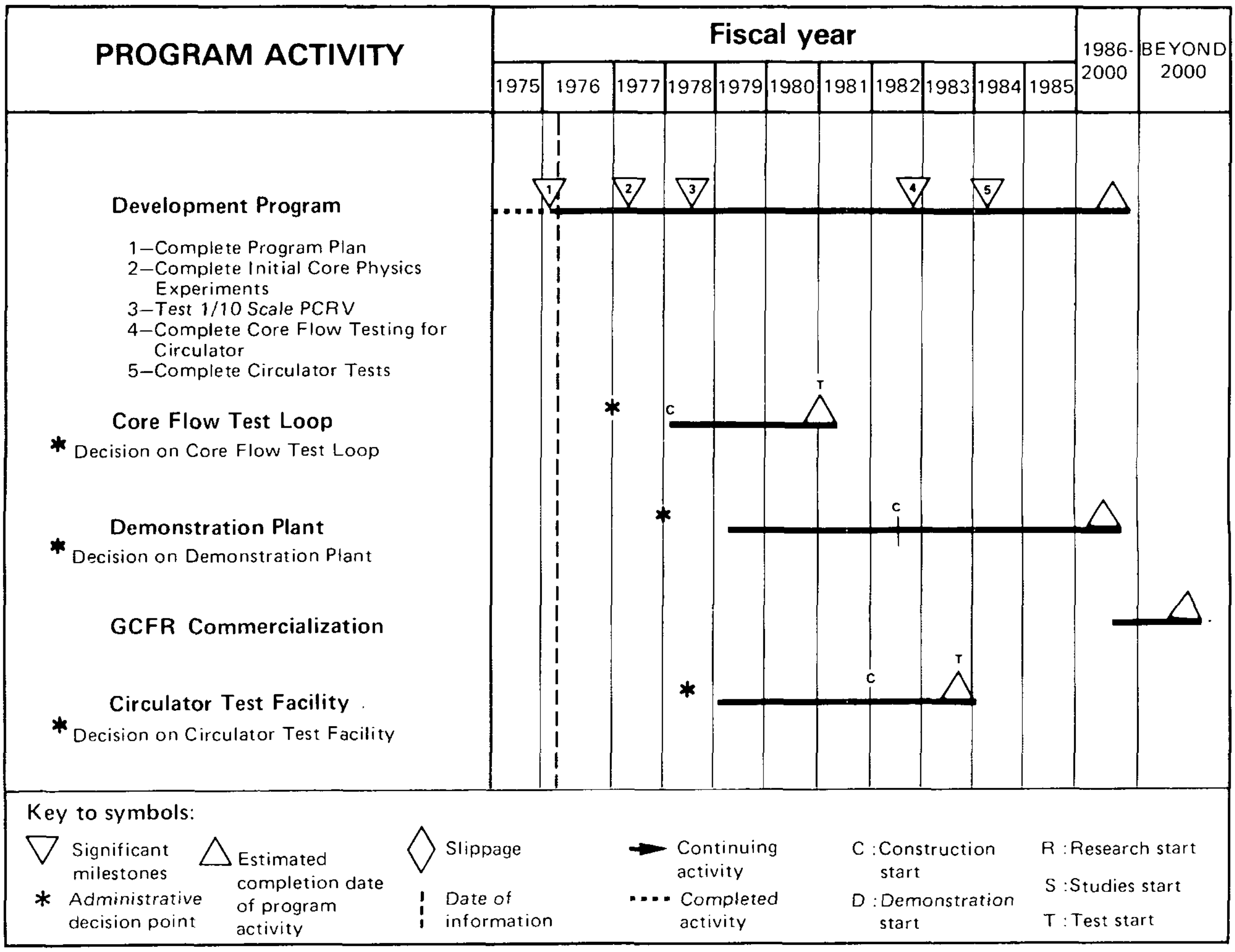
Federal Energy RD&D Budget **($ Millions)**

Agency	FY 1975		FY 1976*		FY 1977	
	BA	BO	BA	BO	BA	BO
ERDA						
Operating Expenses	6.6	5.4	6.2	6.0	7.8	7.0
Plant and Capital Equipment	0.2	0.1	0.1	0.1	0.3	0.5
Total	6.8	5.5	6.3	6.1	8.1	7.5

* Does not include funds for FY 1976 Transition Quarter.

ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION

FAST BREEDER REACTOR



FISSION POWER

Gas Cooled Reactors

REACTOR SAFETY

Objectives

Near-Term:
(–1985)

- To identify, investigate and develop the gas-cooled reactor safety technology necessary to establish criteria, perform evaluations, develop design options, and determine plant characteristics. This includes work on the High Temperature Reactor (VHTR) for process heat applications, and the Gas Cooled Fast Breeder Reactor (GCFR).

Other federal agency objectives include:

- To perform the necessary confirmatory research to provide adequate assurance of the safety of gas-cooled reactors (GCR) licensed by the NRC.
- To assess technology methods or procedures that will minimize or solve problems inherent to GCR waste heat rejection and radioactive discharges.

Mid-Term:
(–2000)

- To extend needed gas cooled reactor safety technology in the event of large-scale use of gas cooled reactors in cooperation with industry.

National Energy Technology Goals Supported

Primary

- Protect and enhance the general health, safety, welfare and environment related to energy.

Secondary

- Efficiently transform fuel resources into more desirable forms.

Strategy

The strategy for all four concepts is the same although it will be carried out on different time schedules. The first part of the strategy is to identify key safety information needs through accident risk analysis and design review.

The second part is to investigate means of providing these information needs, and the third part is to develop the safety technology. These efforts are to be closely coordinated with the reactor design and development activities in order to produce practical designs with adequate safety.

Efforts for the HTGR steam cycle have direct application to all of the other concepts. The highest priority GCFR effort is to obtain data for fuel and core safety margins under various GCFR accident conditions. Alternate means for obtaining this data and the required schedule to acquire the data are being studied. This has lead to conceptual design for a helium cooled in-pile test loop, the Gas Reactor In-Pile Safety Test (GRIST).

The program approach is to establish four lines of assurance that the hazardous material associated with the fission process in a gas cooled reactor will not be made available to the environment. These lines are:

1. Prevent accidents
2. Limit core damages
3. Contain accidents in primary system
4. Attenuate radiological products.

Other elements of the federal strategy include:

Establish data and methods needed for granting construction permits and operating licenses for GCR's. (NRC)

Delineate accidents, describe hypothetical accidents and undertake probabilistic analyses of accident likelihoods for designs encountered in the licensing process. (NRC)

Assess the safety of advanced high temperature reactors on a time phase basis dictated by their rate of development and commercialization. (NRC)

Federal Role

The Energy Reorganization Act of 1974 charges ERDA with the responsibility for the development of nuclear power concepts. Because the potential for public risk is fundamentally and specifically affected by design, this requires the development of a base technology associated with safe design and operation.

The responsibility for licensing actions is the responsibility of the license applicant, usually a utility, assisted by the reactor manufacturer. This responsibility includes providing licensing information for all four lines of defense. Where safety-related technology needs for gas cooled reactors are identified, ERDA will assist in developing this information during development, demonstration, and first deployment of the reactor concept. It is presently planned to terminate ERDA effort when the concepts become fully commercialized.

The Nuclear Regulatory Commission is also sponsoring Gas Cooled Reactor Safety R&D as part of its confirmatory research activities for regulation. This work is independent of ERDA efforts although there is coordination and interchange of information between the NRC and ERDA safety programs.

International Cooperation

The international cooperation in HTGR safety is part of the overall HTGR program and includes exchanges of technical data and of visits. As examples: exchange of risk analysis results on all reactor concepts is contemplated with Germany, and HTGR core seismic information exchange is contemplated with Japan.

The NRC cooperates with the International Atomic Energy Agency, the International Standards Organization and other international organizations in nuclear safety and regulatory matters. The NRC has bilateral agreements with the Denmark, Federal Republic of Germany, France, Italy, Japan, Spain, Sweden, Switzerland and the United Kingdom to exchange regulatory and safety information. Technical reports and visits of experts are exchanged with Federal Republic of Germany, France, Italy, Japan and Sweden.

Technological Status and Problems

Status:

The federal government has supported a modest HTGR steam cycle safety program for a decade, concentrating on investigating the behavior of fission products released from HTGR fuels under abnormal conditions. The characterization of the steam-carbon reaction, which could result from steam generator leaks, was also studied. In 1974 the government-funded program was bolstered.

Problems:

- Currently identified safety concerns in the HTGR steam cycle safety program include the possibility of:
  1. Steam generator failures causing overpressure in reactor vessel and containment structure.
  2. Core support structural failure.
  3. Loss of core shutdown and/or cooling capability during or after seismic excitation.
- The currently identified safety concerns being investigated by the HTGR gas turbine cycle safety program include the following:
  1. Failure modes of rotating machinery (turbine missiles).
  2. Fission product release as related to fuel failure rates.
- The major VHTR safety concerns currently defined which require attention include the following:
  1. Development of safety requirements for primary components such as high temperature process heat exchangers.
  2. Safety testing of fuel and core (including process impurity ingress tests).
- The major safety concern in the GCFR safety program is the provision of adequate safety margins in the fuel and core components of the reactor and the understanding of the consequences of under-cooling accidents.
- Data are required to independently evaluate vendor safety codes.

Institutional Status and Problems

Status:

- The steam cycle HTGR design was established for the first commercial HTGR prior to cancellation of the Delmarva Power and Light plant contract in October 1975. The environmental phase of the NRC review of the plant construction application has been completed and a limited work authorization had been issued. The safety phase of the NRC review had been substantially completed. The NRC review has been terminated because of withdrawal of the application. A GA Standard Safety Analytic Report (GASSAR) has been submitted to NRC by the General Atomic Company (GA) for a standardized steam cycle HTGR plant.

- GA has submitted a Preliminary Safety Analysis Report to NRC for a Direct Cycle HTGR and a similar report for a 300 MWe GCFR Demonstration Plant.

Problems:

- Evolving technology which results in changing regulations during the construction phase has serious impact on the commercialization of the gas reactor technology.

Environmental Status and Problems

Status:

- These are the same as for other reactor programs. There are none peculiar to the gas cooled reactor safety programs. Efforts in this area will draw heavily on LWR and LMFBR results. General Atomic and ERDA are cooperating to provide environmental reports for all gas reactor concepts. These environmental reports include construction and land use, heat dissipation, discharge of chemicals and release of radioactive materials. As an example, in 1974 the AEC Directorate of Licensing requested that a Preliminary Environmental Impact Report be submitted for the GCFR. This report is now undergoing review by the Nuclear Regulatory Commission.

Problems:

- The environmental impacts associated with gas cooled reactors are the same in nature but of less severity than other nuclear reactors.

Program Implementation

Energy Research and Development Administration

HTGR Steam Cycle:

- Determination of priority ranking for areas of future HTGR safety research and development of application of risk analysis techniques to gas cooled reactor systems.
- Completion of 1/5 scale HTGR Core Seismic Tests.
- Initiation of testing of selected, critical HTGR components under simulated accident conditions.

HTGR Gas Turbine Cycle:

- Initiate HTGR gas turbine cycle safety studies.
- Initially identify key safety criteria and requirements through conceptual design review and comparison of differences with HTGR steam cycle.

VHTR Process Heat Cycle:

- Initiate VHTR Safety Studies.
- Initial identification of key safety requirements through review of both feasibility studies and conceptual designs.

GCFR:

- Complete ANL evaluation of GCFR safety concerns including analysis of core disruptive accidents and post-accident heat removal to develop safety criteria for these accidents.
- Complete GA Summary Report on GCFR Accident Analysis.
- Complete ANL Report on Pre-Stressed Concrete Reactor Vessel (PCRV).
- Complete ANL/HNL Scoping Safety Evaluation of GCFR PCRV.
- ANL Initiation of Post-Accident Heat Removal Test Program.
- Start Tests of GCFR Fuel in Helium in the TREAT Facility.

The full responsibility for licensing actions for all of the concepts lies presently with General Atomics. This requires GA to develop all safety information needed for licensing. ERDA will provide assistance for safety-related technology during development, demonstration, and first deployment of gas-cooled reactors.

Nuclear Regulatory Commission

NRC is responsible for the following:

Determining the source of fission products and their transport under several hypothetical accident conditions.

Investigating primary coolant properties in order to define and measure ingress of steam or other accidental impurities.

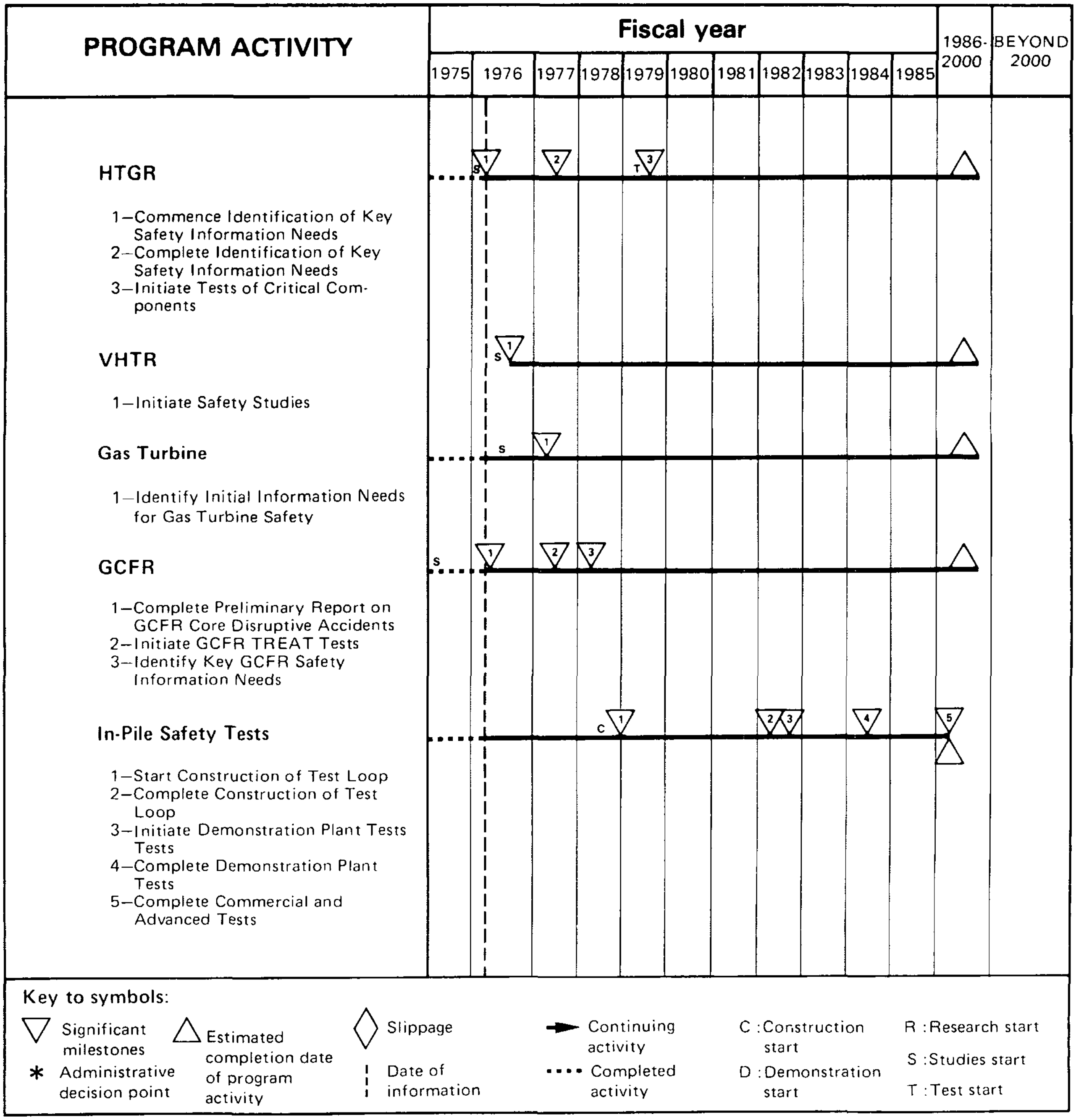
Studying the interaction between steam and graphite.

Investigating the effect of control modes of instabilities introduced by xenon resulting from the fission process.

Conducting tests on the reliability of critical core components and control systems components.

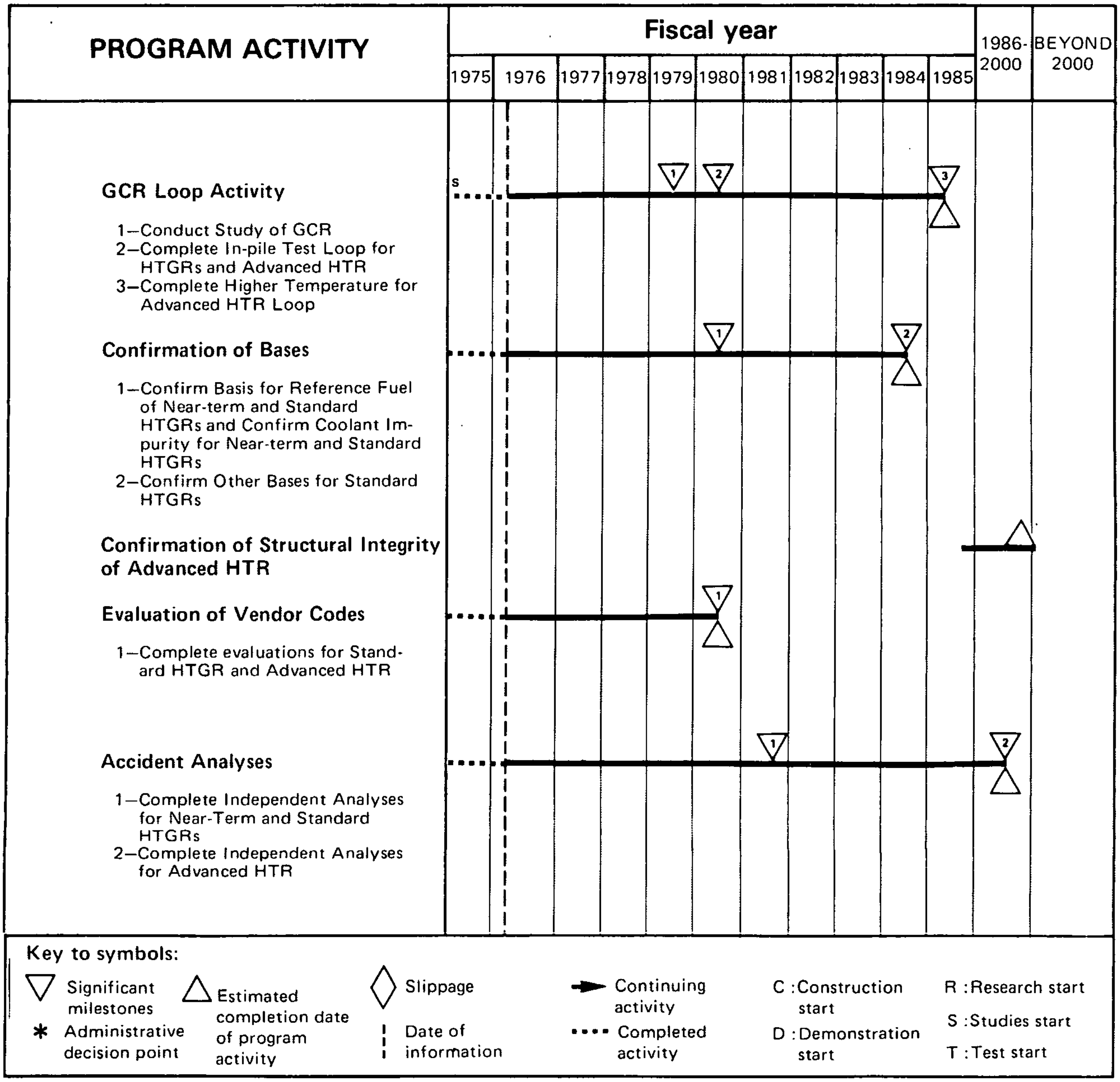
ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION

GAS COOLED REACTORS – REACTOR SAFETY



NUCLEAR REGULATORY COMMISSION

GAS COOLED REACTORS—REACTOR SAFETY



REACTOR SAFETY—GAS COOLED REACTORS

Federal Energy RD&D Budget ($ Millions)

Agency	FY 1975		FY 1976*		FY 1977	
	BA	BO	BA	BO	BA	BO
ERDA						
Operating Expenses	3.6	3.0	4.3	4.0	5.3	5.0
Plant and Capital Equipment	0	0	0.1	0	0.4	0.4
Total	3.6	3.0	4.4	4.0	5.7	5.4
NRC	2.9	2.5	3.7	3.6	3.6	3.4
Total	6.5	5.5	8.1	7.6	9.3	8.8

* Does not include funds for FY 1976 Transition Quarter.

FISSION POWER

Light Water Technology

Objectives

Near-Term:
(–1985)

- To expedite development and implementation of improvements by industry in the Light Water Technology Plant Systems and components design, plant construction and plant operation and maintenance to maximize the contribution of light water reactors to the Nation's energy needs. The successful achievement of this program will result in improvements of five to 10 percentage points in plant productivity by 1985.
- To assure the safety of light water nuclear reactors licensed by the federal government. (NRC)
- To investigate and evaluate technology and research on the safety of the light water fission reactor. (TVA)

Mid-Term:
(–2000)

- To stimulate the design, construction and operation of LWR plants which will apply the integrated improvements developed in the LWR Technology program to achieve maximum savings in engineering and construction time and cost and the highest practicable plant productivity.

National Energy Technology Goals Supported

Primary

- Increase the efficiency and reliability of the processes used in the energy conversion and delivery systems.

Secondary

- Protect and enhance the general health, safety, welfare, and environment related to energy. (NRC)

Strategy

The strategy is to make available a limited amount of government support in those areas which may result in increased productivity, increased reliability and/or lower design and construction costs of existing and future LWR plants, through:

(a) Technology improvements in materials, design and processes to reduce the causes for plant deratings, reduced performance or prolonged maintenance downtime.

(b) Accelerated development of plant systems standardization and modularization and improved construction techniques to reduce engineering and construction time and cost.

(c) Improvements in systems and components design features and maintainability in areas which have been identified as significant contributors to plant downtime (reduced plant availability).

(d) Support for siting investigations and studies to reduce the total acquisition period (until beneficial power operation) of new plants.

(e) Support for industry/national society development and use of needed improved engineering standards for systems and components design, fabrication, test processing, and operation and maintenance through the National Voluntary Consensus Standards effort.

Other agencies, strategies include:

(a) Develop solidily supported technical information and systems models needed to verify the safety of light water reactor technology. (NRC)

(b) Investigate and evaluate the technology of advanced nuclear reactor concepts. (TVA)

(c) Make recommendations on research priorities to the EPRI Nuclear Divisional Industry Advisory Committee. (TVA)

To assure the most effective use of the technology being developed, it is intended that the work be done primarily by organizations active in the industry—architect-engineers, reactors manufacturers, equipment manufacturers, utilities and others with strong vested interests in applying the results commercially.

Federal Role

Certain non-safety areas of technology of significant economic value to the public are not being adequately supported by industry due to their long-term payout, or lack of sufficient benefit to the industrial group involved to make it worthwhile in a period of capital scarcity.

The federal role is to provide seed funding for determining and demonstrating the potential value of technology and technique improvements. This should result in:

- Reducing the lead time associated with placing this technology in practice.
- Mitigating the commercial uncertainties and financial risk to the private sector from bringing this technology into existence.
- Accelerating progress beyond normal commercial capability.

Each proposed effort will be integrated with national energy policy activities of the FEA and with the NRC with respect to the applicability of the effort to safeguards, safety and reliability.

International Cooperation

With respect to nuclear safety and regulation, NRC cooperates with various international organizations. It has related bilateral agreements with Western European countries and with Japan. NRC also cooperates in multilateral reactor safety technology programs under the auspices of OECD's IEA and has suggested four bilateral agreements on safety technology studies with IEA countries.

Technological Status and Problems

Status:

- During 1975, a total of approximately 50 commercial LWR plants produced about eight percent of the nation's electrical energy requirements.
- The current LWR total acquisition time projected by NRC amounts to 11 years, including an average of seven years for construction.
- Current LWR power plants are operating safety. Analytic and inspection methods which assure safe operation under current licensing procedures are in use. (NRC)

Problems:

- The average construction period has increased from four years in 1970 to seven years in 1975.
- Refueling shutdown periods are excessive due generally to inefficient refueling operations.
- Recurrent component deficiencies, which are not individually serious, but in total result in substantial plant outage.
- Performance limitations, derating, maintenance and inspection requirements indicate the need for additional technological development and application.
- Uncertainties in electrical load forecasts, lead to cancellations or deferrals of new plant capacity.
- Inefficient fabrication and construction practices result in prolonged construction periods.
- Key construction craft availability, skills, and productivity impact on construction time and costs.
- Continuing high degree of selection of "tailor made" plant designs that drastically increase engineering and construction time and costs over standardized designs.

Institutional Status and Problems

Status:

- New plant construction involves high capital costs.
- Utility rate structures are regulated by federal, state and local authorities. Benefits of improved productivity largely accrue to ratepayer.
- Existing governmental (local, state, federal) regulations impact siting construction of LWR plants.

Problems:

- Cost of and competition for capital in the current economy, and high cost of new plant acquisition could discourage further utility/industry investments in nuclear power plants.
- Shortages of trained craft labor and poor productivity cause delays and increase costs in plant construction.
- Variations in regulatory techniques and requirements cause delays and increase costs.

Environmental Status and Problems

Status:

- More than 225 reactor-years of commerical nuclear power plant operation have been accumulated without a major nuclear accident or a radiation injury to any member of the public.

- LWRs comply with existing environmental regulations. However, public concerns remain, and efforts are being made to resolve these concerns.

Problems:

- The risks associated with low probability/high consequence accidents must be further highlighted in resolving public concerns.
- Problems associated with health effects and disposal of transuranics must be fully determined.

Program Implementation

The program will include:

- An analysis of component failure cause and effect, and development and demonstration of needed improvements.
- An evaluation of the factors which presently or prospectively limit LWR productivity and implementation of the improvements.
- A program to identify and resolve technical uncertainties associated with plant deratings, performance limitations or excessive inspection and maintenance requirements.
- Development of improved design and construction standardization, modularization and techniques, and demonstration of the efficiency of these improvements.
- A program to promulgate nuclear industry engineering standards.
- Development and documentation of information for improved LWR plant designs that will achieve highest practicable availability and minimum construction period.

LIGHT WATER TECHNOLOGY

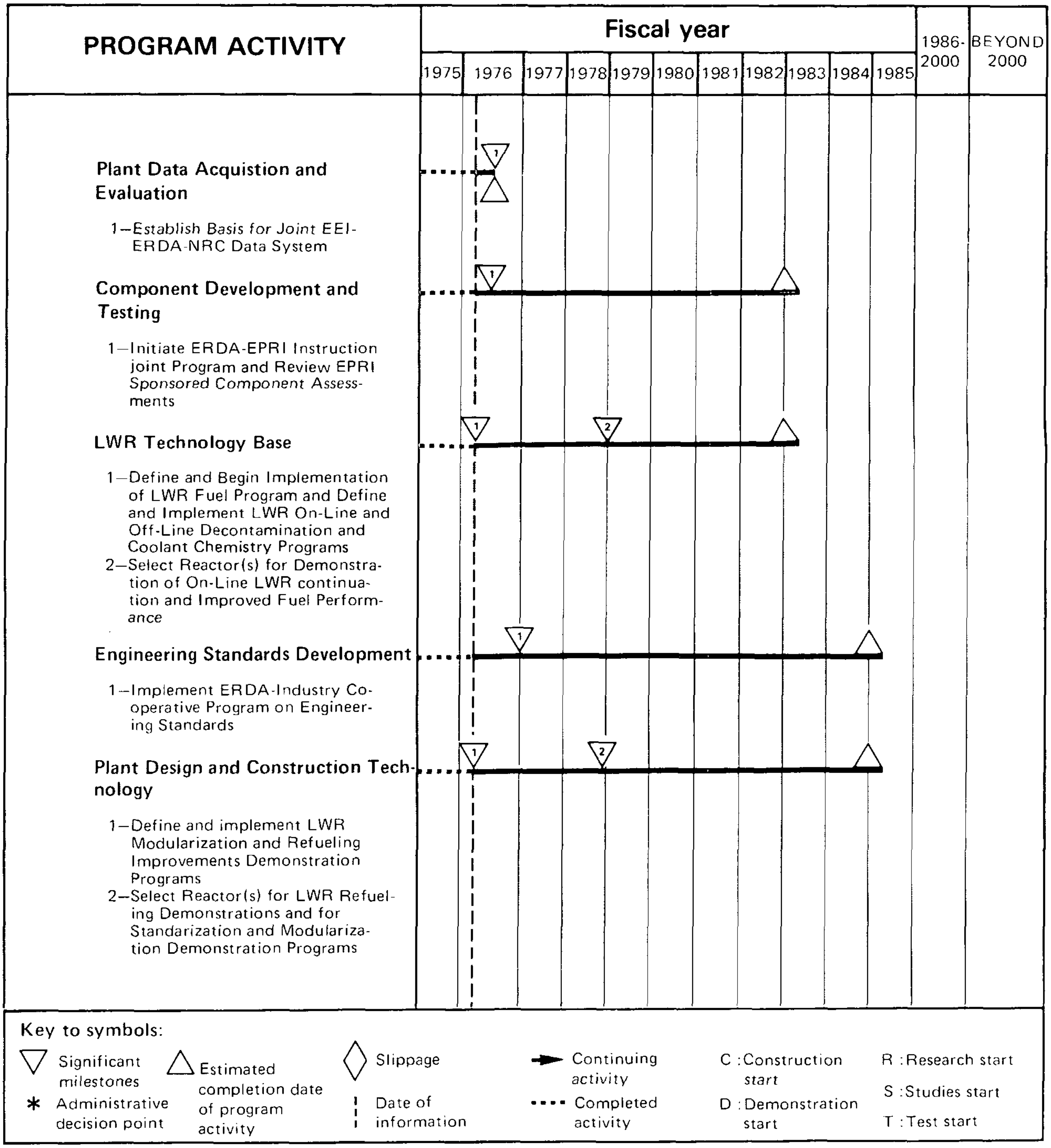
Federal Energy RD&D Budget **($ Millions)**

Agency	FY 1975		FY 1976*		FY 1977	
	BA	BO	BA	BO	BA	BO
ERDA						
Operating Expenses	0	0	4.0	3.0	12.5	10.0
Plant and Capital Equipment	0	0	0	0	0	0
Total	0	0	4.0	3.0	12.5	10.0
NRC	51.4	45.2	69.4	59.7	69.6	65.7
Total	51.4	45.2	73.4	62.7	82.1	75.7

* Does not include funds for FY 1976 Transition Quarter.

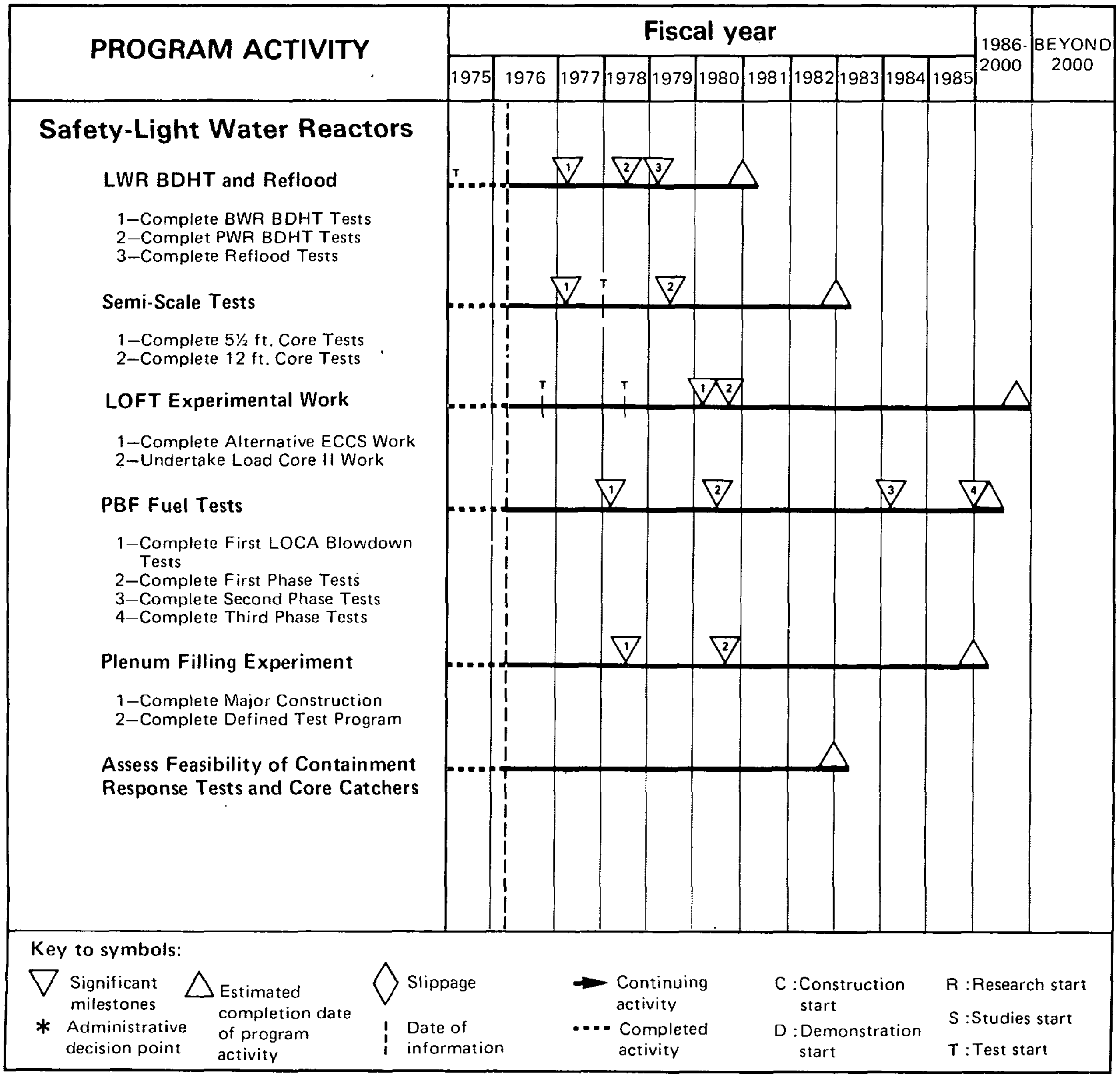
ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION

LIGHT WATER TECHNOLOGY



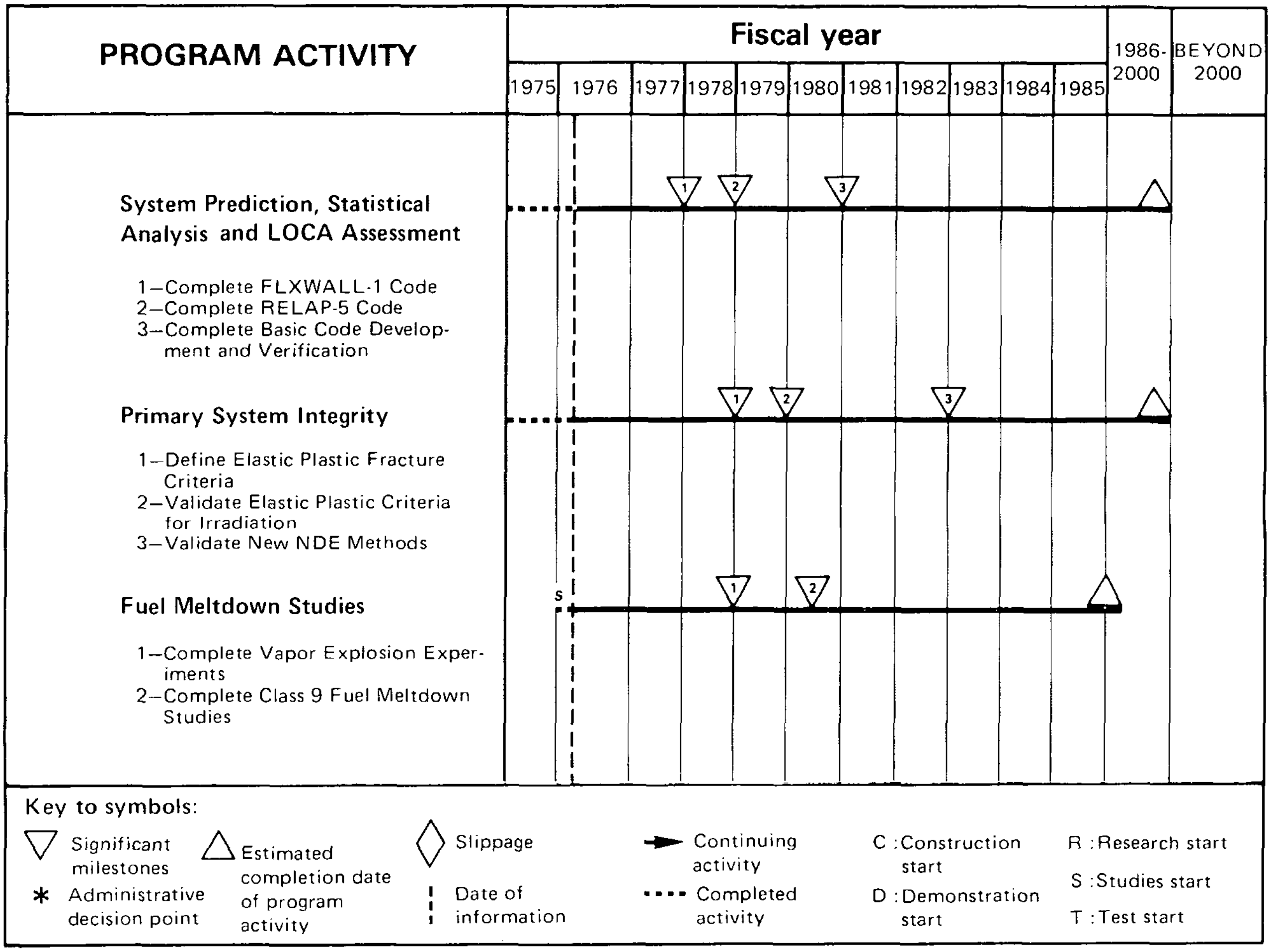
NUCLEAR REGULATORY COMMISSION

LIGHT WATER TECHNOLOGY



NUCLEAR REGULATORY COMMISSION

LIGHT WATER TECHNOLOGY (continued)



FISSION POWER

Supporting Activities

Objectives

Near-Term (–1985), Mid-Term (–2000), and Long-Term (Beyond 2000):

- To conduct studies and other activities in support of current and potential reactor development efforts, including activities that may cut across the spectrum of reactor concepts or may be independent of reactor concept. These efforts include energy systems analysis, environmental activities, desalting and other processes, codes and standards, dry cooling systems, and general laboratory site support. Any given study which may be concentrated on assessing the merits of a near-term decision on initiating an RD&D program would normally incorporate the consideration of the mid-term and/or long-term implications of pursuing the technology.

Other agency supporting activities:

- To prepare a comprehensive evaluation, on a regional or basin level, of storage requirements, estuarine characteristics, and other hydrologic factors specific to power plant siting requirements.
- To provide neutron standards for the nuclear power and related industries.

National Energy Technology Goals Supported

Primary

- Perform basic and supporting research and technical services related to energy.

Secondary

- Increase the use of essentially inexhaustible domestic energy resources.
- Protect and enhance the general health, safety, welfare, and environment related to energy.
- Efficiently transform fuel resources into more desirable forms.
- Increase the efficiency and reliability of the processes used in energy conversion and delivery systems.

Strategy

Analyses and assessments are conducted to support the requirements of management planning and decision-making for the overall civilian nuclear fission reactor development program. Studies known to be needed on a continuing basis are systematically updated while special studies are conducted as required. The types of studies include: comparisons of alternative nuclear program strategies, cost-benefit analyses, risk-cost-benefit analyses, nuclear energy center evaluations, nuclear process heat and desalting studies, capital cost studies and environmental impact assessments related to new concepts as well as concepts under development or approaching commercialization.

About 30 percent of the total U.S. energy consumption is for industrial non-electrical process uses which are fossil fueled. The strategy for displacing part of this requirement for fossil fuels with nuclear energy is directed toward the evaluation of three potential applications:

- The use of large present-generation nuclear central station power systems to supply industrial process heat or steam in addition to electricity.
- The use of smaller light water reactor plants for meeting process industrial energy needs and military installation energy requirements.
- The development of advanced high temperature gas cooled reactors to meet current and projected high temperature installation energy requirements.

In addition, current generation nuclear power systems can be applied to desalt saline waters and hence provide new sources of fresh water for municipal, industrial and agricultural purposes.

- The strategy for codes and standards is to develop those required for reactor development projects and to cooperate with the national standards organizations.
- The dry cooling tower program strategy places emphasis on scaling up the capacity and improving the economics and reliability of dry cooling towers currently in use by the chemical processing industry and by a smaller number of power plants throughout the world. It is hoped that this technology can be made available to U.S. utilities which will then have the option of dry cooling in the early 1980's when it is anticipated that limited availability of water in certain areas of the U.S. will dictate the increased use of dry cooling systems.
- Cognizance is maintained of expanding programmatic needs of the national laboratories to identify related support requirements for inclusion in fiscal plans and budgetary submissions.

Other elements of the federal strategy include the following:

- Development of the measurement and interpretation capability as required to predict transportation of radioactive nuclides into and within hydrologic systems.
- Provision of neutron standards for all phases of neutron development activity such as dosimetry, design optimization performance and online performance monitoring.

Federal Role

The responsibility for studies such as alternative nuclear energy strategy projections and environmental impact assessments relating to future energy options lies principally with the federal government because of the exploratory nature of the concepts studied and the long-lead times, large funding requirements and commercial uncertainties associated with potential projects, including institutional and environmental constraints. Generally, the role of industry in these types of activities is to perform or participate in studies supported by federal funding. In addition, the advice of industry is solicited as appropriate. In most cases, significant industrial involvement would not be expected until such time as major project efforts might eventually evolve from the studies.

International Cooperation

There is an agreement for U.S.-U.S.S.R. technical exchange of information under the U.S.-U.S.S.R. Joint Coordinating Committee on Scientific and Technical Cooperation in the Field of Thermal Power Plant Heat Rejection Systems and Water Supply Systems under which drying cooling water information could be exchanged. Other important areas of potential cooperation are in nuclear desalting and process heat; and a number of possible arrangements are being explored with various foreign nations.

The U.S. is collaborating with IAEA in the sponsorship of an International Nuclear Project Training Program at ANL. Construction funds have been provided by ERDA for facility modifications to support this joint endeavor by the United States, West Germany, and France.

Technological Status and Problems

Status:

- Technological status differs for the various concepts being studied and developed. For example, technology does not appear as a serious barrier to near-term nuclear desalting and low temperature process heat applications, while significant technology development would be needed for very high temperature nuclear process heat reactors.
- Effort is continuing to assess the radiological implications in the year 2000 of the continued commercial introduction of nuclear central station power plants in the Tennessee Valley region.
- Data and models for cost-benefit and capital cost analyses are in the process of continued updating.
- NSF, NRC, and ERDA have completed preliminary technological assessments of energy centers on a generic basis.
- Utilities are now ordering wet/dry towers from commercial vendors. Wet/dry towers use significantly less water than conventional wet towers. The cost of dry towers remains high, but siting restrictions may force utilities to consider them in the early 1980's.
- Insufficient data are available for the complete evaluation of the hydrologic impact of thermal and radionuclide releases from nuclear power plants. (DOI)

- Techniques are available for measuring the neutron cross sections of species related to nuclear reactors and nuclear applications.

Problems:

- The technology for very high temperature nuclear process heat reactors is not fully established, and some engineering and component testing is required for small nuclear process heat reactors.
- Methods to predict the impact of atmospheric heat releases from nuclear energy centers have not been developed.
- Methods of utilization of plutonium at energy centers should be defined.
- The capital cost of dry cooling towers is high and the power loss penalty on hot days is severe. The cost of wet/dry towers is also high. Technological advancements may be able to alleviate these problems.
- The need exists for some technology development for large dual-purpose (water/power) desalting plants.
- Improved instrumentation is required to make the needed measurements for rapid determination of hydrology of potential nuclear reactor sites.
- Data are required for improved modeling of heat and radionuclide transport in potential nuclear reactor sites.

Institutional Status and Problems

Status:

- Analysis and assessments studies are coordinated with other government agencies and interested entities.
- Regulations and standards governing withdrawals, allowable water temperature increases and the release of radionuclides into streams vary among states.

Problems:

- Lack of hydrologic regulatory standards among states pose problems in preparing guidelines and standards.

Environmental Status and Problems

Status:

- A preliminary report describing streams adequate for siting 1,000 MWe nuclear power plants has been completed. (DOI)

Problems:

- The study and analysis character of this program precludes explicit environmental problems. Those hardware problems (e.g., dry cooling towers) are specifically oriented toward solutions to environmental problems already existing.

Program Implementation

Energy Research and Development Administration

Implementation of the *ERDA* program largely consists of the conduct and completion of studies with appropriate recommendations for any justified follow-on activities in the form of technology development programs, cooperative projects, or other activities. The results of the studies cannot be prejudged, and the output constitutes a source of information to management for future planning and decision making.

Cooperative studies will be conducted with utilities and industry of present generation nuclear central station power systems for supplying process heat or steam in addition to electricity at specific locations in order to define the incentives and problems and to suggest possible solutions to the problems.

Cooperative studies will be conducted with industry and the Department of Defense of small light water reactor plants for providing process energy at specific locations in order to define the incentives and problems and to suggest possible solutions to the problems.

Various advanced high temperature gas cooled reactor designs optimized for representative high temperature process heat applications will be evaluated in order to define the economics, technical problems, developmental requirements, and costs. This activity will be coordinated with other ERDA efforts on the potential application of nuclear heat, for example, to coal conversion processes and the thermochemical production of hydrogen from water.

LMFBR standards already developed will be refined and improved through the feedback of application experience obtained in demonstration program phases. These standards form the basis of the body of national voluntary nuclear standards needed for LMFBR commercialization in the 1990's.

The Department of Interior water-air heat exchange studies are underway to better determine heat balances in thermal discharge systems. Measurement techniques and models are being developed for making hydrologic assessments of potential nuclear power plant sites.

The Department of Commerce will continue its program designed to improve neutron differential data standards.

SUPPORTING ACTIVITIES

Federal Energy RD&D Budget **($ Millions)**

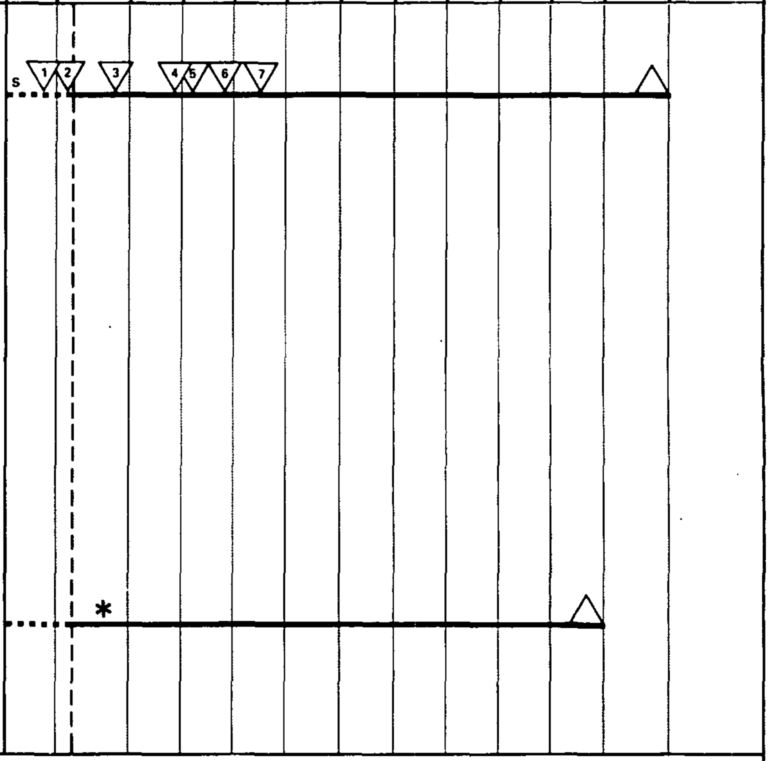
Agency	FY 1975		FY 1976*		FY 1977	
	BA	BO	BA	BO	BA	BO
ERDA						
Operating Expenses	9.0	8.3	14.8	12.8	17.3	16.7
Plant and Capital Equipment	4.2	0.5	2.6	1.9	2.8	4.6
Total	13.2	8.8	17.4	14.7	20.1	21.3

* Does not include funds for FY 1976 Transition Quarter.

ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION

SUPPORTING ACTIVITIES

PROGRAM ACTIVITY	Fiscal year											1986-2000	BEYOND 2000
	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985		



Analysis and Studies

1—Issue Final LMFBR EIS
2—Complete LMFBR Program Alternatives Study and Conceptual Nuc. Energy Center Rpt.
3—Complete TVA Region 2000 Radiological Analysis and Initial High Temperature. Nuclear Process Heat Evaluation
4—Define Small Nuclear Process Heat Plant Demonstration Project and Complete Preliminary Evaluation of Energy Center Atmospheric Effects Models
5—Define Large-Scale Nuclear Fuel Purpose Plant Demonstration
6—Complete Preliminary EIS for Environmental Assessment Advanced Gas Reactor
7—Complete Preliminary EIS for Environmental Assessment Advanced LMFBR Fuels

Dry Cooling Towers

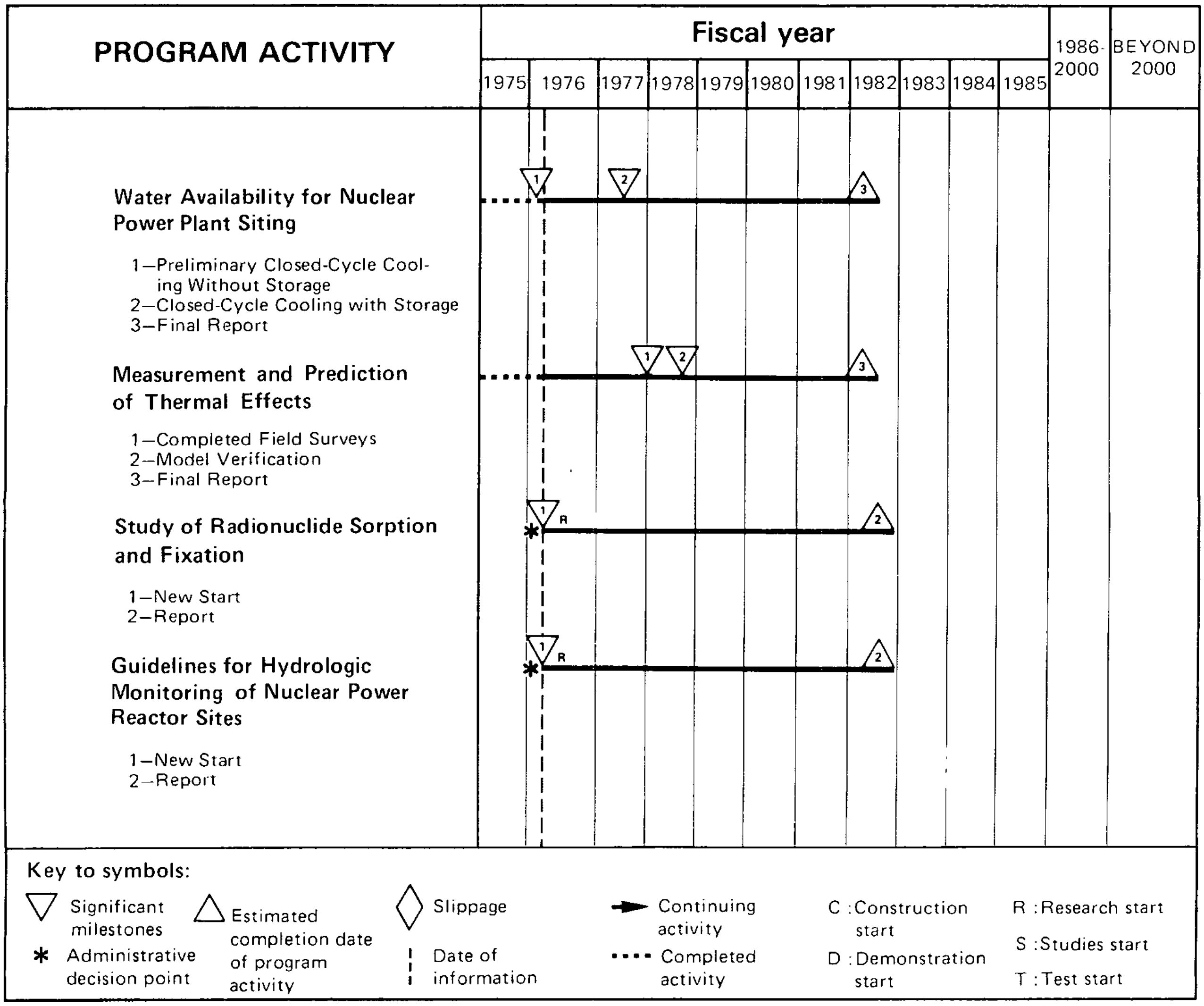
*Decide on Scope of Demonstration Program.

Key to symbols:

- ▽ Significant milestones
- * Administrative decision point
- △ Estimated completion date of program activity
- ◇ Slippage
- ¦ Date of information
- → Continuing activity
- •••• Completed activity
- C : Construction start
- D : Demonstration start
- R : Research start
- S : Studies start
- T : Test start

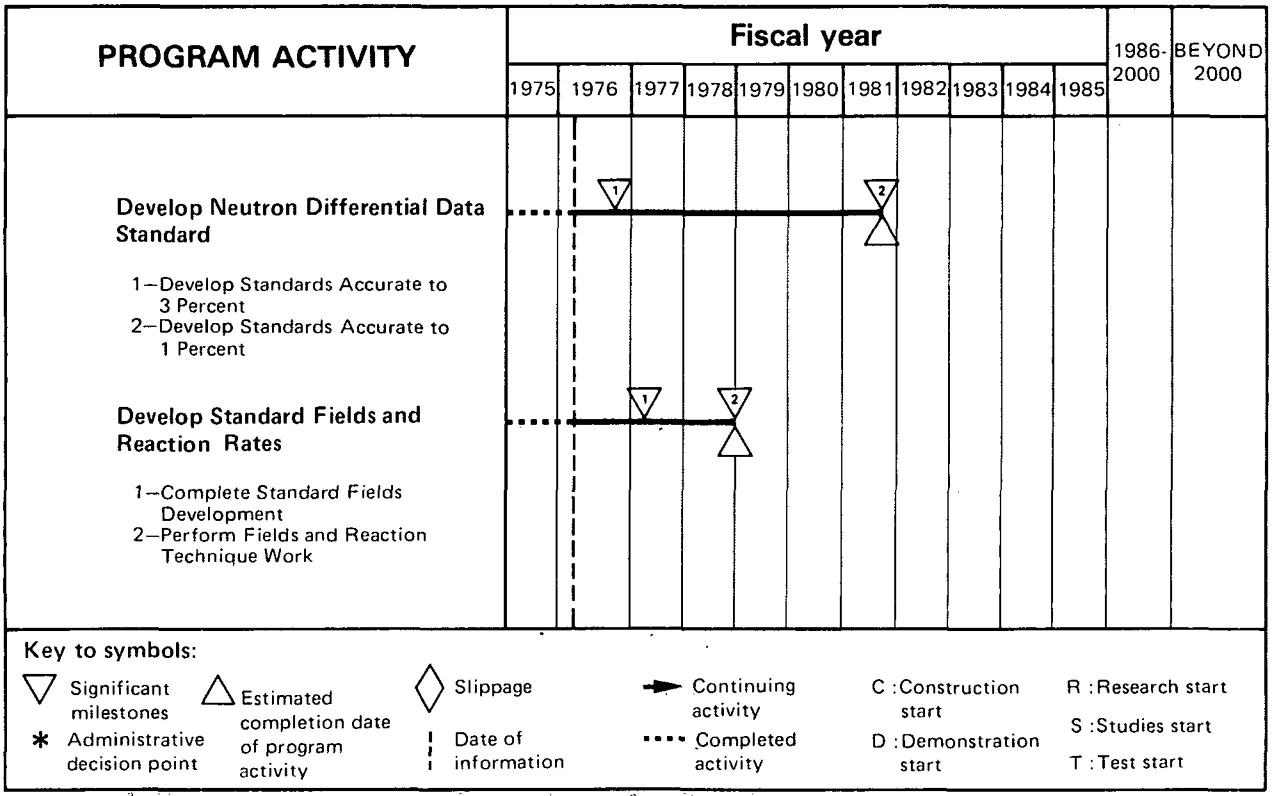
DEPARTMENT OF THE INTERIOR

SUPPORTING ACTIVITIES



DEPARTMENT OF COMMERCE

SUPPORTING ACTIVITIES



FISSION POWER

Reactor Safety Facilities

Objectives

Near-Term:
(–1985)

- To support the reactor safety research (RSR) effort of the Nuclear Regulatory Commission (NRC) by: (1) budgeting for and constructing the two major facilities currently needed to conduct the research, (2) budgeting for and constructing such additional facilities as may be needed, (3) coordinating all RSR programs of NRC performed in ERDA facilities, and (4) operating certain ERDA facilities on a cost reimbursable basis for NRC.

Mid-Term (–2000), and Long-Term (Beyond 2000):

- To provide support within ERDA for such NRC research as may be needed on the safety and environmental aspects of nuclear facilities.

National Energy Technology Goals Supported

Primary

- Perform basic and supporting research and technical services related to energy.

Secondary

- Protect and enhance the general health, safety, welfare, and environment related to energy.

Strategy

The assured safety of commercial nuclear power facilities is of great national importance in the coming years. The safety aspects of such commercial facilities must be reviewed and approved by the NRC prior to construction and operation of the plants. The reactor safety research program is intended to provide the safety data required by NRC to establish a technical basis for their approval. This NRC program includes the development of analytical models to predict reactor performance under a variety of abnormal conditions and also the performance of various experiments. The experiments are carried out to confirm the adequacy of current safety systems, and to determine if any unexpected phenomena occur when such experiments are conducted.

The NRC RSR program is carried out to a large extent by ERDA, using its facilities. The ERDA Office of Reactor Safety Research Coordination is budgeting for and directing the completion of two unique and highly specialized experimental facilities—the Loss of Fluid Test (LOFT) and Plenum Filling Experimental (PFE) Facilities. This office also coordinates all the NRC RSR programs being conducted in ERDA laboratories. ERDA Operations Offices and Laboratories are responsible for the operation of ERDA facilities for NRC and for the performance of supporting activities and programmatic work requested by NRC. These functions provide for the efficient utilization of ERDA facilities in support of NRC while assuring that this effort does not impact ongoing priority ERDA programs or the stability of the ERDA laboratories.

Under the Energy Reorganization Act of 1974, the evaluation of alternative strategies and subsequent program decisions are the prerogative of NRC. Since ERDA's role is that of assisting in the implementation of the program, these activities are not discussed in this report.

Federal Role

The Energy Reorganization Act of 1974 assigned the functions of the former Atomic Energy Commission to ERDA and NRC. One of the functions given to ERDA was the responsibility for operation of national laboratories. One of the functions given to NRC was the responsibility for performance of confirmatory reactor safety research. Section 205 of the Act requires ERDA to furnish such research services as may be needed by NRC in the performance of its functions. The Act also provides for ERDA and NRC to consult and cooperate on research and development matters of mutual interest and for ERDA assistance to NRC in acquiring the expertise necessary to perform its licensing and related regulatory functions.

This federal role has been established to provide a research capability which is not dependent on the industry being regulated. ERDA's participation in this research is essentially that of a contractor to NRC, performing work on request. NRC also contracts with other organizations including universities and private industry as deemed appropriate.

The federal funding of these research facilities supports:

- timely development of improved safety systems for nuclear reactors;
- confirmation of analytical techniques used to predict the response of nuclear power plants to accident situations;
- reduction of economic and operational penalties to power reactors from current safety analysis methods;
- improved public aceptance of nuclear electric power generation.

International Cooperation

Technical exchange arrangements by NRC with Japan, France, Germany, and Spain include nuclear safety among the topics covered. LWR safety R&D is one of the areas identified for cooperation in the IEA framework and is an area where commercial considerations may be less inhibiting than for other LWR development work.

Technological Status and Problems

Status:

- LOFT—The LOFT facility is a small scale, fully integrated nuclear reactor facility that is engineered to simulate breaks in reactor coolant piping and investigate the resulting rapid decompression and emergency core cooling phenomena. The construction of the facility is nearing completion and systems testing has been initiated.
- PFE—The PFE facility is a nonnuclear test facility containing large simulated reactor plant components which will closely resemble certain aspects of existing commercial pressurized water reactors (PWR). The design of this facility is nearing completion and the major construction phase is scheduled to begin during FY 1977. A facility capability study is currently underway and program redirection may result.

Problems:

- LOFT—Problems associated with systems testing could delay the initiation of the experimental program. Also, a plant requalification program must be developed to ensure that the experimental program can continue to be safely and reliably executed. This program is necessary due to large mechanical loadings resulting from rapid decompression of the primary system.
- PFE—Detailed investigations have revealed that it may be necessary to purchase new equipment to replace a major portion of the government furnished equipment originally believed serviceable for this facility. Also, the large hydraulic forces and thermal transients associated with the experiment create high mechanical stresses which are requiring some redesign effort.

Institutional Status

- A memorandum of Understanding on the LOFT facility has been agreed to and signed between ERDA and NRC. An interagency agreement between ERDA and NRC is being negotiated on the PFE facility.

Environmental Status and Problems

Status:

- LOFT—The final Environmental Statement for LOFT was published in *WASH–1517* dated January 1973. The environmental issues that were identified at that time have been resolved and no new environmental issues have arisen since that time.
- PFE—This facility uses large amounts of hot water. Studies to evaluate alternative methods of disposing of this effluent are currently in progress.

Problems:

- PFE—An effective method to dispose of the large amounts of hot water effluent in an environmentally acceptable manner must be determined.

Program Implementation

ERDA to a large extent implements the NRC

RSR program for NRC by (1) budgeting for and constructing the two major facilities currently needed to conduct the research, (2) budgeting for and constructing such additional facilities as may be needed, (3) coordinating all RSR programs of NRC performed in ERDA facilities, and (4) operating certain ERDA facilities on a cost reimbursable basis for NRC.

As the facilities needed by NRC are completed, they will be utilized to support NRC research to develop and test analytical methods for assessing the effects of loss of cooling and the effectiveness of emergency core cooling.

The LOFT facility will be used to test analytical predictions of core and reactor systems response following a loss-of-coolant event. Nuclear testing in this facility is scheduled to begin in early FY 1978 and to continue for a number of years.

The PFE facility will be utilized to evaluate fluid conditions and system geometry effects when emergency core cooling water is injected into a PWR system after a simulated break in the primary piping system. Of particular interest is the amount of injected coolant which bypasses the core and leaves the system through the simulated break. The major construction effort on this facility is scheduled to begin in FY 1977 with research testing scheduled to begin in FY 1978 and continued for several years.

The results of the research program are made available to NRC and others in technical reports which are issued upon completion of the various tests.

Preliminary plans are under development for other test facilities that would be designed and constructed in the FY 1978–1980 period.

REACTOR SAFETY FACILITIES

Federal Energy RD&D Budget ($ Millions)

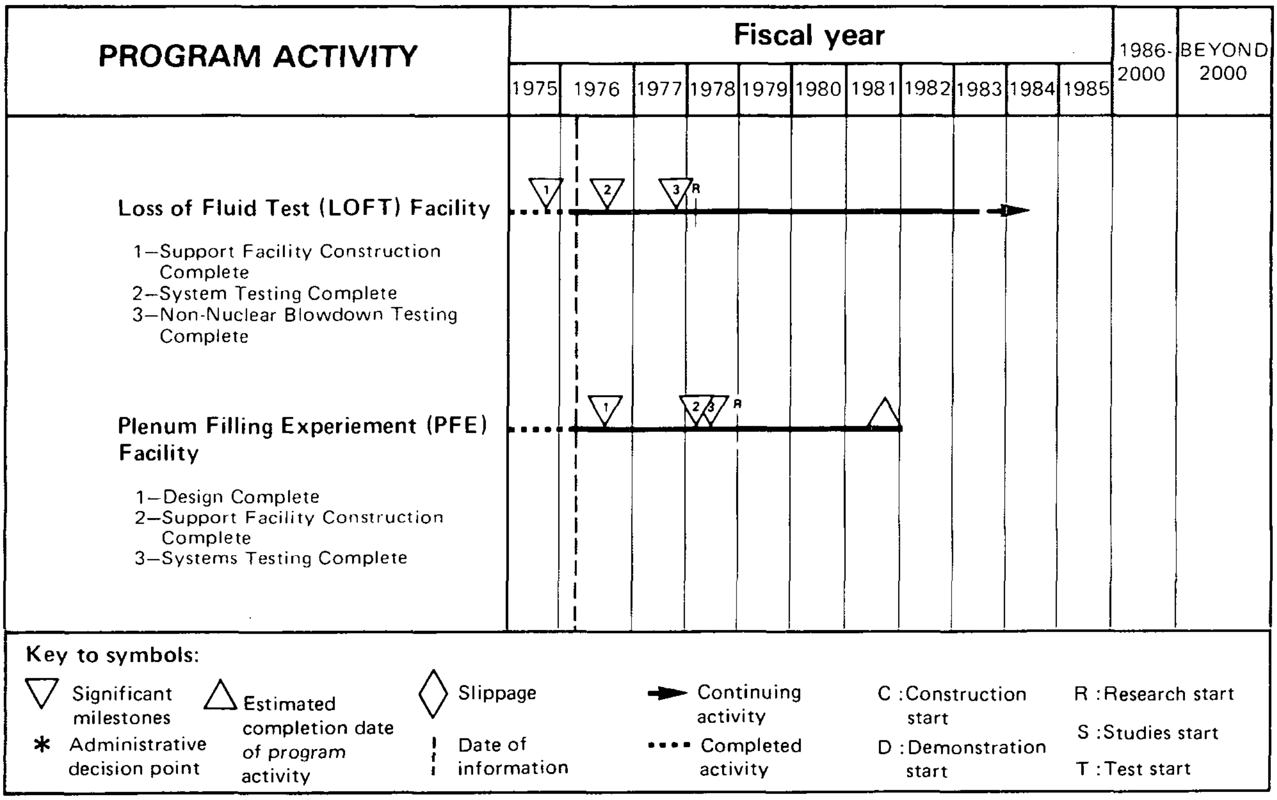
Agency	FY 1975 BA	FY 1975 BO	FY 1976* BA	FY 1976* BO	FY 1977 BA	FY 1977 BO
ERDA						
Operating Expenses	—	—	—	—	33.3	24.7
Plant and Capital Equipment	—	—	—	—	0	0
Total	(1)	(1)	(1)	(1)	33.3	24.7

(1) This program was funded by the AEC until January 18, 1975 and then carried by NRC through FY 1976. The amounts are as follows: FY 1975 = $22.3 (BA and BO); FY 1976 = $22.3 (BA and BO). ERDA assumed the budgeting function in FY 1977.

* Does not include funds for FY 1976 Transition Quarter.

ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION

REACTOR SAFETY FACILITIES



ENVIRONMENTAL CONTROL TECHNOLOGY EXECUTIVE SUMMARY

ERDA's program provides an independent assessment of environmental control technology activities within ERDA, other federal agencies, state and local governments, educational institutions, and industry. Major ERDA RD&D activities in environmental control technology will take place as an integral part of the energy technology programs themselves.

The assessment activities and issues addressed by Environmental Control Technology aim to ensure that producing technologies are environmentally and socially acceptable. Areas covered include assessing environmental control technology for waste management, energy systems and materials transport, and for the disposal of contaminated facilities.

For convenience, the Environmental Control Technology building block includes highly summarized information in matrix form on the development of environmental controls submitted for the National Plan by other federal agencies and ERDA organizations.

ENVIRONMENTAL CONTROL TECHNOLOGY

Environmental Control Technology*

Objectives

Near-Term (–1985), Mid-Term (–2000) and Long-Term (Beyond 2000):

- Independent evaluation of environmental control technology activities, with ERDA, other federal agencies, state and local governments, educational institutes, and industries.
- Assessment of technology for the control of emissions and discharges; the management and disposal of wastes; and the mitigation of environmental impacts from energy systems, the transportation of energy materials, and the disposition of surplus radioactively-contaminated ERDA facilities; and assurance that these tasks are accomplished in compliance with environmental and social acceptability criteria.

National Energy Technology Goals Supported

Primary

- Protect and enhance the general health, safety, welfare and environment related to energy.

Secondary

- Increase the efficiency and reliability of the processes used in the energy conversion and delivery systems.

Strategy

To support and advance environmental control, waste management and transportation technology RD&D activities by recommending procedures, processes, systems and strategies; and by providing required technical data with emphasis on systems presently under development. Major ERDA RD&D activities in environmental control technology will take place in the energy technology RD&D programs themselves.

To maintain contact with all organizations involved in energy-related environmental control technology.

Technology for the decontamination and decommissioning of surplus contaminated facilities will be developed and demonstrated, and will be directed toward developing the optimum balance between perpetual site dedication and control and return of the site to a contamination free state.

Federal Role

Energy technologies which are under development by the federal government have environmental impacts, the mitigation of which is also a federal government responsibility. Activities involved in fulfilling this responsibility include:

- Coordination of federal efforts for the solutions of environmental control, waste management and transportation technology problems which have broad applications across energy technology development.
- Encouragement of industry initiatives for the identification and development of environmental control, waste management and transportation.
- Provision of guidance and direction to the national energy effort to ensure balance between energy development and environmental protection.

International Cooperation

International Atomic Energy Agency (IAEA) development of international standards for transport safety.

Technology information exchanges with Great Britain, the Federal Republic of Germany, Poland, Yugoslavia, U.S.S.R., Turkey, Japan, South Africa

* Activities under this building block will be limited to review and assessment of the status of environmental control technology development. Energy technology programs have the primary responsibility within ERDA for the development of necessary control systems.

and the IAEA for the development of joint research and development programs.

Sponsorship of International Nuclear Transport Symposia.

Partipication in International Energy Agency (IEA) working group investigating disposal of high level radioactive wastes in the deep ocean.

Technological Status and Problems

Status:

- Priorities have been established for performing assessment of environmental control technology associated with near-term energy systems development.
- Current assessments focus on alternative technologies for the transport of nuclear energy materials and wastes.
- Decommissioning of facilities are under way at Canoga Park and Nuclear Rocket Development Station (NRDS). Plans for future decommissioning of surplus radioactive facilities are being prepared for all sites.
- Curriculum for an oil spill prevention and control course is being developed to meet the needs of ERDA, the Coast Guard, and other agencies. An advisory committee with members from ERDA, the Coast Guard, and EPA is supporting this effort.

Problems:

- Control capability and system tradeoffs associated with contamination and consumptive use of water, land reclamation, solid waste disposal, toxic trace elements and process heat rejection need to be identified.
- A comprehensive study of the state of technology for the prevention, containment and cleanup of oil spills is required.
- To conserve and recycle scarce or valuable resources, methods and criteria must be developed for their radioactive decontamination.
- Transportation systems and technology may be inadequate to meet expanding needs for transport of fuels and waste materials associated with energy production in an environmentally and publicly acceptable manner.
- Methods for volume reduction of radioactive wastes must be developed.

Program Implementation

The Environmental Control Technology Division is compiling an inventory of energy-related environmental control technology for FY 1976 in connection with the Biomedical and Environmental Research Division federal inventory of biomedical and environmental research. (See *ERDA 110, Federal Inventory of Energy-Related Biomedical and Environmental Research for FY 1974 and FY 1975,* October 1975.) All federal agencies involved have been requested to provide descriptions and status of energy-related environmental control technology under way or planned for FY 1976. These data will be used in developing or modifying environmental control technology RD&D programs assuring the most effective use of available resources. Results of the survey will be published by the start of FY 1977, providing the first comprehensive national summary of environmental control technology development. Preliminary information on the development of environmental controls which has been submitted for the National Plan by the other federal agencies and ERDA organizations is included herein in matrix format.

Environmental Control and Waste Management Survey and Assessment

- Characterize energy cycle processes and discharges.
- Assess state-of-the-art and identify gaps in control systems designs.
- Survey energy development activities to ensure proper emphasis on environmental control and evaluate control function against environmental and health standards and criteria.
- Evaluate Environmental Impact Assessments and Statements to ensure adequacy of proposed environmental controls.
- Identify RD&D programs required to achieve proper environmental controls where energy technology programs are inadequate.
- Identify advanced alternate control systems and approaches which show promise of increased effectiveness and/or applicability to more than one primary energy system.

Energy Systems Materials Transport Survey and Assessment

- Assess fuel and waste transport safety and environmental protection requirements in energy system development.

- Assess methods for packaging and transporting nuclear materials in a secure and environmentally safe manner.
- Perform Risk Assessments of fuel and waste transport.
- Assess energy technology program materials transport development and identify RD&D efforts required to overcome inadequacies.
- Recommend energy system materials transport standards and criteria to regulatory agencies.
- Initiate studies required to ensure achievement of transportation standards and criteria.
- Conduct tests on nuclear packaging and vehicle systems and perform trade-off studies.

Disposal of Surplus Contaminated Facilities

- Prepare a program plan covering the disposition alternatives and establishing priorities for ERDA surplus contaminated facilities.
- Perform cost benefit trade-offs between removal of contaminated materials and disposition on site.
- Develop techniques for dismantlement of surplus contaminated facilities and equipment.
- Perform in situ stabilization of uranium mill tailings whenever possible.

FEDERAL ACTIVITIES IN ENVIRONMENTAL CONTROL TECHNOLOGY*

TECHNOLOGY	FOSSIL	NUCLEAR	CONSERVATION	SOLAR/GEOTHERMAL
Agency:	**Activity**			
DOI (Bureau of Mines, USGS)	• Demonstrate effectiveness of citrate process for scrubbing sulfur oxides from High-Sulfur Coal Burning Power Plants	• Conduct nuclear hydrology programs to deal with disposal of high-level and low-level radioactive waste		
EPA	• Physical and Chemical Coal Cleaning-Assess environmental impacts and develop advanced processes and associated control equipment (DOI support) • Identify impacts and propose means to quantify and control effects of advanced energy conversion cycles (MHD, open and closed cycle gas turbines, etc.) • Determine impacts of Synthetic fuel production as a basis for control technology, performance requirements (with ERDA) • Develop thermal pollution control options for fossil-fueled power plants (with TVA) • Assess impacts of utility and industrial combustion as a basis for standard setting and development of flue gas control technology for fine particulates, sulfur oxides,	• Develop Thermal Pollution control technology for Nuclear Power Plants (with TVA) • Assess environmental impacts of nuclear cycle wastes and effluents	• Assess impacts and develop control support process development activities for: —waste recovery —indoor air quality —energy conserving industrial processes —advanced energy conversion cycles • Develop technology to convert municipal and industrial waste to usable energy	• Assess environmental effects to support development of standards, control technology, and siting guidelines for geothermal • Characterize both indirect and direct impacts of solar systems

* *This matrix represents activities in other federal agencies and in technology programs within ERDA.*

TECHNOLOGY Agency:	FOSSIL Activity	NUCLEAR	CONSERVATION	SOLAR/GEOTHERMAL
EPA	nitrogen oxides and hazardous pollutants and controls for water and solid waste effluents from these systems • Determine and assess the land and water impacts of commercial mining operations for coal, oil, gas and oil shale			
ERDA	• Assess and minimize environmental impacts of coal gasification, liquefaction through development of process modification, hot-gas cleanup systems and other control technology systems • Demonstrate the environmental acceptability of coal and oil shale conversion processes prior to commercialization • Investigate environmentally attractive technologies such as MHD and fluidized bed • Develop stack gas cleanup technologies • Develop analytical tools to measure trace elements and to characterize by products of coal conversion as a basis for control technology development	• Define environmental impact and develop standards for construction and operation of various nuclear concepts • Develop large-scale dry cooling systems for nuclear reactors • Minimize impacts from power plants supplying power to separation facilities • Identify and develop safe technology for nuclear fuel cycle • Investigate reactors such as thermal reactors which are environmentally attractive • Develop methods for safe transport and disposal of radioactive wastes	• Assess environmental impact of alternative high capacity transmission systems and develop environmental criteria • Develop environmental controls for systems designs to convert wastes to fuel • Insure end-use conservation options are environmentally acceptable	• Determine environmental impacts of geothermal systems and develop control technology for gaseous emissions subsidence and other identified problems • Identify potential environmental effects of —large multi-unit wind energy conversion units —solar thermal power plants —ocean thermal energy conversion systems —production of fuel from biomass —solar heating and cooling —minimize impacts in technology developments
TVA	• Evaluate methods to reduce thermal impacts at fossil fueled power plants (with EPA) • Characterize and/or reduce volume of wastewater and develop more efficient waste handling systems for coal-fired utility boilers • Assess and develop concepts for NO_x, fine particulate control at fossil plants. Characterize trace elements impacts • Develop and demonstrate both regenerative and non-regenerative flue gas desulfurization systems	• Evaluate methods to reduce thermal impacts at nuclear power plants (with EPA) • Develop techniques for prediction and control of shut-down radiation levels in boiling water reactors		

TECHNOLOGY	FOSSIL	NUCLEAR	CONSERVATION	SOLAR/GEOTHERMAL
Agency:	Activity			
TVA	• Investigate strip mine reclamation techniques and monitor sites for recovery			
DOA	• Develop reclamation technology and land management in potential mining areas • Develop technologies for reclaiming lands affected by mining including overburden analysis; redeposition; control of run-off, sedimentation and chemical pollution of surface and subsurface waters; soil amendments; development of plant materials for revegetation; and field demonstrations of the total reclamation process-planning, extraction, reclamation. • Develop criteria for environmentally and economically feasible systems for development			

ENVIRONMENTAL CONTROL TECHNOLOGY

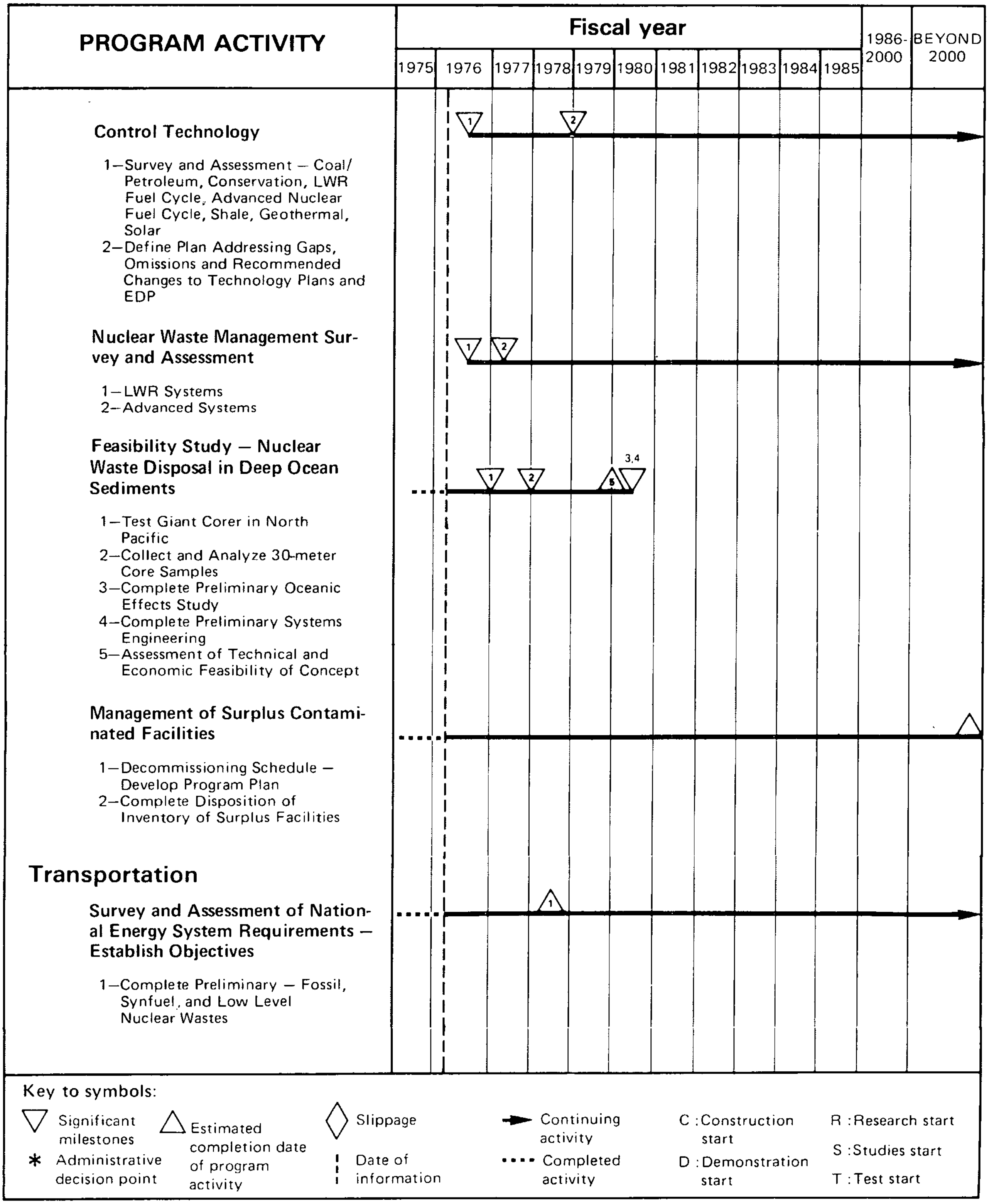
Federal Energy RD&D Budget *($ Millions)*

	FY 1975		FY 1976*		FY 1977	
Agency	BA	BO	BA	BO	BA	BO
ERDA						
Operating Expenses	8.2	7.1	12.6	11.5	15.6	14.2
Plant and Capital Equipment	0.1	0.1	0.4	0.3	0.5	0.5
Total	8.3	7.2	13.0	11.8	16.1	14.7
EPA	80.8	18.2	56.8	76.5	55.4	76.6
DOI	0	0	0.5	0.5	0.5	0.5
Total	89.1	25.4	70.3	88.8	72.0	91.8

* Does not include funds for FY 1976 Transition Quarter.

ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION

ENVIRONMENTAL CONTROL TECHNOLOGY



SYNTHETIC FUELS COMMERCIAL DEMONSTRATION PROGRAM EXECUTIVE SUMMARY

An incentive program for Synthetic Fuels Commercial Demonstration was proposed by the President in his 1975 State-of-the-Union message to support a goal of developing a production capacity of one million barrels per day crude equivalent of synthetic fuels by 1985. This program would create, through federal incentives, commercial demonstration of a limited amount of synthetic fuel production using technology that can be applied between now and 1985.

In response to the President's goal, an Interagency Federal Task Force was established to recommend an implementation plan. The objectives of the program recommended are to utilize existing technology and U.S. industrial capacity to:

- Gain early information and develop industry infrastructure to have a production capacity of 350,000 barrels per day in the early 1980's to facilitate possible major expansion of up to five million barrels per day synthetic fuels production capacity by 1995.
- Increase domestic energy production.
- Improve U.S. international position in energy matters.

In order to initiate a Synthetic Fuels Industry with an initial capacity of 350,000 barrels per day, the nation will require an early "commercialization program" to resolve a number of uncertainties related to regulation, environment, financing, labor and transportation. These uncertainties must be resolved by the middle 1980's in order to enhance plant investment in the middle 1980's so that significant production can be achieved by the 1990's.

Based on the extent of U.S. energy resources, the availability of technology and the classes of potential investors and users, the program scope would include the following fuel/resource group:

- Oil from shale
- Electric utility and industrial fuels (includes low and medium Btu gas and methanol clean fuels from coal as well as fuels derived from organic waste)
- High Btu (or pipeline quality) gas from coal.

Initiation of this program will depend on Congressional approval of the loan guaranty and community impact assistance authorization and appropriation request. The remaining statutory authority necessary to implement the recommended program exists under the Federal Nonnuclear Energy Research and Development Act of 1974.

SYNTHETIC FUELS COMMERCIAL DEMONSTRATION

Objectives

Near-Term:
(–1985)

- To initiate a U.S. Synthetic Fuels industry, with the cooperation of private industry and state/local government, by demonstrating available and forthcoming technology at a commercial scale of 350,000 barrels per day capacity and by gaining early environmental, economic, institutional, and technical information on large-scale plants.
- To increase domestic energy production.
- To improve the U.S. international position in energy matters by demonstrating U.S. capability to tap its vast coal and oil shale resources.

Mid-Term:
(–2000)

- By 1995, to assist industry in developing a capacity of approximately 5 million barrels per day of synthetic fuel production.

National Energy Technology Goals Supported

Primary

- Efficiently transform fuel resources into more desirable forms.

Secondary

- Increase the efficiency and reliability of the processes used in the energy conversion and delivery system.
- Expand the domestic supply of economically recoverable energy producing raw materials.

Strategy

The strategy for the commercialization of synthetic fuels, which are defined as liquids and/or gas derived from coal, oil shale, or urban wastes, is to accelerate industrialization/commercialization of the development of these fuels through a stimulation of industrial efforts by the application of federally supported incentives and the demonstration of environmentally acceptable and commercially viable synthetic fuel processes.

The federally supported incentives could take the form of loan guarantees, price guarantees and/or construction grants which would be justified after the cycle of public notifications, requests for industry proposals and formal proposal selection. The level and type of suport would vary with the synthetic fuel type and with each specific project.

The demonstration plan for synthetic fuels to support their commercialization might include:

- High Btu gas plants with a total daily output equivalent to 120,000 barrels of oil per day supported by a loan guarantee of up to 75% of the project costs.
- Shale oil plants with a total daily output of up to 100,000 barrels per day supported by a 50% federal non-recourse guaranteed loan plus guarantees.
- Utility/industrial gas plants with a total output up to 100,000 barrels of oil per day supported by a federal 50% construction grant for regulated gas companies and a federal 50% non-recourse loan guarantee plus price guarantees for unregulated plants.
- Five to eight biomass plants for converting metropolitan wastes with a total output equivalent to 30,000 barrels of oil per day supported by a federal 75% non-recourse loan guarantee.
- Utilization will be made of state-of-the-art developments that may be suggested or developed by National Laboratories, universities, private research centers, industry, and international data sources. Prime concurrence and coordination points are Congress, governors of the affected states, the Attorney General, the EPA, the CEQ, affected communities and Indian tribes.

Federal Role

The uncertainty in the future prices of world oil is perhaps the most important factor discouraging private investment in the commercialization of synthetic fuel. If the world oil prices were to fall substantially, large plant investments could not be paid off from revenues of low price, but high cost, synthetic fuels. In addition to the financial risk, there are numerous environmental uncertainties and regulations that must be met; and uncertainties concerning the adequacy of available labor and materials. The federal government is needed to overcome these financial, environmental and regulatory uncertainties.

Technological Status and Problems

Status:

- First generation technology, which is that presently in competitive use but not necessarily in a free market, is limited to coal gasification processes (both high and low Btu) developed in Germany in the 1930's and evolutionarily improved since then. The candidate processes are:

Process	Operating Units	in	Operating Plants
Lurgi	63		13
Koppers Totzek	52		20
Winkler	36		16

- Fischer-Tropsch for the conversion of coal-derived synthesis gas to chemicals and light fuels (indirect liquefaction) is commercial in South Africa.
- Other technologies range from pilot plant (liquefaction of coal) to advanced demonstration plants (liquefaction of shale and metropolitan wastes).

Problems:

- Although the bulk of the technical problems have been resolved or can be overcome in time to support the production goals, technical risk still exists, however, and questions of economies of scale, process efficiency, reliability, and maintenance still remain to be settled by the commercialization program.

Institutional Status and Problems

Status:

- Basic statutory authority concerning price support and construction grants necessary to implement this program at the 350,000 barrel per day level exists under the Federal Nonnuclear Energy Research and Development Act of 1974.

Problems:

- Establish loan guarantee authority for ERDA.
- Authorize the Department of Interior to grant oil shale lease holders approval for environmentally sound off-site disposal of residue where necessary.
- Change the Natural Gas Act to provide the FPC with clear regulatory jurisdiction over synthetic gas plants in the event that natural gas is not deregulated.
- Authority for community impact assistance.

Environmental Status and Problems

Status:

- Public and Congressional concern for environmental protection and community protection has been expressed in evaluations and discussions of synthetic fuel plants.
- As a program policy, plant approvals will require compliance with EPA and local standards plus community protection measures.
- Environmental Impact Statements have been filed on several synthetic fuel projects and environmental assessments are available to varying degrees on others.

Problems:

- With regard to environmental impact, considerable uncertainty surrounds the commercialization of synthetic fuels. These uncertainties include choice of process, effluents from the processes chosen, pollutant transport mechanims, site location, and others. Based on the environmental impact assessment it is judged that:

  —the environmental impacts currently estimated to result from the 350,000 barrels per day option appear acceptable when considered in light of the environmental and economic information likely to be gained from the program;

  —the environmental impacts likely to result from application of *current* technologies and pollution abatement technologies on a large scale (one million barrels per day or more) would be regional in scope and could be severe;

—it appears that pollution abatement technologies can be developed which will render synthetic fuels commercialization acceptable. The 350,000 barrels per day option would provide data for rapid diagnosis and treatment of environmental problems of synfuels production at commercial scale.

—the program should provide for community assistance to evaluate and then to ameliorate the community life style changes that a large synthetic fuel plant would induce.

Program Implementation

Energy Research and Development Administration

The President has approved implementation of the 350,000 barrels per day commercial demonstration program involving 12 to 15 plants. The overall life of the program guarantees may extend from 25 to 30 years depending on the actual operating life of the plants but the federal government involvement is scheduled to be concluded by 1985.

The major steps to program implementation include:

—Conduct studies and analysis
—Enactment of authorization legislation
—Publish Program Regulations
—Issue Environmental Impact Statements
—Prepare Inflationary Impact Assesments
—Establish Advisory Boards
—Issue Request for Proposals
—Notify governors of potentially affected states
—Initiate impact planning
—Evaluate proposals and award contract.

A preliminary near-term implementation plan has been prepared and an inventory has been completed of current and recent industry projects which can be utilized to supply the needs of synthetic fuels commercialization. Without federal assistance, these projects cannot be expected to proceed due to market uncertainties. However, sufficient work has been done to support the requirements of the attached schedule.

Current plans have not yet specified the order of specific plant developments. However, the basic schedule calls for the first project solicitation to be issued in September 1976, and the first award in August 1977. Successive project starts would be initiated at succeeding intervals.

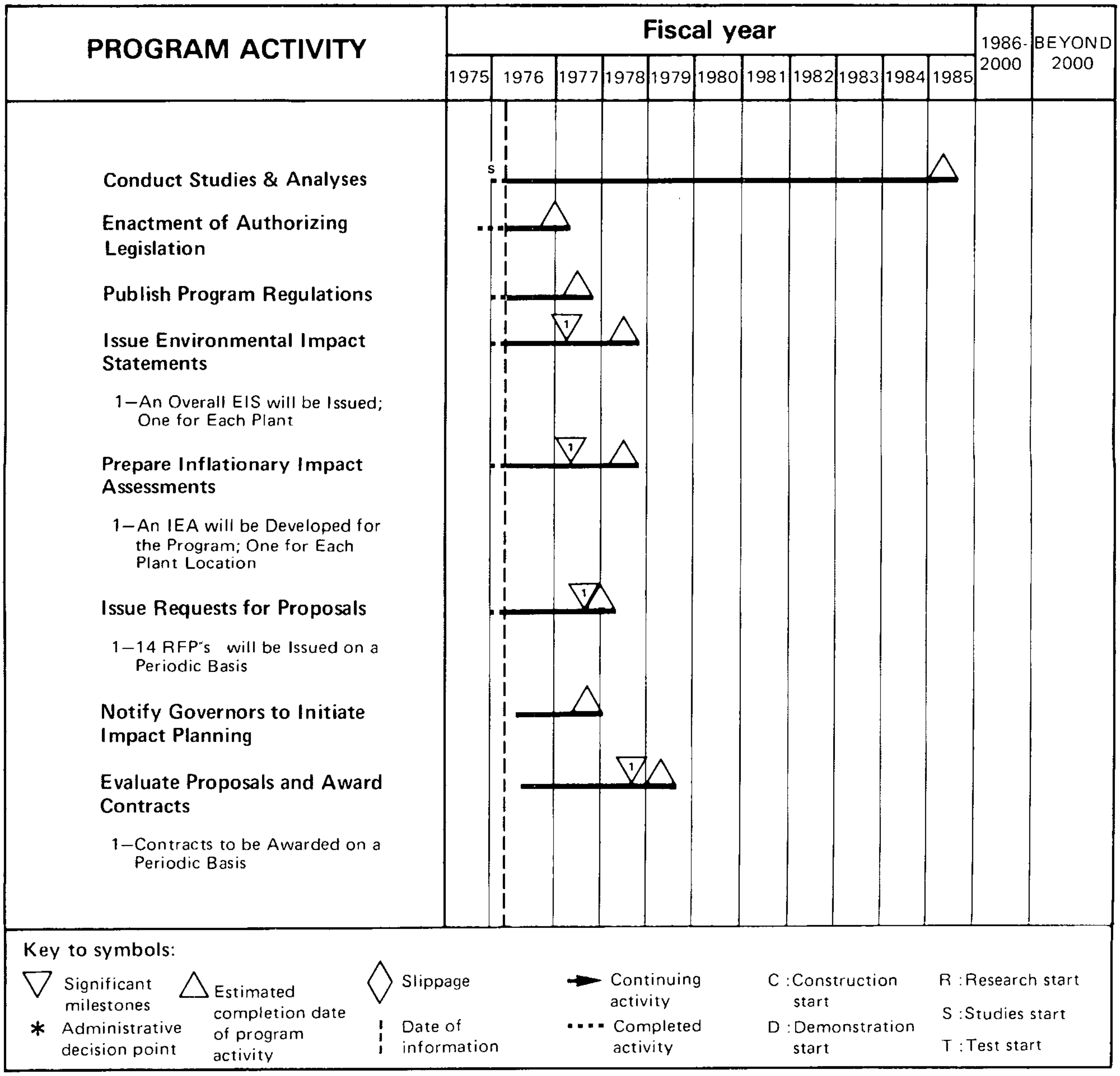
Basically, each plant is expected to evolve through a seven year development cycle for design, construction and shakedown except for the biomass plants which should complete their installations in three years.

This program will use a strict environmental protection strategy that will incorporate:

—Federal review and state approval of detailed site development plans.
—Extensive coordinated efforts to develop an environmental data base.
—Comprehensive environmental monitoring of plant operations.
—An Environmental Advisory Board with state and other representation to ensure regional and state participation in the decision process.
—Adherence to all applicable federal and state environmental laws and regulations.

ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION

SYNTHETIC FUELS COMMERCIAL DEMONSTRATION PROGRAM



PART II—SUPPORTING TECHNOLOGY PROGRAMS

INTRODUCTION

This second Part of Volume 2 contains eight supporting energy technology Building Blocks, grouped into two major program areas:

Environmental Research and Safety

Basic Energy Sciences

These Building Blocks contain information on energy RD&D activities of twelve federal agencies, namely:

- Department of Agriculture
- Department of Commerce
- Department of Health, Education, and Welfare
- Department of Interior
- Energy Research and Development Administration
- Environmental Protection Agency
- Federal Power Commission
- National Aeronautics and Space Administration
- National Science Foundation
- Nuclear Regulatory Commission
- Tennessee Valley Authority
- Water Resources Council

BIOMEDICAL AND ENVIRONMENTAL RESEARCH PROGRAM SUMMARY

Objectives

To ensure that the national goal of increasing domestic energy production is achieved with minimal adverse impact on man and his environment. To develop and integrate health, biological, physical, environmental, and socio-economic data in order to provide timely information for decision making. To perform research needed to determine the adverse effects of energy technologies and to identify methods of mitigating or eliminating these adverse effects. To provide the ERDA Program Offices, responsible for the development of energy production technologies, with the information and support needed to ensure environmental acceptability during the development and ultimate commercialization of the technologies. To provide a basis for informed public judgment of the environmental costs, risks, and benefit trade-offs involved in the development of energy resources and production technologies.

All the above will be performed in a time-frame to support energy technology development.

National Energy Technology Goals Supported

Primary

- Protect and enhance the general health, safety, welfare, and environment related to energy.

Secondary

- Perform basic and supporting research and technical services related to energy.

Strategy

The major Biomedical and Environmental Research building blocks are as follows:

- Health Studies
- Biological Studies
- Environmental Studies
- Physical and Technological Studies
- Assessments

Health studies research provides qualitative health effects data using human clinical and epidemiological studies, and using studies will well controlled animal populations.

Biological Studies are closely related to and support health studies, but are more fundamental in nature, examining basic mechanisms of life and of biological damage and repair.

Environmental Studies include land, freshwater, marine and atmospheric studies. These studies quantify environmental effects, providing the information necessary for cost and benefit analyses of energy choices. The research programs are geared to specific technological developments or specific problem areas associated with current processes and operations.

Physical and Technological Studies include research into the physical and chemical mechanisms that underlie radiation and other pollutant interactions in biological and environmental systems. Also included are characterization, measurement, and monitoring activities related to environment and health programs. These activities provide means and methods for supplying the basic information needed for health, biological, and environmental studies.

Assessments are efforts to integrate and analyze environmental, health, and socio-economic data and current policies in order to supply decision makers in the federal and local governments, as well as the general public, with information needed to evaluate the environmental acceptability of each ERDA technology.

In line with current national priorities, a concerted effort has been initiated to implement a balanced program between fossil, nuclear, and advanced energy research to support time-critical decisions within all technological areas. This has meant an increased emphasis on fossil fuel studies for the near-term period.

Federal Role

Energy technologies under development by the federal government have associated environmental and occupational health and safety implications. Because the benefits of research on these impacts will accrue to the public at large, there is little incentive for the private sector to assume a leading role in funding this research. In addition, some of the detrimental health and safety impacts of commercial energy systems are national in scope and come under the purview of the federal government. For these reasons, it is the responsibility of the federal government to perform research to anticipate and permit complete evaluation of the environmental consequences of energy technologies—to provide a better basis for setting standards, to establish guidelines for modification of the technology and, overall, to permit a fair and complete evaluation of energy alternatives.

Although these functions—standards setting and technology development—reside in different federal agencies, much of the same environmental research is needed for both purposes. Included in this category is basic data on health, biological and ecological effects. Likewise, pollutant characterization, measurement, and monitoring are essential to identify and quantify hazards and to ensure compliance with standards. There are organizations within ERDA and other agencies (EPA, HEW, NSF, DOC, DOI, DOA, NBS, DOD, TVA, NASA) which perform specific portions of this research.* The matrices included with each building block describe the major thrust of other agency involvement in environmental research.

It is essential that the information developed in the above studies is managed and integrated so that it is used effectively. Within ERDA, assessments are conducted to keep Program Offices cognizant of environmental research and policy developments occurring throughout the federal government. To accomplish this, ERDA has developed a comprehensive inventory of federal environmental research to be updated annually.* Another mechanism is the Federal Interagency Energy/Environmental R&D Program which was developed by an Interagency Working Group including ERDA to coordinate the programs of federal agencies supported by pass-through funds. Such mechanisms of coordination assist in the integration of research efforts and help identify gaps and priorities for new research.

The federal government, with industry cooperation, surveys facilities, acquires information about processes and samples of products, by-products, residues, and effluents for specific high priority technologies. A specific example of industry/government cooperation is the case of toxicological studies for oil shale facilities for which cost-sharing negotiations have begun. Consumer Representation Plans now under development will aid in communication and coordination about environmental issues and concerns with various publics.

* Federal Inventory of Energy-Related Biomedical and Environmental Research for FY 74 and FY 75, ERDA–110, October 1975.

BIOMEDICAL AND ENVIRONMENTAL RESEARCH

Federal Energy RD&D Budget

($ Millions)

Building Block	FY 1975		FY 1976 *		FY 1977	
	BA	BO	BA	BO	BA	BO
Health Studies	81.4	60.6	85.0	86.2	83.6	86.4
Biological Studies	46.5	38.0	50.9	45.2	52.1	50.4
Environmental Studies	102.9	68.8	132.6	125.9	141.4	137.1
Physical & Technological Studies	29.6	16.1	31.2	26.2	31.3	29.1
Assessments	14.4	10.2	18.9	18.0	26.4	23.6
Total	274.8	193.7	318.6	301.5	334.8	326.6

* Does not include funds for FY 1976 Transition Quarter.

BIOMEDICAL AND ENVIRONMENTAL RESEARCH

Health Studies

Objectives

Near-Term (—1985), Mid-Term (—2000) and Long Term (Beyond 2000):

- To ensure that the national goal of increasing domestic energy production is achieved with minimal impact on human health.
- To supply information required to develop the health impacts of technologies for environmental impact statements and cost-benefit analyses.
- To supply energy technology development programs with the information required to design and evaluate the adequacy of, and need for, containment measures and control technology.

Strategy

Health research and development activities are balanced to reflect the national priorities for energy technology development. Studies and experiments are conducted to determine the human health risk in the form of acute, subacute and late effects of energy-related physical, chemical, and biological agents. The figure below illustrates the relationship of the major components of health effects research. The priorities for research are based on: (1) The severity of the health problem, (2) the magnitude of the impact (population size), and (3) the time-frame for needed information in terms of each technology.

These studies are being carried out by ERDA on-site laboratories, other research contractors, and other federal laboratories.

International Cooperation

The continuing study of late pathophysiological and genetic effects due to radiation exposure from the Hiroshima and Nagasaki nuclear explosions is one specific example of international cooperation. This effort, directed by the Radiation Effects Research Foundation (RERF), is jointly and equally funded and administered by the United States (ERDA) and Japan. In support of the United Nations Scientific Committee On Effects of Atomic Radiation (UNSCEAR), the United States is participating in programs of the International Commission on Radiological Protection (ICRP), International Commission on Radiation Units (ICRU), and other scientific bodies involved in radiation protection, standards and units. International energy-related health studies are coordinated under the multinational aegis of the Organization for Economic Cooperation and Development (OECD) and the United Nations Environmental Program/Global Environmental Monitoring System (UNEP/GEMS) among others.

Technological Status and Problems

Status:

- Programs which identify health effects relative to human exposure to radiation and radioactive materials have been conducted for 30 years. Programs have been initiated within ERDA to provide needed identification of and hazard assessment for agents related to nonnuclear energy sources.

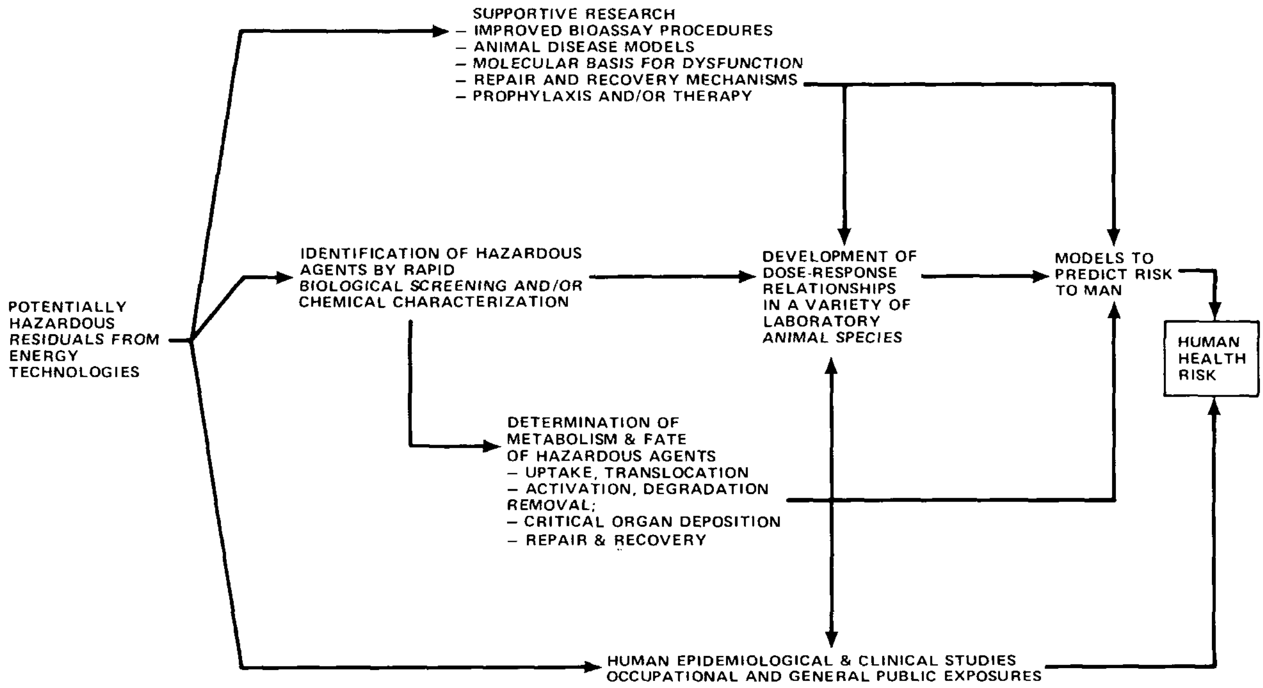
Problems:

- Delayed or latent diseases, including cancer, may represent the most costly of health problems concerned with energy development. Sufficient delayed effects data are not available and acquisition of reliable dose-effect data is costly, requiring two to ten years to study in experimental animals. In addition, the methodology for extrapolation of animal data to man requires experimental development.

Program Implementation

Energy Research and Development Administration

In order to provide a better understanding of the effects of nonnuclear energy-related pollutants


SUPPORTIVE RESEARCH
– IMPROVED BIOASSAY PROCEDURES
– ANIMAL DISEASE MODELS
– MOLECULAR BASIS FOR DYSFUNCTION
– REPAIR AND RECOVERY MECHANISMS
– PROPHYLAXIS AND/OR THERAPY
POTENTIALLY HAZARDOUS RESIDUALS FROM ENERGY TECHNOLOGIES
IDENTIFICATION OF HAZARDOUS AGENTS BY RAPID BIOLOGICAL SCREENING AND/OR CHEMICAL CHARACTERIZATION
DEVELOPMENT OF DOSE-RESPONSE RELATIONSHIPS IN A VARIETY OF LABORATORY ANIMAL SPECIES
MODELS TO PREDICT RISK TO MAN
HUMAN HEALTH RISK
DETERMINATION OF METABOLISM & FATE OF HAZARDOUS AGENTS
– UPTAKE, TRANSLOCATION
– ACTIVATION, DEGRADATION REMOVAL;
– CRITICAL ORGAN DEPOSITION
– REPAIR & RECOVERY
HUMAN EPIDEMIOLOGICAL & CLINICAL STUDIES
OCCUPATIONAL AND GENERAL PUBLIC EXPOSURES

on human health, a major research effort has been initiated, in eventual cooperation with industry representatives, for the evaluation of coal conversion and oil shale processes. The effort will provide rapid chemical and biological identification of potentially mutagenic, carcinogenic, teratogenic, and otherwise toxic chemical agents used and produced as end- or by-products of fossil energy technologies. Systematic quantification of the metabolism, distribution, and retention of potentially hazardous agents in sensitive organs and tissues will be conducted. Evaluation will be made of acute, subacute, and late effects of hazardous agents on short and long-lived model experimental animals under conditions which simulate real-life exposure. Health risks from cancer or other debilitating diseases that reduce life span will be assessed based on both theoretical and experimental models to allow extrapolation to man, especially for low level exposures. All available human information will be used to confirm the accuracy of the animal data extrapolation.

In the nuclear technology area, on-going studies of late effects to evaluate health risk from large-scale advanced nuclear energy developments, related to advanced converter and breeder reactors and planned fuel reprocessing concepts as well as waste management, will continue. Special projects concerned with controlled fusion reactors have been initiated.

To support other energy development technologies, efforts are planned or underway in support of solar, geothermal and other advanced systems, and conservation practices. These include a study of the effects of ultra high voltage electrical transmission lines on living organisms. Many generic problems have emerged and are being addressed in the programs described.

Under the medical applications program, medical capabilities will be advanced by developing instruments, new radionuclides, and radiopharmaceuticals for medical diagnoses and by conducting clinical feasibility studies on new nuclear medicine techniques. Emphasis will be placed on cardiopulmonary and cardiovascular disorders.

The milestone chart displays ERDA R&D activities only. The major thrust of health effects R&D in other agencies is summarized in matrix format. More detailed information is contained in the report, *Federal Inventory of Energy-Related Biomedical and Environmental Research for FY 1974 and FY 1975, ERDA-110,* October 1975.

OTHER FEDERAL ACTIVITIES IN HEALTH STUDIES RESEARCH

TECHNOLOGY	FOSSIL	NUCLEAR	CONSERVATION	SOLAR/GEOTHERMAL
Agency:	**Activity:**			
EPA	• Expand present knowledge on health and effects of pollutants from fossil combustion as a basis for standard setting. • Study health impacts of sulfates, nitrates, particulate material, organic constituents, and trace elements resulting from coal, oil, and oil shale and extraction, conversion and utilization. • Study occupational exposures to recirculated exhaust air in coal conversion facilities (in conjunction with NIOSH).	• Study effects of low-level chronic exposure to ^{85}Kr and ^{3}H resulting from nuclear energy activities.	• Evaluate potential impacts resulting from residential or industrial energy conservation measures. • Evaluate health effects of waste-fuel as a basis for standard setting.	
HEW (NCI, NHLI, NIEHS, NIOSH)	Support research and training on the cause, prevention, and cure of health problems in the working and general population arising from energy-related hazardous agents.			

OTHER FEDERAL ACTIVITIES IN HEALTH STUDIES RESEARCH

TECHNOLOGY	FOSSIL	NUCLEAR	CONSERVATION	SOLAR/GEOTHERMAL
Agency:	**Activity:**			
NRC		• Support confirmatory studies in areas such as assessment of population exposures, dose effect relationships, and adequacy of protective measures and systems.		

HEALTH STUDIES

Federal Energy RD&D Budget ($ Millions)

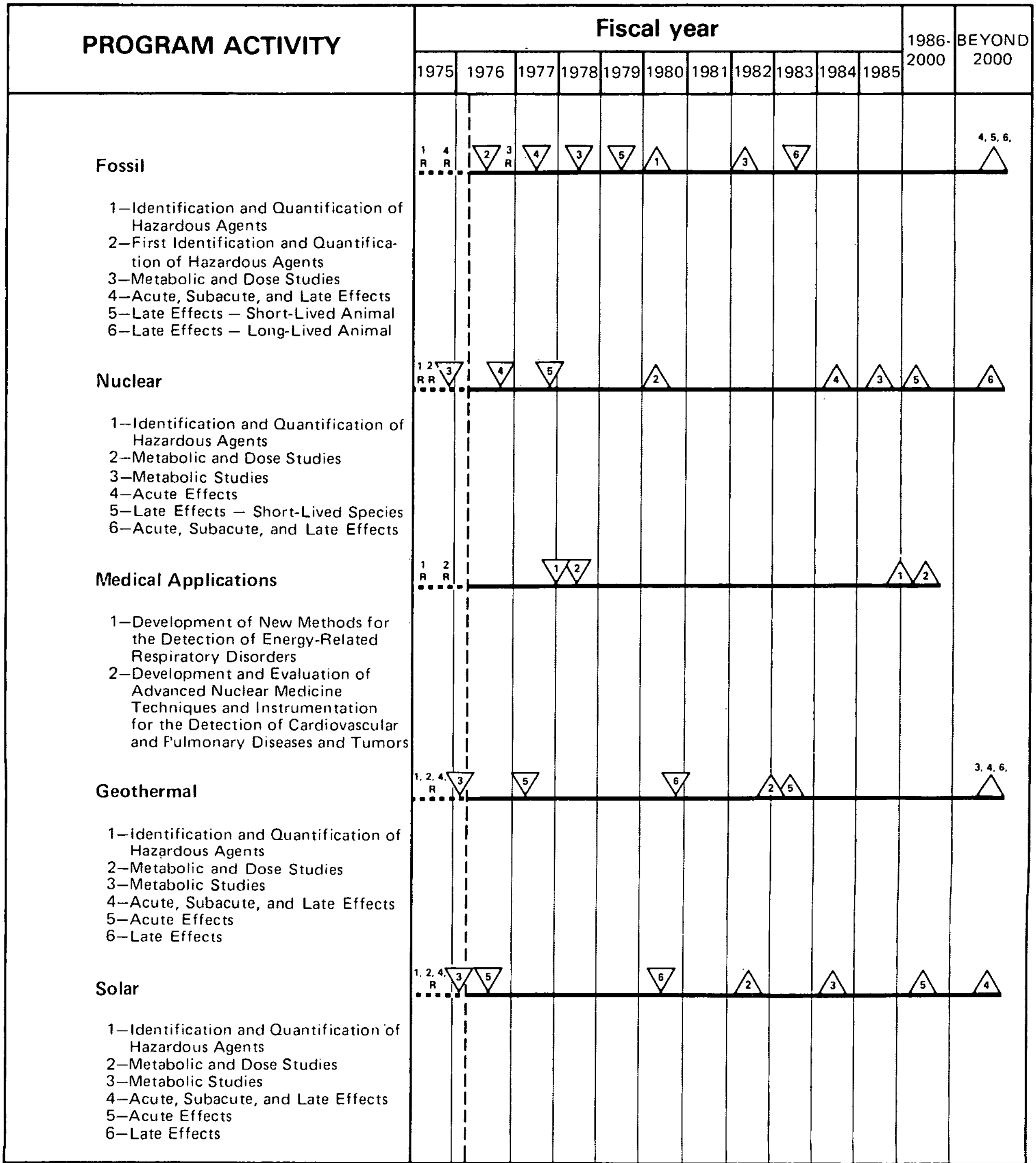
Building Block	FY 1975 BA	FY 1975 BO	FY 1976 * BA	FY 1976 * BO	FY 1977 BA	FY 1977 BO
ERDA						
Operating Expenses	57.0	55.0	65.1	64.1	63.4	62.4
Plant and Capital Equipment	5.6	4.4	6.2	4.8	7.2	6.7
Total	62.6	59.4	71.3	68.9	70.6	69.1
EPA	18.8	1.2	13.7	17.3	13.0	17.3
Total	81.4	60.6	85.0	86.2	83.6	86.4

* Does not include funds for FY 1976 Transition Quarter.

ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION

BIOMEDICAL AND ENVIRONMENTAL RESEARCH

HEALTH STUDIES



Key to symbols:

- ▽ Significant milestones
- * Administrative decision point
- △ Estimated completion date of program activity
- ◇ Slippage
- ¦ Date of information
- ➔ Continuing activity
- •••• Completed activity
- C : Construction start
- D : Demonstration start
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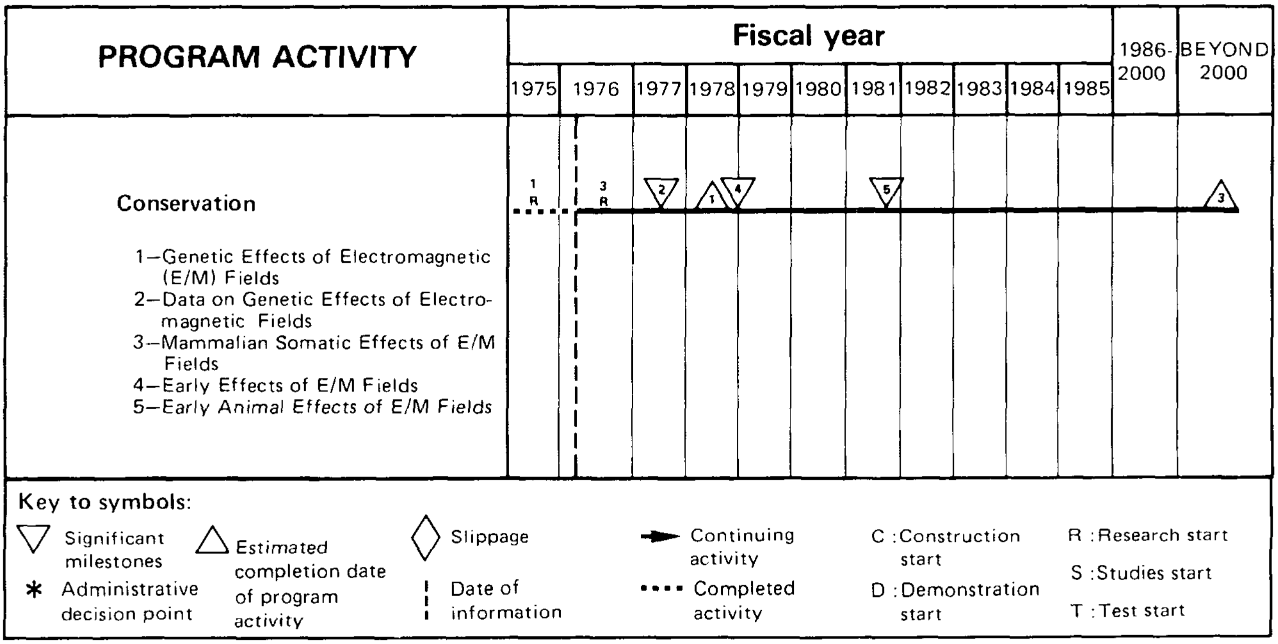
ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION

BIOMEDICAL AND ENVIRONMENTAL RESEARCH

HEALTH STUDIES (continued)



BIOMEDICAL AND ENVIRONMENTAL RESEARCH

Biological Studies

Objectives

Near-Term (—1985), Mid-Term (—2000) and Long Term (Beyond 2000):

- To develop and validate rapid biological, biochemical and automated cytochemical screening techniques for: (1) identification of energy-related hazardous agents, (2) detection of early indicators of damage in human populations, and (3) identification of susceptible human sub-populations.
- To support epidemiological and animal studies through insights gained from research on the effects of hazardous agents at the molecular and cellular level.
- To examine the potential genetic and developmental effects of energy production by studies of mutagenesis, teratogensis (fetal malformations), and their consequences.
- To perform basic research on plants to provide data which can be applied to assure that potential impacts of energy production on plants are understood and controlled, and to develop plant cell and tissue culture assays for investigation of potential mutagens and carcinogens.

Strategy

Biological studies examine the processes of damage and repair at the molecular, organelle, and cellular level to provide mechanistic descriptions of the action of hazardous agents resulting from energy production.

These studies provide data to help circumvent the inherent statistical and time limitations unavoidable in direct human and experimental animal studies.

Rapid screening techniques are being developed to minimize delay in identifying hazards and susceptible sub-populations. The mutagenic, carcinogenic, and other toxic potentials of agents are to be evaluated at the cellular, organelle and macromolecular level and validated by studies in animals.

International Cooperation

ERDA staff are participating in international energy-related biological studies and personnel exchange activities. National Laboratory and university staff regularly attend international biological science colloquia and meetings, spend sabbatical periods in foreign laboratories, and exchange students and post-doctoral appointees with foreign colleagues.

Technological Status and Problems

Status:

- A variety of simple rapid screening methods are under development for detection of mutagens and carcinogens in the environment. Testing units to evaluate mutagens and carcinogens in fossil fuel conversion products, by-products and effluents have been established at Oak Ridge National Laboratory and at Pacific Northwest Laboratory.

Problems:

- Not enough is presently known about basic mechanisms of production of disease states resulting from exposure to low levels of physical and chemical agents to warrant the use of routine biological monitoring as a means of protecting exposed populations.
- Recognition of damage to a number of critical organs at an early stage after exposure to potentially toxic agents will be required for medical surveillance of occupational groups involved in emerging energy technologies. In order to generalize the effects of hazardous chemical and physical agents involved in new energy technologies, basic mechanisms of cellular and molecular damage and biological repair must be better understood.

Program Implementation

Energy Research and Development Administration

Considerable information has been obtained from past, current and on-going programs on the pathophysiological effects of radiation and the means by which damage is inflicted and repaired at the cellular and molecular levels in living organisms. It is believed that an understanding of the linked fundamental causal events and mechanisms in these studies will be of benefit in understanding disease and recovery processes in human populations exposed to both nuclear and nonnuclear energy-related hazardous agents. These similarities are being confirmed and models are being constructed for their extrapolation to man. Basic studies aimed at understanding the fundamental mechanisms of damage, recovery, and repair are providing more techniques and methods for rapid screening of human populations for energy-related damage.

A battery of semi-automated screening techniques is being developed to detect changes in tissue cells in key subcellular organelles or macromolecules that are predictive indicators of pathological change and can be used, therefore, as early warning systems for exposure to hazardous agents.

A mammalian cell system is being perfected which can be used to evaluate both mutagens and carcinogens. The system will be used to evaluate the potential of metabolites of benzopyrene during FY 1976 and 1977, and will then be applied to other fossil related polycyclic hydrocarbons.

Research is continuing to perfect cytological, biochemical, and physiological indicators to detect those abnormal components in blood, urine, and other body fluids which characterize damage to sensitive or critical organs and which can be applied to occupational groups in routine medical surveillance.

Specific programs are directed toward the investigation and clarification of basic genetic effects and ultimate population genetic burdens.

In addition to the above biological studies which support health effects, other basic studies in the area of photobiology and photosynthesis will provide useful information in support of the solar and conservation programs.

The milestone chart displays ERDA biological R&D only. Information submitted by other federal agencies identifying biological research performed primarily to support energy development is summarized in matrix format. The report, *Federal Inventory of Energy Related Biomedical and Environmental Research for FY 1974 and FY 1975, ERDA–110,* October 1975, should be consulted for additional information on biological research applicable to energy production.

OTHER FEDERAL ACTIVITIES IN HEALTH STUDIES RESEARCH

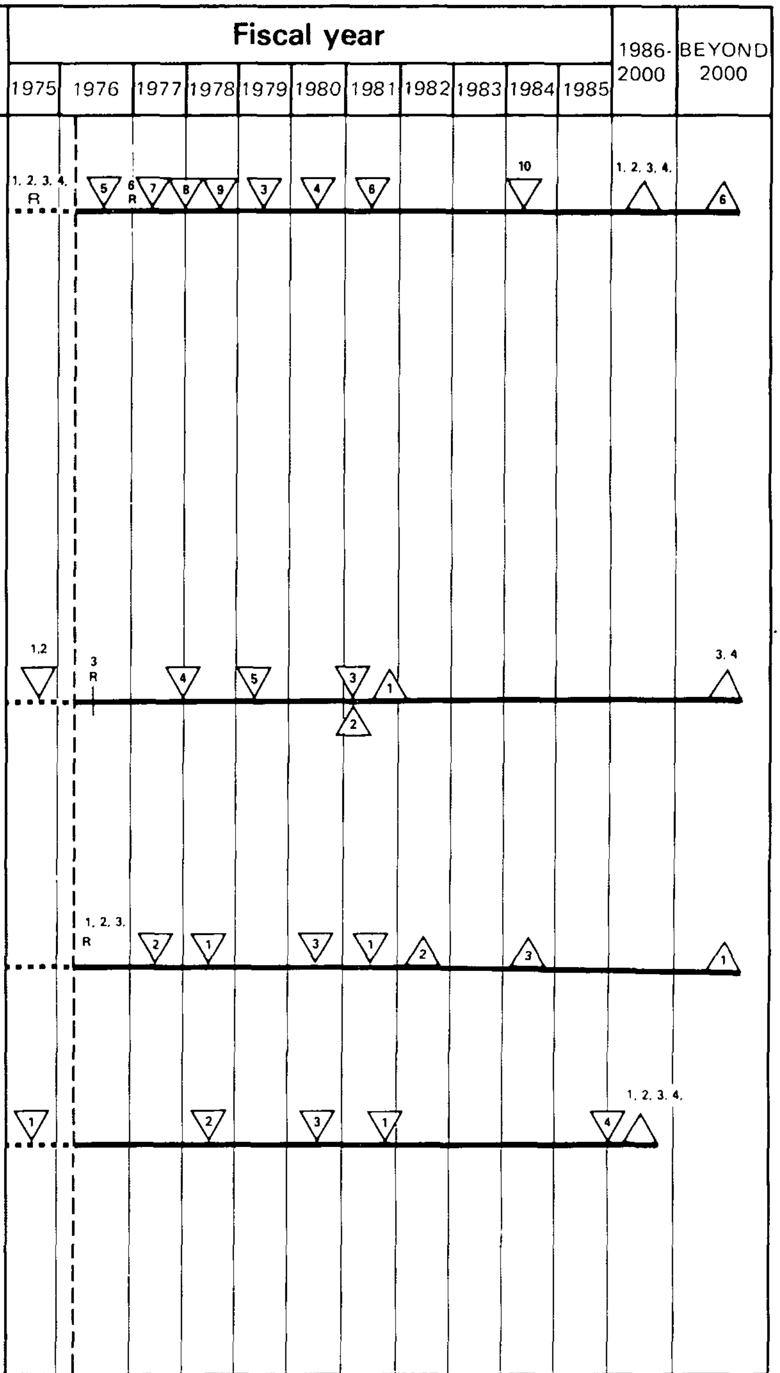
<table>
<tr><th>TECHNOLOGY</th><th>FOSSIL</th><th>NUCLEAR</th><th>CONSERVATION</th><th>SOLAR/GEOTHERMAL</th></tr>
<tr><td>Agency:</td><td colspan="4">Activity:</td></tr>
<tr><td>EPA</td><td colspan="4">• Develop models, utilizing cellular systems or intact organisms, to measure precisely damages to man caused by pollutants, regardless of source.
• Implement common methodologies for all technologies, to determine metabolism and fate of pollutant species.
• Evaluate potential toxic, carcinogenic, mutagenic, or teratogenic behavior of pollutants, alone or in combination.
• Develop in-vivo and in-vitro bioassays for rapid, accurate, inexpensive screening and testing of potentially hazardous materials.</td></tr>
<tr><td rowspan="2">ERDA</td><td>• Investigate disease and recovery processes and pathophysiological effects of non-nuclear energy-related hazardous agents
• Apply screening techniques and research in the nuclear area to fossil-related hazardous agents
• Evaluate effects of mutagens and carcinogens on a mammalian cell system</td><td>• Obtain information on pathophysiological effects of radiation and means for infliction/repair of damage</td><td rowspan="2"></td><td rowspan="2">• Conduct photobiology and photosynthesis studies to support bioconversion, improved biomass production</td></tr>
<tr><td colspan="2">• Use semi-automated screening techniques to detect changes in tissue cells that can be used as early warnings for exposure to hazardous agents</td></tr>
<tr><td>HEW</td><td colspan="4">• Detect and understand the events at the molecular and cellular level which lead to biological damage from energy-related hazardous agents.
• Determine how energy-related hazardous agents affect, are absorbed, distributed, stored, metabolized and ultimately disposed of by intact marine and terrestrial animal species.
• Develop more rapid screening tests for the action of energy-related hazardous agents on the genetic and reproductive integrity of biological systems.
• Develop simpler, more reliable methods for the extrapolation of laboratory animal data to man
• Determine the presence and magnitude of health problems resulting from long-term exposure of various human populations to low doses of energy-related hazardous agents through epidemiological studies.</td></tr>
<tr><td>TVA</td><td>• Characterize dose/response relationship of NO_2, SO_2, and their compounds on foliar appearance and crop yield.
• Characterize impacts of these compounds and acid precipitation on a terrestrial ecosystem.</td><td></td><td></td><td></td></tr>
</table>

ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION

BIOMEDICAL AND ENVIRONMENTAL RESEARCH

BIOLOGICAL STUDIES

PROGRAM ACTIVITY



Fossil

1—Biological Screening Techniques/Indicators of Damage
2—Damage and Repair Mechanisms
3—Pathophysiological Effects
4—Genetic Effects — Baseline Human Population
5—Damage and Repairs Mechanisms First Significant Data
6—Chemical Mutagens Dose Effect Animal Studies
7—First Significant Results — Biological Screens
8— Early Baseline Data — Human Population Genetic Study
9—First Significant Data — Indicators of Damage
10—Screening Techniques/Indicators of Damage — Application to Population

Nuclear

1—Damage and Repair Mechanisms
2—Pathophysiological Effects
3—Exposed Human Population Genetic Studies
4—Biological Screening Techniques/Indicators of Damage
5—Applications of Screens to Population

Geothermal

1—Biological Screening Techniques/Indicators of Damage
2—Damage and Repair Mechanisms
3—Pathophysiological Effects

Solar

1—Genetic Effects — Baseline Human Population
2—Biomass Crop Improvement Data
3—Data on Photosynthesis
4—Direct Conversion of Sunlight to Energy

Key to symbols:

▽ Significant milestones
* Administrative decision point
△ Estimated completion date of program activity
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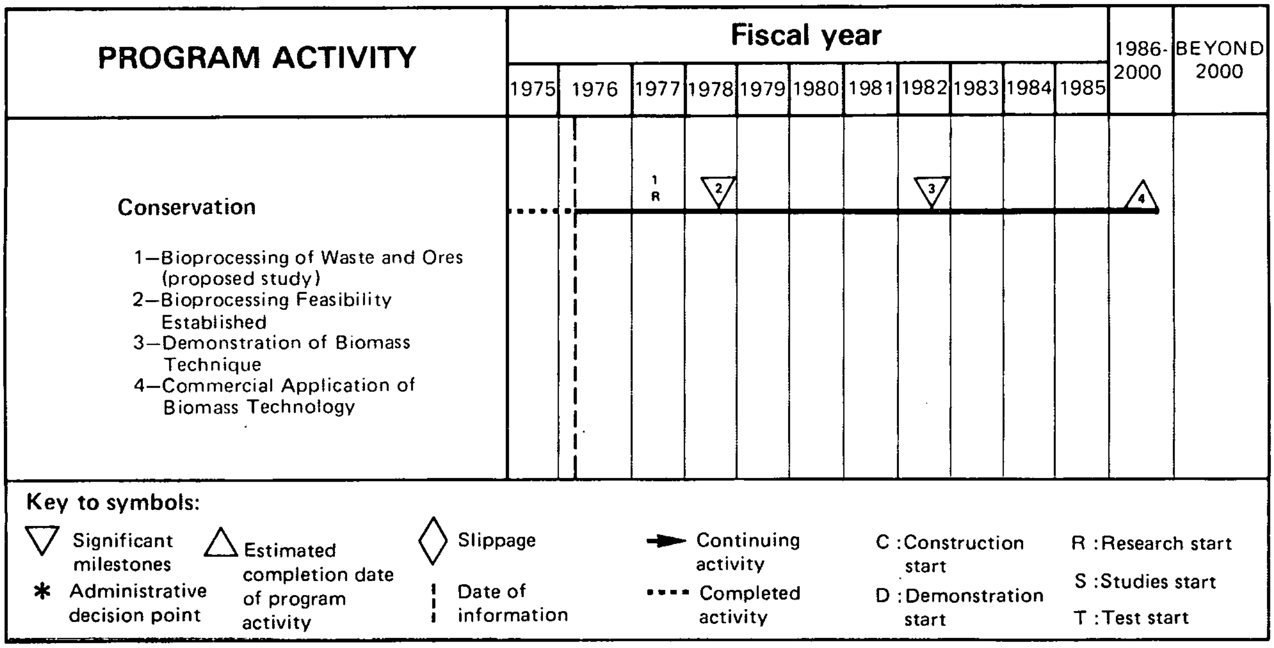
ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION

BIOMEDICAL AND ENVIRONMENTAL RESEARCH

BIOLOGICAL STUDIES (Continued)



BIOLOGICAL STUDIES

Federal Energy RD&D Budget **($ Millions)**

Building Block	FY 1975 BA	FY 1975 BO	FY 1976 * BA	FY 1976 * BO	FY 1977 BA	FY 1977 BO
ERDA						
Operating Expenses	28.5	27.3	34.0	31.4	34.0	33.2
Plant and Capital Equipment	8.0	5.1	6.9	7.8	7.4	7.9
Total	36.5	32.4	40.9	39.2	41.4	41.1
NSF	10.0	5.6	10.0	6.0	10.7	9.3
Total	46.5	38.0	50.9	45.2	52.1	50.4

* Does not include funds for FY 1976 Transition Quarter.

BIOMEDICAL AND ENVIRONMENTAL RESEARCH

ENVIRONMENTAL STUDIES

Objectives

Near-Term (—1985), Mid-Term (—2000) and Long Term (Beyond 2000):

- To define and quantify the transport of energy-related pollutants in the atmosphere, on land, and in aquatic systems.
- To determine the effects of massive physical environmental disturbances and disruptions on all environmental compartments.
- To identify the major pathways by which these pollutants are transferred through the biotic compartments of the environment and their rates of transfer.
- To describe the organismic and ecological responses to pollutants and stresses related to energy development and evaluate rates of recovery and mechanisms by which systems can accommodate such stresses.
- To define management strategies for land, atmospheric, and water resources subject to impact during energy development and develop criteria for the development of control strategies.
- To develop and evaluate countermeasures to eliminate pathways to man or to lessen the impact on the environment.
- To use environmental information to increase the efficiency of energy resource utilization.
- To guide fundamental research in geophysical media, structure of ecosystems, responses of biotic communities to stress, and methods for early detection of changes in environmental systems.
- To provide operational support to environmental programs and ERDA activities.
- To set aside land in National Environmental Research Parks (NERPs) where long-term studies on the impact of energy production on ecosystems can be compared to similar studies on controlled (no impact) ecosystems.
- To continue the investigation of the effects of energy development on the land, freshwater, marine and atmospheric environments, emphasizing those regions and environments most affected by the specific energy production technologies being implemented.

Strategy

Environmental studies involve the collection of baseline information, the evaluation of environmental impacts and the development of ecological management procedures. Depending on technology and fuel cycle stage, studies will be conducted in a variety of habitats including freshwater, terrestrial, and marine ecosystems. The figure below describes the research efforts which will be conducted in each of these categories. These studies will provide important generic support to technology-oriented environmental research. This research will have a strong site and regional orientation.

These activities will produce data which will be of use in estimating environmental impacts and in anticipating upcoming standards and regulations relating to developing ERDA energy technologies, both nuclear and nonnuclear. They are being carried out by ERDA laboratories and other research contractors. These studies will be coordinated with those of other federal agencies whose efforts are aimed at developing standards and regulations.

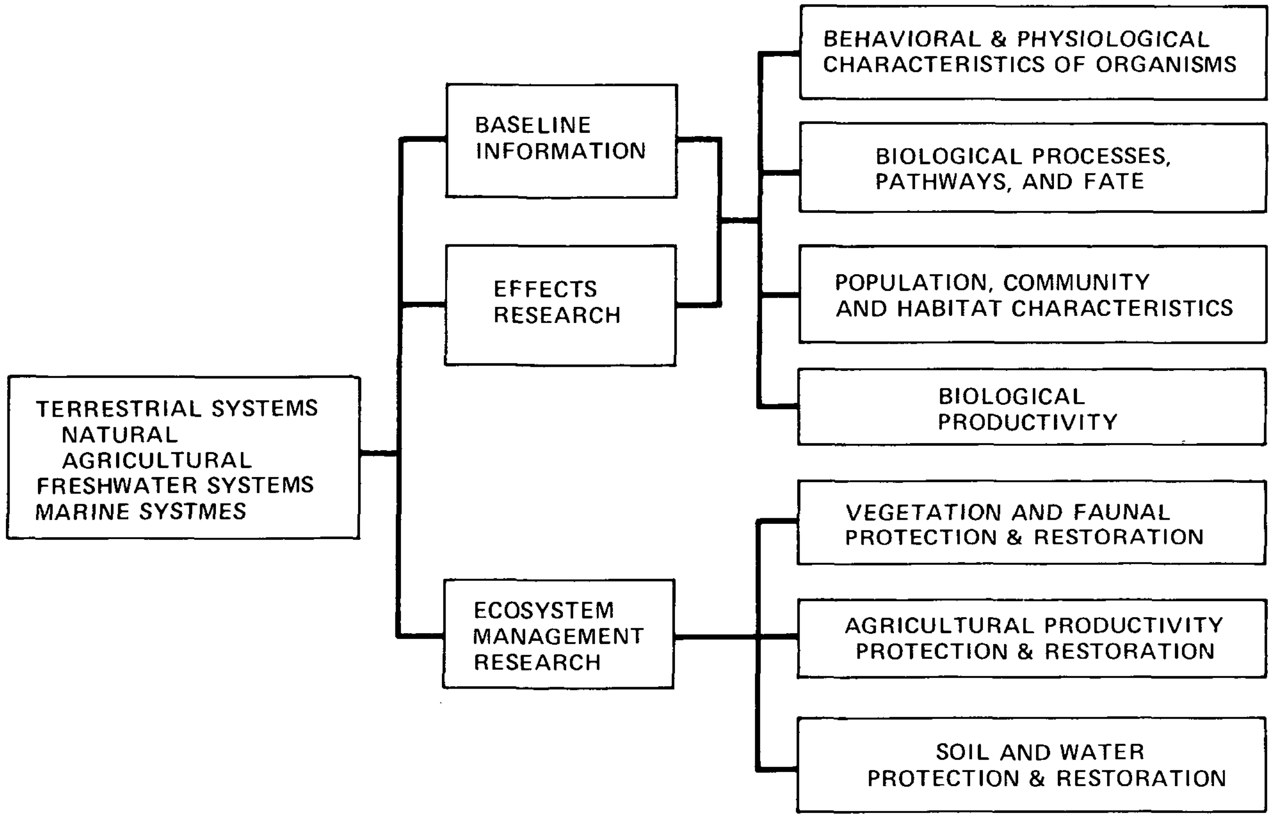
International Cooperation

Information exchange with, and participation in, activities of the United Nations Environment Program and the World Meteorological Organization are currently underway.

Technological Status and Problems

Status:

- Major new programs have been instituted, or are planned, to address questions in areas of surface and deep coal and shale mining and coastal oil extraction.


TERRESTRIAL SYSTEMS
NATURAL
AGRICULTURAL
FRESHWATER SYSTEMS
MARINE SYSTMES
BASELINE INFORMATION
EFFECTS RESEARCH
ECOSYSTEM MANAGEMENT RESEARCH
BEHAVIORAL & PHYSIOLOGICAL CHARACTERISTICS OF ORGANISMS
BIOLOGICAL PROCESSES, PATHWAYS, AND FATE
POPULATION, COMMUNITY AND HABITAT CHARACTERISTICS
BIOLOGICAL PRODUCTIVITY
VEGETATION AND FAUNAL PROTECTION & RESTORATION
AGRICULTURAL PRODUCTIVITY PROTECTION & RESTORATION
SOIL AND WATER PROTECTION & RESTORATION

- Determination of the magnitude and nature of pollution resulting from the processing, transportation, and disposal of fossil fuel materials is the subject of significant new and enlarged activity. Similar problems arise in the geothermal area and similar approaches to a solution are being developed.
- Environmental processes are critical in transferring radioactive materials through all physical and biological media to man. The behavior and fate of the long-lived nuclides are the particular subjects of continued activity in terrestrial and marine environments.

Problems:

- In those energy technology areas marked by major disruptions of natural soil, water, atmosphere and associated biological systems, environmental information is insufficient for prior assessment and subsequent reclamation.
- The impacts of processing, transportation, and disposal of fossil fuel materials are also poorly understood, particularly in the area of pollution transported by air and water and deposited on land surfaces.
- The use of such renewable resources as the wind, solar radiation, and ocean thermal gradients raises questions of land use, resource availability and climatic conditions and, in the case of ocean thermal gradients, marine effects.
- One of the major deficiencies in the assessment of environmental impacts and in comparison of energy alternatives is the lack of quantitative physical, chemical, and ecological data required for cost and benefit analyses.

Program Implementation

Energy Research and Development Administration

To acquire the information needed for the understanding of the environmental effects of energy technology and resource development, research efforts have been initiated in ten major program areas. As shown on the milestone chart, the ten major program areas are:

1. The land reclamation of coal and uranium mines (e.g., amelioration of land disruption effects in Montana and New Mexico, and acid mine drainage in Tennessee).
2. The evaluation of coal conversion impacts including baseline studies for documentation of environmental effects.
3. The evaluation of oil development. Construction related activities and oil toxicity studies are major areas of research. This effort includes studies of effects, mostly on sensitive coastal zones of offshore oil development on the East and Golf coasts, and to a lesser extent of oil development and transport in Alaska.
4. The determination of the impacts of oil shale mining, retorting, and management of spent shale.
5. The evaluation of physical, chemical, and ecological disturbances brought on by geothermal energy extraction, such as the effect of brine releases. As an example, an air and water pollution research measurement and modeling program has been initiated in the Imperial Valley.
6. The determination of the environmental behavior of radioactive nuclides associated with nuclear fuel cycles, including transport mechanisms and the ultimate fate of the materials. Particular emphasis is on the environmental fate and mechanisms of the transuranium elements.
7. The evaluation of environmental impacts of solar technologies such as the use of ocean thermal gradients for power generation and the efficient use of wind energy. In addition, techniques are being developed to enhance resin production in conifers as an improved source of chemical feedstocks.
8. Conservation of energy by the use of waste heat from energy production facilities for the enhancement of agricultural productivity.
9. The evaluation of transport, transformations, and biological effects of fossil fuel combustion products. A specific example is the Multistate Atmospheric Power Production Pollution Studies Program (MAP3S) which is to determine large-scale energy sources, the atmospheric pollutants generated by these sources, and the broad regional transport and effects of sulfates, nitrogen dioxide, particulates, and trace metals.
10. The determination of the impact of energy-related releases of heat, moisture, and pollutants on local, regional and global weather and climate.

The milestone chart includes ERDA environmental studies only. Research at other federal agencies, being performed to aid in determining or mitigating the environmental impacts of energy development, is summarized in matrix format. An ERDA report* provides more information on these energy related research activities. This report will be updated annually.

* *Federal Inventory of Energy-Related Biomedical and Environmental Research for FY 1974 and FY 1975, ERDA-110,* October, 1975.

OTHER FEDERAL ACTIVITIES IN ENVIRONMENTAL STUDIES

TECHNOLOGY	FOSSIL	NUCLEAR	CONSERVATION	SOLAR/GEOTHERMAL
Agency:	**Activity:**			
DOC	• Determine origin, load, transport pathways, transfer rate and fate of energy related pollutants			
DOI (Fish & Wildlife)	• *Study Western energy* related land and water use problems with —coal extraction and conversion and oil shale • Examine coastal zone impacts from energy development • Develop ecological criteria for energy activities	• *Develop data base on* land and water use problems of uranium mining and nuclear power generation.		• *Study impacts of geo*-thermal facilities on land and water use.
DOI (BLM)	• Minimize surface mining impact through site selection and evaluation of mining plans • Establish baseline and monitor impacts of off-shore oil and gas development			
DOI	• Establish baseline for coal and oil shale lands • Predict effects of surface mining on landscape and hydrologic systems • Monitor impacts of surface mining on federal leased lands • Prepare environmental impact statements • Monitor impact of trans-Alaska pipeline and predict impacts of similar construction	• Identify environmental hazards and constraints on safe siting of reactors • Determine behavior of waste in geologic and hydrologic systems		• Assess the impact of geothermal development on the surface and subsurface environment
EPA	• Determine the nature, distribution, and effects of pollutants from coal and	• Determine effects of thermal discharges on marine forms		

OTHER FEDERAL ACTIVITIES IN ENVIRONMENTAL STUDIES

TECHNOLOGY	FOSSIL	NUCLEAR	CONSERVATION	SOLAR/GEOTHERMAL
Agency:	**Activity:**			
EPA (cont'd)	oil shale in freshwater and marine ecosystems and from petroleum from offshore drilling and oil spills • Evaluate chronic low-level exposure to pollutants • Assess water quality of strip-mined areas and determine reclamation practices • Determine the mechanisms by which primary pollutants from coal, oil and shale are converted to secondary pollutants • Develop techniques for predicting transformation and atmospheric transport of pollutants from coal, oil and oil shale • Determine the transport and biogeochemical cycling of trace contaminants from coal and the sorption of pollutant gases by soil	• Measure thermal effects and fluid mechanics at critical locations in rivers and reservoirs • Assess the radiological impact of power plant releases through evaluation and improvement of current dispersion models		
ERDA	• Assess impacts of surface coal and uranium mines and oil shale development • Evaluate coal conversion impacts • Evaluate effects of offshore oil and gas development, conduct oil toxicity studies • Evaluate transport, transformation and biological effects of fossil fuel combustion products	• Determine behavior, transfer and fate of radioactive species associated with nuclear fuel cycles	• Evaluate beneficial uses of waste heat • Enhance resin production in conifers	• Evaluate physical, chemical, and ecological disturbances resultant from geothermal energy extraction • Evaluate effects of using ocean thermal gradients for power generation
HEW (NIEHS)	• Determine how energy-related hazardous agents affect, are absorbed, distributed, stored, metabolized, and ultimately disposed of by intact marine and terrestrial animal species.			
NRC		• Assess environmental and safety concerns of operating nuclear reactors and nuclear reprocessing plants and disposing of nuclear wastes • Support confirmatory investigations on physical transport of radionuclides		

OTHER FEDERAL ACTIVITIES IN ENVIRONMENTAL STUDIES

TECHNOLOGY	FOSSIL	NUCLEAR	CONSERVATION	SOLAR/GEOTHERMAL
Agency:	**Activity:**			
NRC (cont'd)		critical pathways, and radioecological processes and on ecological and socio-economic impacts of nuclear facilities		
TVA	• Determine chemical interactions of atmospheric emissions from coal fired power plants, especially SO_2, and develop predictive capability • Investigate effects of thermal effluents on the aquatic environment	• Investigate utility of a fish pump to protect aquatic life at Browns Ferry Nuclear Plant		
DOA	• Determine potential physical and socio-economic impacts on mining operations and resultant air pollutants on agricultural, forest, and selected ecosystems • Classify ecosystems on lands subject to mining and develop baseline ecological guidelines for evaluating the adequacy of restoration measures			

ENVIRONMENTAL STUDIES

Federal Energy RD&D Budget (\$ Millions)

Agency	FY 1975		FY 1976 *		FY 1977	
	BA	BO	BA	BO	BA	BO
ERDA						
Operating Expenses	32.8	31.2	43.0	39.3	46.6	43.0
Plant and Capital Equipment	13.1	3.0	2.4	5.7	2.3	6.9
Total	45.9	34.2	45.4	45.0	48.9	49.9
DOI	30.2	28.2	56.0	54.0	63.7	62.4
EPA	19.9	1.8	16.8	15.1	18.4	15.1
NRC	2.3	2.1	9.6	9.1	5.3	5.3
NSF	4.6	2.5	4.8	2.7	5.1	4.4
Total	102.9	68.8	132.6	125.9	141.4	137.1

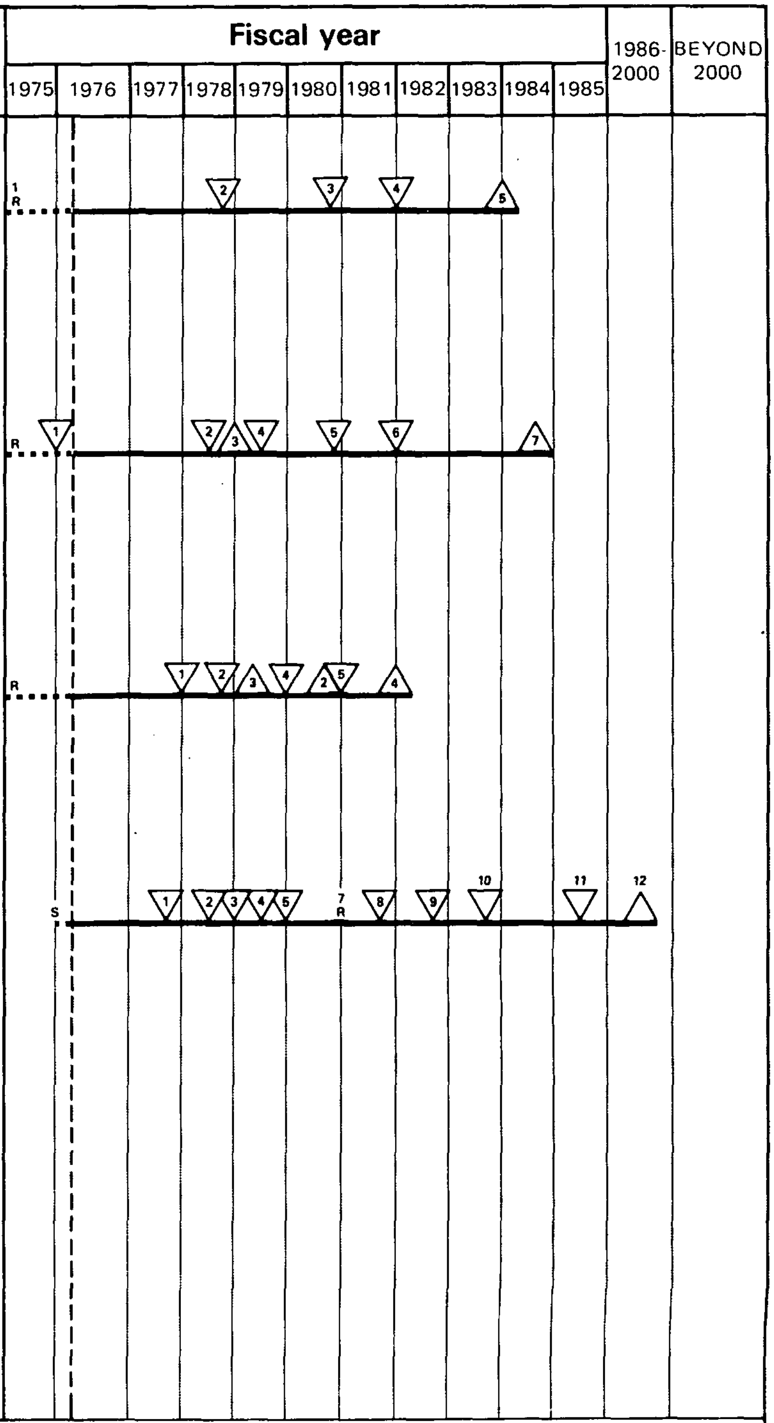
* Does not include funds for FY 1976 Transition Quarter.

ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION

BIOMEDICAL AND ENVIRONMENTAL RESEARCH

ENVIRONMENTAL STUDIES

PROGRAM ACTIVITY



Coal/Uranium Extraction

1—Begin Research on Guidelines on Alternative Land Uses
2—Midwest Data
3—Appalachian Northern Great Plains Data
4—Southwest Data
5—Complete Cost Benefit Data Base

Coal Conversion

1—Initial Baseline Study
2—Synthoil First Screening
3—Complete Baseline Studies
4—Solvent Refined Coal Evaluation
5—H-Coal Evaluation
6—Synthoil Evaluation
7—Synthoil Post-Operation Evaluation

Oil/Gas Extraction, Transport, Processing

1—Alaska Evaluation
2—Oil Toxicity Evaluation
3—Alaska Evaluation
4—Deep Port Study
5—Subsidence Enhanced Recovery

Oil Shale

1—In Situ Report
2—Preliminary Evaluation Stabilization, Rehabilitation of Spent Shale
3—Baseline Pilost
4—Dose/Response at Organism Level
5—Preliminary Operation Major Development Sites
6—Complete Baseline Studies
7—Begin Post Operation Studies
8—Air Pollution Concentrations
9—Preliminary Characterization of Surface Hydrology and Erosion
10—Pollutant Deposition Pattern in Soils and Vegetation
11—Selection of Stabilization and Revegetation Techniques
12—Full-Scale Stabilization of Spent Shale

Key to symbols:

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* Administrative decision point
△ Estimated completion date of program activity
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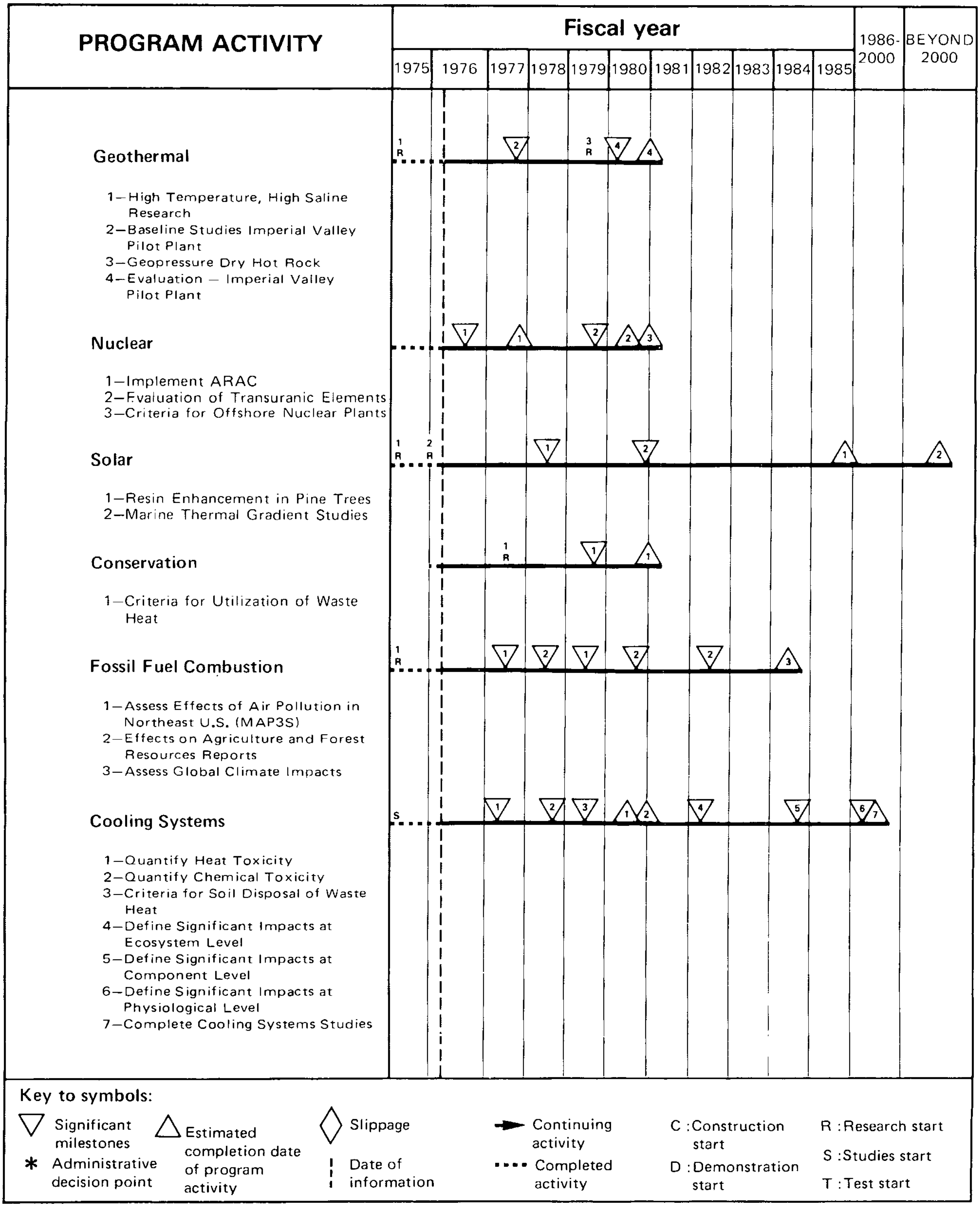
ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION

BIOMEDICAL AND ENVIRONMENTAL RESEARCH

ENVIRONMENTAL STUDIES (continued)



BIOMEDICAL AND ENVIRONMENTAL RESEARCH

Physical and Technological Studies

Objectives

Near-Term (—1985), Mid-Term (—2000) and Long Term (Beyond 2000):

- To characterize, measure and monitor energy-related hazardous agents.
- To obtain a better understanding of the physics and chemistry of pollutant interactions in the environment and in biological systems.
- To develop advanced engineering and instrumentation systems for the characterization, measurement, and monitoring of energy-related pollutants.

Strategy

The characterization, measurement, and monitoring research efforts are in support of the environmental, biological, and health studies building blocks. Characterization projects are undertaken to determine the distributions, concentrations, and properties of potentially hazardous agents associated with energy fuel cycle operations at sites under consideration or where developmental operations are already in progress. Monitoring activities involve the development of improved methods, procedures, and instrumentation for the determination of occupational and population exposure.

Measurement technology projects ensure that adequate measurement tools are available when they are needed for environment and safety purposes and that procedures are developed for the most effective employment of these tools. Projects are carried on to: (1) identify current technology and its applicability in ERDA environmental and safety activities, and (2) develop advanced instruments and systems for which needs and priorities have been established for present and developing energy technologies.

Physical and technological studies provide the basic information on the underlying physical and chemical mechanisms that govern pollutant interactions in the environment. A fundamental understanding of these processes is sought since it is essential to the development of satisfactory pollutant transport models and to the determination of chemical transformation into toxic substances.

These studies provide basic data required for the environmental, biological and health studies. Currently, in line with national priorities, research related to fossil fuel technologies is being emphasized.

Research continues into the physical mechanisms of radiation interaction with biological systems, but the emphasis in this area has been decreased to permit expansion of the fossil fuel effort.

International Cooperation

ERDA staff are participating in international energy-related studies and personnel exchange activities. National laboratory and university staff regularly attend international science colloquia and meetings, spend sabbatical periods in foreign laboratories, and exchange students and postdoctoral appointees with foreign colleagues.

Technological Status and Problems

Status:

- While efforts have been underway for several years to study the chemistry of pollutant interactions with and in the environment, there is an increasingly important need for research into the underlying physical and chemical mechanisms that govern complex pollutant interaction proccesses, such as chemical transformations that occur on the surfaces of particulates and gas-to-particulate conversion reactions. For example, research on the transformation of SO_2, NO_2, NH_3, and trace elements on particulate surfaces produced from coal combustion is needed to define their transformation to chemically toxic substances.

- Baseline monitoring for large-scale geothermal energy development is required before regional expansion of this technology. Methods and instruments for conducting this effort as well as for monitoring the sites after development are not completely developed.
- While radiation detectors are at an advanced stage of development, more sensitive and accurate site and personnel monitoring instruments must be produced, validated and applied for protection of the work force in advanced fuel reprocessing facilities.

Problems:

- Many of the hazardous agents associated with developing energy technologies have not been adequately characterized. This must be accomplished before suitable biomedical, environmental, occupational and environmental control technology research and development programs can be focused on the agents of interest.
- Present instrumentation and techniques to measure and monitor the occurrence and transport of pollutants are not adequate.
- The physical and chemical mechanisms that govern pollutant interactions with and within the environment (e.g., ozone and nitrogen oxides) are not sufficiently well understood.

Program Implementation

Energy Research and Development Administration

Baseline preoperation studies were initiated at the geothermal sites in the Imperial Valley in FY 1976, and will continue. More intensive baseline studies will be initiated at the Raft River site and at the geopressured areas in the Gulf States in FY 1977. Operation characterization and monitoring will start in FY 1977 and continue. Regional baseline and characterization of effluents at the Ames, Iowa, Waste Combustion Plant will begin in FY 1976 and continue for several years.

Development of solid state neutron detectors and neutron and alpha particle personnel monitors and dosimeters will continue to the demonstration stage, now planned for FY 1982–83. Integrated radiation site monitors, an on-going effort, will continue to FY 1978, at which stage they will be transferred to commercial organizations.

Programs were initiated to develop personnel monitors for occupational groups involved in fossil fuel technologies. These efforts are expected to progress to technique demonstration in FY 1978 and to application by FY 1982. In addition, characterization of effluents associated with a true in situ oil shale retort operation was initiated in FY 1976; extension to other oil shale operations is planned. A joint National Laboratory/National Bureau of Standards program to develop Standard Reference Materials and Standard Research Materials for coal conversion and oil shale processes was started in FY 1976. Initiation of a development program in advanced laser spectroscopy for atmospheric monitoring of fossil fuel and geothermal sites occurred in FY 1975 and will be expanded over several years.

Research categorized by other federal agencies as physical and technological studies, primarily supporting energy technologies, is summarized in matrix format. Additional information is contained in the report, *Federal Inventory of Energy-Related Biomedical and Environmental Research for FY 1974 and FY 1975, ERDA–110,* October 1975 This report will be updated annually. The milestone chart depicts ERDA activities only.

OTHER FEDERAL ACTIVITIES IN PHYSICAL & TECHNOLOGICAL STUDIES

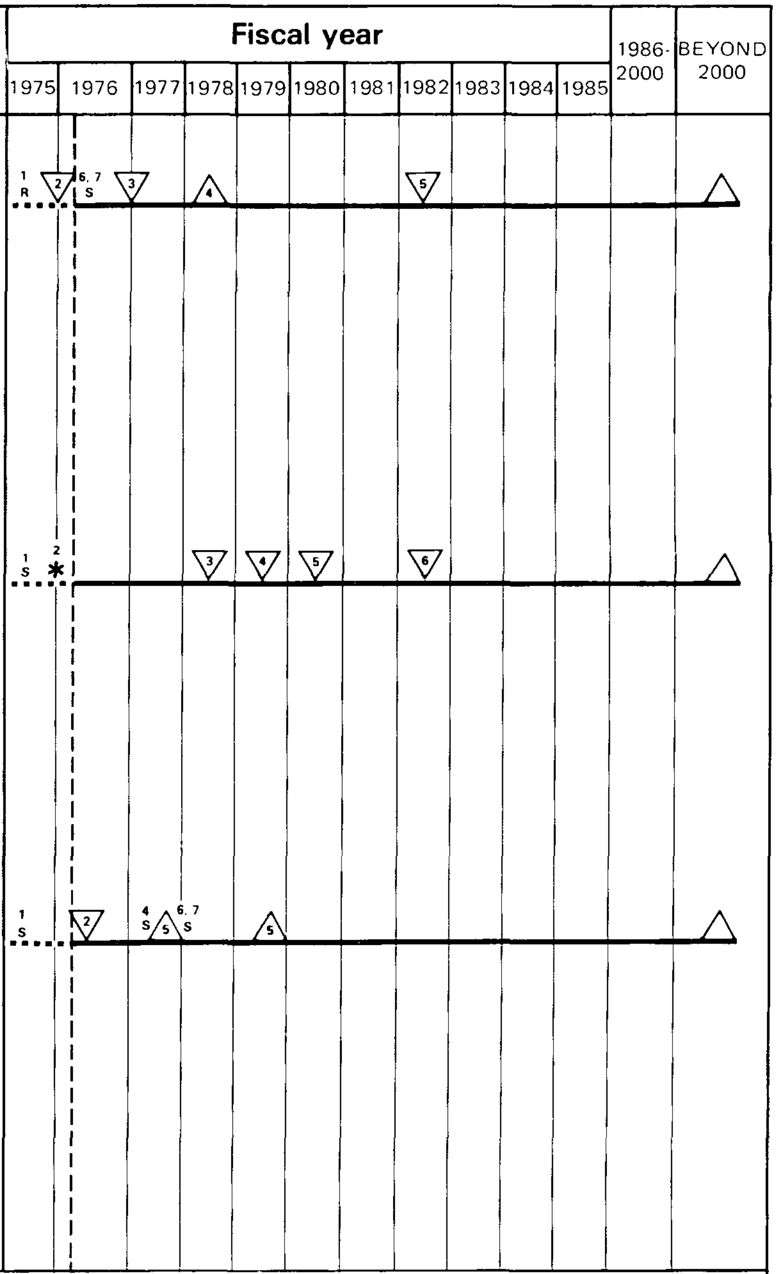
TECHNOLOGY	FOSSIL	NUCLEAR	CONSERVATION	SOLAR/GEOTHERMAL
Agency:	**Activity:**			
DOC (NBS)		• Develop radioactivity and personnel monitoring standards for the nuclear power industry		
DOI (USGS)	• Establish baseline air and water quality data for the western states			• Conduct baseline studies and operational characterization studies at geothermal sites
EPA	• Establish air, water, and land quality base line for: —coal mining and power plants in the Northern Great Plains —oil shale in Colorado, Wyoming and Utah —power plants in Four Corners Area —coal mining in Black Mesa region • Develop air quality models for Western Energy Development, sector and conduct in-situ characterization of power plant emissions • Forecast ocean oil spills and continue shipboard marine monitoring system (with NOAA) • Develop analytical procedures for detection of energy-related pollutants • Atmospheric SO_x (with NASA, NBS) regional effects evaluation (with NASA) crops and vegetation (with TVA) potentially carinogenic organic waste • Provide standard reference material for research related pollutants (with NBS)	• Monitor uranium mining and fuel cycle activities mainly in Western states • Improve radiological monitoring systems and prepare standard reference material		• Develop groundwater methodology and strategy for geothermal energy of California • Assess research needs for EPA establishment of federal standards and of energy-related pollutants including Imperial Valley. guidelines for the geothermal industry under the Clean Air Act, Water Pollution Control Act, and other legislative responsibilities of EPA
FPC	• Develop information on probable environmental impacts of current and proposed policies related to fuel supply and electric power generation			
TVA		• Develop an optimized radiological monitoring program		

ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION

BIOMEDICAL AND ENVIRONMENTAL RESEARCH

PHYSICAL AND TECHNOLOGICAL STUDIES

PROGRAM ACTIVITY



Geothermal

1—Begin Research on Personal Monitors
2—Personnel Monitors – Advanced Concepts
3—Advances in Laser Measurement
4—Personnel Monitors – Baseline Studies
5—Application of Personnel Monitors
6—Characterize True In-Situ Oil Shale Retort Effluents (Rock Springs)
7—Develop Standard Reference Materials, Coal Conversion, and Oil Shale

Nuclear

1—Multi-Site Integrated Monitor Systems
2—Decision on Final Dosimeter Design
3—Technique and Strategy for Implementation of Integrated Site Monitors
4—Technique and Strategy for Human Measurements of Plutonium
5—Improve Solid State Neutron Detectors
6—*Demonstration of Personnel Neutron, Pu- Dosimeters*

Fossil

1—Baseline Studies – Imperial Valley
2—Facility, Site-Specific Pilot Plant Data
3—Baseline Studies
4—Start Raft River Baseline Studies
5—Raft River Baseline Studies
6—Operational Characterization Imperial Valley
7—Baseline Studies in Geopressured Areas

Key to symbols:

- ▽ Significant milestones
- * Administrative decision point
- △ Estimated completion date of program activity
- ◇ Slippage
- ¦ Date of information
- ➔ Continuing activity
- •••• Completed activity
- C : Construction start
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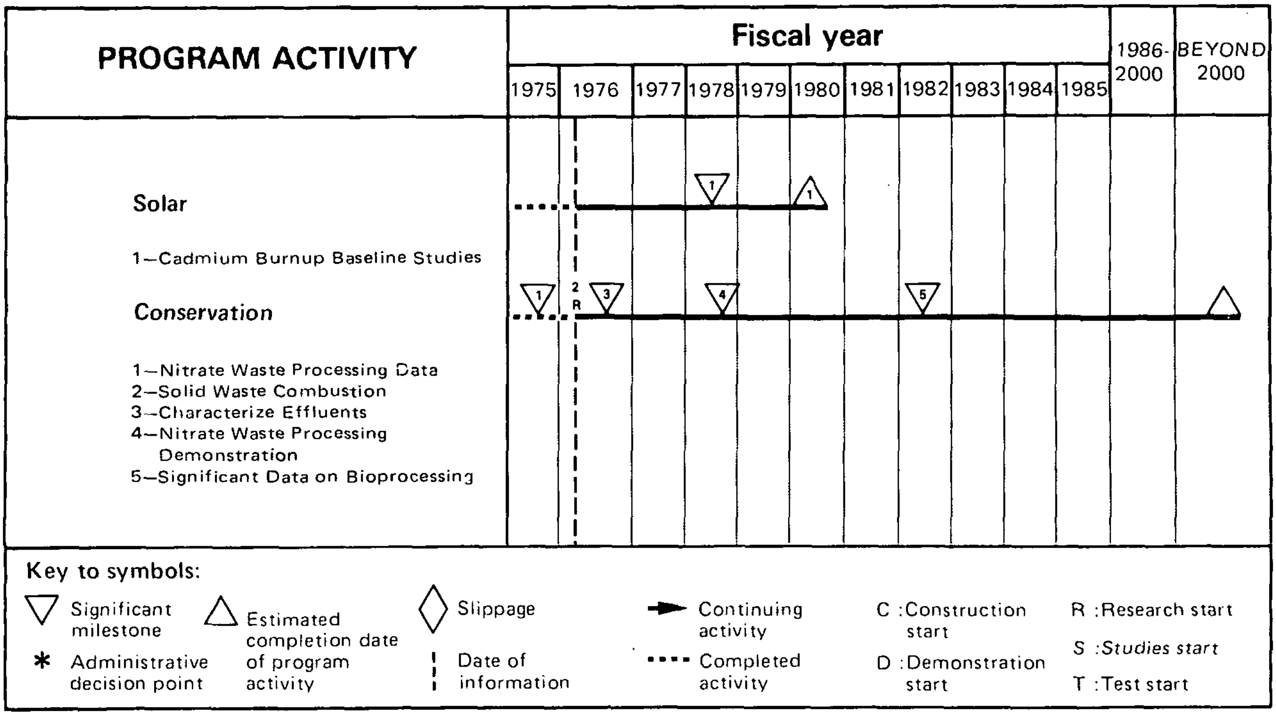
ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION

BIOMEDICAL AND ENVIRONMENTAL RESEARCH

PHYSICAL AND TECHNOLOGICAL STUDIES (Continued)



PHYSICAL AND TECHNOLOGICAL STUDIES

Federal Energy RD&D Budget **($ Millions)**

Agency	FY 1975		FY 1976 *		FY 1977	
	BA	BO	BA	BO	BA	BO
ERDA						
Operating Expenses	14.2	12.2	17.4	15.1	17.8	17.1
Plant and Capital Equipment	1.0	0.9	1.2	1.2	1.3	1.3
Total	15.2	13.1	18.6	16.3	19.1	18.4
EPA	10.4	0.7	8.6	7.2	8.2	7.2
NSF	4.0	2.3	4.0	2.7	4.0	3.5
Total	29.6	16.1	31.2	26.2	31.3	29.1

* Does not include funds for FY 1976 Transition Quarter.

BIOMEDICAL AND ENVIRONMENTAL RESEARCH

Assessments

Objectives

Near-Term (—1985), Mid-Term (—2000) and Long-Term (Beyond 2000):

- To analyze relationships among environmental, health, technical, economic and societal factors and regulations as they may affect energy RD&D policy decisions, or affect commercialization of developed energy systems.
- To ensure, on a continuing basis, adequate emphasis on environmental, health, and safety considerations in formulating and implementing ERDA energy technology decisions, plans, and programs.
- To assure that all ERDA Environmental Impact Statements (EIS) and supporting documents are accurate, complete and consistent in the treatment of the environmental issues, and provide independent judgment regarding cost/risk/benefit acceptability.
- To provide integrated assessments for program guidance of the health, environmental, social, economic, and cultural consequences of energy development alternatives and to suggest strategies for implementation and approaches for mitigation of environmental impact.

Strategy

Four functions comprise the Environmental and Safety Assessments: policy analysis, overview management, EIS monitor and review, and integrated assessment.

The environmental policy analysis activity will examine health, safety and environmental regulations, energy development policies, and economic conditions as a basis for identifying environmental, health and safety policy issues which affect R&D policy decisions or commercialization of energy systems. Issues will be selected for analysis by the ERDA Assistant Administrator For Environment and Safety (AES) based on multi-agency contacts.

Issues will be analyzed through identification of the information base, examination of assumptions, and a comparison of objectives. Recommendations will be made as to alternative sources or methods for obtaining technical information, as well as the need for a reexamination of policies or regulations, where appropriate. The analysis of issues and alternatives will be made available to affected programs throughout ERDA for consideration in making decisions on R,D&D and commercialization efforts. ERDA will work closely with other federal agencies and utilize its scientific and technical expertise, including the resources of the national (multi-program) laboratories, in the selection and analysis of issues, validation and review of analyses.

- The ERDA environmental planning process is supported by a new overview management function which will provide a program level focal point for coordination of ERDA environment, health, and safety activities internally and with other federal agencies, for liaison with state and local governments, industrial and international organizations, and for exchange of environmental information and views with the public. Research needs and gaps in the energy technology programs related to meeting ERDA environmental requirements will be defined through reviews and assessments of research and energy technology programs. Procedures are being established to assure compliance with ERDA environmental requirements during project design, construction and operation.
- A Federal Inter-agency Energy-Environment R&D Program is in operation with 17 participating agencies. The primary vehicle for integrating the results of this program and satisfying research objectives is a series of major Integrated Technology Assessments which evaluate alternative energy technologies and approaches for implementing energy development, preventing environmental damage, and securing related

benefits. These assessments will aid in identifying gaps in present research programs and indicating new priority research topics which must be addressed in order to support direct agency and program responsibilities.

- An EIS monitoring and review function supports the ERDA environmental planning process through implementation of a formal approval cycle for all ERDA EIS's. Proper depth and timing of the review process will be assured by evaluating the material within all ERDA EIS's during preparation. Emerging issues are identified and analyzed to provide timely review for inclusion of key environmental concerns.
- Within ERDA, environmental assessments and statements are the basic means for factoring environmental considerations into decisions on competing technologies, processes, or geographic locations.
- Integrated assessments provide information to support the environmental planning process and furnish a critical input to policy analyses. Integrated assessments include information integration, socio-economic processes and effects, bioenvironmental impacts, and trade-off analyses. Information integration collects, manages, and compiles information on energy production processes, requirements, strategies and effects supported by development of a comprehensive data management system. Efforts in the social processes and effects area seek to interpret social, economic, and cultural implications of the environmental effects of energy production and pollution control as well as to assess public opinion regarding environmental acceptability. Bioenvironmental assessment includes the evaluation of information on health and ecological effects, and the environmental effects induced by socio-economic change. Trade-off analyses will be performed to evaluate costs, risks, and benefits of energy production and pollution control alternatives.

International Cooperation

ERDA staff are participating in international energy-related studies and personnel exchange activities. National laboratory and off-site contractor staff regularly attend international science colloquia and meetings, spend sabbatical periods in foreign laboratories, and exchange students and postdoctoral appointees with foreign colleagues.

Technological Status and Problems

Status:

- The Federal Inter-agency Energy/Environment R&D Program is involved in providing viable solutions to the technological problems through Integrated Technology Assessment. Two assessments are underway dealing with Western Section energy development, and Electric Utilities Sector development. A third assessment now being planned will evaluate impacts related to expansion of electrical generation and production of synthetic fuels from coal in the Ohio River Basin.
- ERDA has initiated a National Coal Assessment which will determine the impacts of increased coal utilization and the consequences of alternative technology options as a function of geographical distribution.

Problems:

- The quality and validity of the integrated assessments depend upon the adequacy of the data bases available within all federal agencies and the methodology to qualify the many-faceted elements involved. Data management systems and data bases exist at the federal level but are generally inadequate for this purpose.

Program Implementation

Energy Research and Development Administration

Environmental Policy Analysis

- Critical environmental policy issues that may have significant effects on ERDA programs will be identified and studied in FY 1977. Specifically, ERDA plans to examine policy considerations in the area of toxic pollutants, toxic substances, water quality criteria, air quality and radiation protection standards. Initial analyses of their impact on energy program and policy decisions will be developed.
- Capabilities for policy issue development and analysis will be established in public and private sector organizations that specialize in policy studies, and within the ERDA inventory system, in order to support this activity.

Overview Management

- Planning for the overview coordination and liaison activity will be completed by the end of FY 76. Technical liaison agreements will be established internally and with agencies such as EPA, DOT, DOI, and DOC for system monitoring, data interchange, coordination on standards/criteria and RD&D support. Plans will be included for liaison activities with state and local governments and with industrial and international organizations. Negotiations of interagency memoranda of agreement for the necessary interfacing activity will be completed by mid-FY 77.

- The internal review of all environmental and program planning documents will be coordinated by overview management. Requirements will be established early in FY 77 for Environmental Development Plans which identify and plan resolution of environmental issues for each energy technology.
- A regular series of publications and seminars will be instituted in FY 1977 dealing with environmental activities, progress, and problems on each ERDA energy technology RD&D project. The location of annual seminars will reflect those regions most likely to be affected by potential technology development. Consumer information dissemination will be centralized in overview management in FY 1978.

EIS Monitor and Review

- Procedures for the EIS monitoring portion of the environmental planning process, including EIS preparation guidelines, will be established early in FY 1977. These procedures include a critical review meeting cycle, a method for assuring interchange of information on EIS's from similar projects, and technique to identify emerging issues during EIS preparation with the concomitant need for independent analyses. Guidelines will be updated in FY 1978 based on experience with the environmental planning process.
- Implementation of the EIS review and approval cycle will be maintained.

Integrated Assessments

- A technical requirements document will be generated anually to establish assessment priorities consistent with ERDA plans as a basis for planning of assessments.
- A technical information system for the AES to collect, manage and disseminate environment, safety, and other assessment data for use in EIS and environmental planning documents within ERDA is planned for operation by the end of FY 1978. As an element of the current work, Lawrence Livermore Laboratory is engaged in a survey of over 16,000 energy and environmentally-related data bases and computational models and will compile this material into a National Index. Output from this program would provide an initial appraisal of the available information in FY 1976; further work would provide final input to the operational system in FY 1978. Other activities are planned to enhance the capability to manipulate, synthesize, and share the very large regional and generic assessment data bases by taking advantage of operating and evolving networks.
- Integrated Assessments at the national and regional level to determine the cost/risk/benefit trade-offs of planned or projected primary or alternate energy development will be conducted in the four major technology areas: fossil fuels, nuclear solar/geothermal, and conservation. The principal study agencies will be seven National Laboratories: ANL, BNL, ORNL, LASL, LLL, LBL, and PNL. National level studies will be a cooperative, planned program effort of the laboratories and will utilize the results from on-going national laboratory regional studies programs. Considerable knowledge of the impacts associated with energy development has been accumulated through detailed case studies of specific developments, and regional studies involving siting and biomedical/environment assessments. Appraisal of assessment status for each technology is now underway. Work in methodology to support these studies will be accomplished in FY 1976 and 1977 and reports will be issued as studies of local, regional, and national scope progress to completion. The results of these studies form the base case for each technology within the study region. The National Coal Assessment is the first large-scale study of this type.
- Evaluation of energy development alternatives will be made based on national level scenarios which provide the focus to extrapolate and compare their costs, risks and benefits. An initial appraisal of the current status will be completed in FY 1976. Methodology for generating alternate energy development approaches, including the effects of technical, legal, and environmental controls will be finalized in FY 1977. Recommended alternate approaches, further RD&D

needs, and standards/policy revision will be reported for the local/regional and regional/national levels in FY 1978 and 1979, respectively. As conditions and available alternatives/options change, these integrated studies will be updated to reflect the new conditions so that current information will be available for decisions makers.

The milestone chart summarizes ERDA activities in integrated assessments. Specific milestones for the new functions of environmental overview management and environmental policy analyses are under development. The integrated assessment activities of other federal agencies are summarized in matrix format. An ERDA report, *Federal Inventory of Energy-Related Biomedical and Environmental Research for FY 1974 and FY 1975, ERDA–110,* October 1975, provides more information on energy-related assessment activities. This report is updated annually.

OTHER FEDERAL ACTIVITIES IN ASSESSMENT

TECHNOLOGY Agency:	FOSSIL Activity:	NUCLEAR	CONSERVATION	SOLAR/GEOTHERMAL
DOI	• Assess coal and oil-shale mining related hydrological problems and water-control measures in specific situations • Model physical and social impacts of western coal developments			
DOC	• Investigate impacts of petroleum importation and outer continental shelf development			
EPA	• Examine interactions between public and private sectors in assessing and mitigating environmental impacts and identify R&D and commercial gaps. • Evaluate environmental impacts of both energy-related and non-energy-related activities as a basis for determining necessary standards and control measures. • Disseminate information which has been developed on the costs, benefits, and risk of energy activities through symposia, manuals and conferences. • Evaluate existing regional studies in order to correlate health effects with ambient pollutant levels. • Coordinate the design of a national environmental R&D information system. • Develop economic projection models, electric power system models and computer simulations of site specific environmental impact data. • Evaluate economic, social, and cultural consequences of coal and oil shale development.			
FPC	• Develop more effective procedures for identifying environmental impacts of energy facilities			
TVA	• Develop computer model to predict residual outputs from the power system on a plant/plant basis			
WRC	• Assess water requirements and supply availability • Identify water and land resource problems on a state/regional basis			
DOA	• Evaluate costs of alternative reclamation technologies and uses of mined land • Assess current coal and oil shale resource use • Determine the impacts of energy development on employment, income, population, local government and services • Assess impacts of site selection on land and water resources and prepare guidance for state and local authorities on methods of mitigating impacts			

ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION

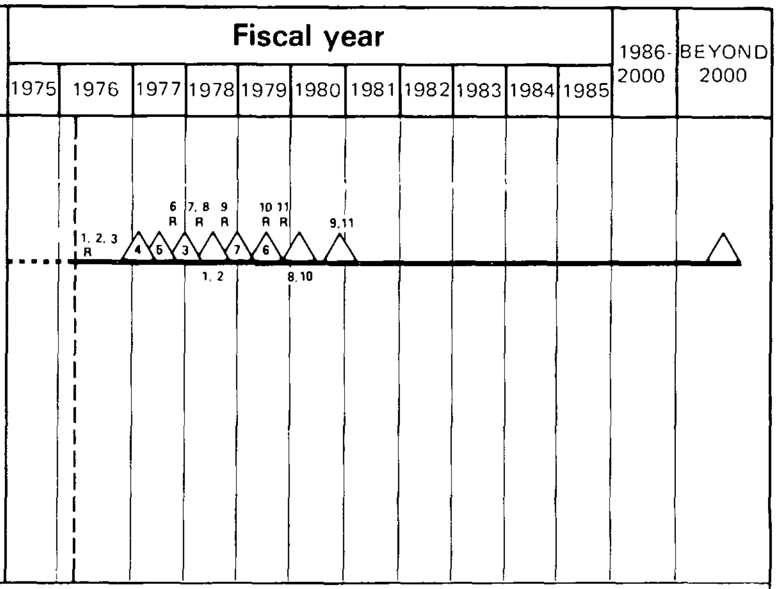
BIOMEDICAL AND ENVIRONMENTAL RESEARCH

ASSESSMENTS

PROGRAM ACTIVITY

Regional/National Assessments

1—Scenario Program
2—Integrated Coal Assessment
3—Integrated Geothermal Assessment
4—Technology Assessment Plans
5—Interim Assessments of Solar, Conservation, Nuclear, and Shale Oil Technologies
6—Oil/Gas Integrated Assessment
7—Shale Oil Integrated Assessment
8—Interfuels Comparison Assessment
9—Nuclear Integrated Assessment
10—Conservation Integrated Assessment
11—Solar Integrated Assessment



Key to symbols:

- ▽ Significant milestones
- ✱ Administrative decision point
- △ Estimated completion date of program activity
- ◇ Slippage
- ¦ Date of information
- ➡ Continuing activity
- •••• Completed activity
- C : Construction start
- D : Demonstration start
- R : Research start
- S : Studies start
- T : Test start

ASSESSMENTS

Federal Energy RD&D Budget **($ Millions)**

Budget Item	FY 1975		FY 1976 *		FY 1977	
	BA	BO	BA	BO	BA	BO
ERDA						
Operating Expenses	7.1	6.0	11.6	11.3	19.0	16.7
Plant and Capital Equipment	0.2	0.2	0.2	0.2	0.3	0.3
Total	7.3	6.2	11.8	11.5	19.3	17.0
DOI	3.0	2.7	3.0	2.7	3.1	2.8
EPA	4.1	1.3	4.1	3.8	4.0	3.8
Total	14.4	10.2	18.9	18.0	26.4	23.6

* Does not include funds for FY 1976 Transition Quarter.

BASIC ENERGY SCIENCES EXECUTIVE SUMMARY

Objectives

Near-Term (–1985), Mid-Term (–2000) and Long-Term (Beyond 2000):

This program carries the responsibility for basic research in the physical sciences that underlies all energy technologies. Experience shows that the energy technologies in use today could not have been developed without scientific discoveries made decades earlier. It is therefore a sound conclusion to expect, along with shorter term benefits, that energy development beyond the year 2000 will depend on discoveries that will be made in the basic energy sciences.

The primary purpose of the Basic Energy Sciences (BES) program is to increase knowledge of the physical phenomena relevant to the goal of meeting our nation's energy needs. The steady accumulation of information and understanding of the properties of matter lead to new capabilities for industrial energy generation and utilization. Occasionally, basic research uncovers a totally new phenomenon (like magnetically-hard superconductors) that revolutionizes established techniques.

A further objective is to develop advanced computational methods, instrumentation and techniques useful in energy development programs. Particle accelerators and neutron beams from reactors, for example, are now widely used by technology.

The BES program also attempts to anticipate possible barriers or limitations to technological development. Comprehensive research programs are then proposed to provide the basis for the solution of clearly foreseeable problems.

National Energy Technology Goals Supported

Primary

- Perform basic and supporting research and technical services related to energy.

Strategy

The disciplines of physics, chemistry, metallurgy, engineering, ceramics, geology and mathematics are used to provide the present basis for and anticipate future needs of advanced energy systems.

Those scientific topics, institutions and people having the potential for gathering new knowledge will be supported, including universities where outstanding scientists are working in fields relevant to energy research. Federal agencies and laboratories will investigate complex problems that require sophisticated, specialized research facilities and the talents of scientists in several fields. Often, a multidisciplinary approach with basic and applied components is needed to optimize progress. The topics of research range from those with immediate applicability to those of long range promise. Many problems in fossil, nuclear, solar, geothermal, and energy conservation have common origins; Basic Energy Sciences looks for common solutions.

The research facilities developed under the Atomic Energy Commission and those of other agencies are being brought to bear on energy related projects. New facilities are being designed and constructed to maintain the ability to provide excellence in research capability. Industrial participation is to be sought, when feasible and scientifically competitive, in order to generate future-oriented industrial capabilities.

University skills are particularly important for research in the Basic Energy Sciences. The BES program currently provides more direct support for research at universities than any other ERDA program. Strong report for energy-related research at universities will be continued.

The BES program maintains close relationships among federal agencies in order to develop jointly the strongest possible national program in basic physical science. International cooperative projects also present opportunities for mutual advancement in fields important to energy objectives.

As a continuing effort, scientific areas critical to rapid progress in energy development are selected for intensive review, the research needs are assesssed jointly with other ERDA programs, and BES program priorities are adjusted accordingly.

Federal Role

Research in areas important to energy technologies constitutes a long-term investment in national economic and technological strength. Although industry participation is encouraged, few private organizations can justify the high risk associated with these costly long-term research ventures. Therefore, the federal government must assume the major responsibility for supporting this research in the interest of current and future national needs.

Technical liaison and cooperation are fostered through individually negotiated case-by-case personnel exchanges and cooperative efforts between U.S. National Laboratories and foreign laboratories, primarily in Western Europe but including those in the U.S.S.R. Research results are exchanged through open literature publications and presentations at international meetings. The subprograms have also sponsored international meetings on such topics as low temperature physics, radiation effects, rapidly quenched materials, superconductivity, and hydrogen in metals. These meetings have world-wide attendance. Cooperation among four neutron data centers (Brookhaven, Saclay, Vienna and Obninsk) has been in effect for a number of years through an agreement worked out by the International Atomic Energy Agency. Programs of cooperation in basic research related to peaceful uses of atomic energy are carried out under the U.S.-U.S.S.R. Agreement of June 21, 1973.

Environmental Status and Problems

Fission reactors and particle accelerators used in research do have potential radiation hazards. However, an excellent record of radiation containment and safety has been achieved at all ERDA-BES research facilities due to shielding design and to radiation monitoring programs of the health physics groups at each institution. Solutions to energy-related environmental problems have often emerged from BES sponsored research.

Program Implementation

The research program balances the needs of a particular energy technology with the general development of physical and mathematical sciences. The following table shows the distribution of assignable fractions of the BES operating expenses to the technical areas. Advances in one technology area are often equally important to several other areas.

Energy Technology	FY 1976	FY 1977
General	54%	49%
Fission	19	16
Fusion	9	9
Conservation	7	8
Fossil	5	8
Solar	4	6
Geothermal	2	4
	100%	100%

The increased emphasis on non-nuclear areas (from 18 to 26%) is indicative of the special needs in these areas and of the continuing evolution of the BES program.

The program is kept responsive to developing research needs by continual review and evaluation of ongoing work and new proposals. Communication among managers and researchers directly responsible for specific technology development and demonstration is carried on by a variety of techniques. BES sponsors special topical conferences of interest to many federal development programs and private industry. Discussion between basic and applied researchers within multi-program ERDA laboratories helps spread research results with identify problems. Dialogues are maintained among programs to assure research relevance, avoid gaps and overlaps in programs, and maximize effectiveness in use of existing laboratory capabilities.

Research participation assignments will continue to be made to university-based faculty and students at ERDA laboratories and contractor facilities. This helps maintain fresh ideas and productive interaction between participants and laboratory research staff. This category of activity serves all areas of energy research of interest to ERDA. Coordination with other manpower programs is provided by the Office of University Programs.

The following pages give a detailed view of each subprogram's objectives, status, problems, and methods of implementation of specific objectives.

BASIC ENERGY SCIENCES

Federal Energy RD&D Budget

($ Millions)

Agency	FY 1975		FY 1976*		FY 1977	
	BA	BO	BA	BO	BA	BO
Materials Sciences	69.6	58.6	76.0	64.9	104.3	81.1
Molecular, Mathematical and Geo-sciences	103.0	80.7	118.2	92.1	127.7	114.7
Nuclear Sciences	102.0	80.5	110.0	92.5	95.8	96.2
Total	274.6	219.8	304.2	249.5	327.8	292.0

* Does not include funds for FY 1976 Transition Quarter.

BASIC ENERGY SCIENCES

Materials Sciences

Objectives

Near-Term (–1985), Mid-Term (–2000) and Long-Term (Beyond 2000):

- To advance the understanding of matter in the condensed state to provide a foundation for improving materials technology and for uncovering new materials options in areas associated with energy.
- To identify deficiencies in existing materials which impose serious limitations on energy technologies; to conduct research to determine the reasons for the deficiencies, and to propose pathways for the development of urgently needed superior materials.

In support of this goal to perform basic research related to energy, the program in this area will specifically:

1. Conduct research to provide basis for the solving of materials problems.
2. Maintain a broad program to provide for the prediction or solution of energy-related materials problems not yet anticipated that past experience has shown invariably develop in the evolution of advanced technologies.
3. Proceed in an interdisciplinary way to increase knowledge of materials and to lead the way to new avenues and approaches to the solution of longer-term materials-related energy problems.
4. Conduct an ongoing program to develop instrumentation and measurement techniques essential to gaining an increased knowledge of materials.

Technological Status and Problems

Status:

Greater attention is being given to strengthening basic materials research important to solar, geothermal, fossil and conservation technologies. These latter areas previously have not received the focused attention commensurate with their newly emerged importance to the national economy. Benefits can be anticipated similar to those provided the nuclear technologies—e.g., the development of ion simulation techniques to study radiation damage and the discovery of low swelling alloys for the breeder reactor programs. Research on superconductivity is of immediate benefit to power transmission and energy storage technologies.

- With the increase in understanding of properties and phenomena in relatively simple materials systems, the time is now ripe to progress into more complex phenomena and materials—to apply this understanding to materials processes and phenomena of engineering significance.
- Engineering materials science must receive increased attention to facilitate the application of the emerging understanding of fundamental concepts to materials problems such as nondestructive evaluation, erosion, welding, forming, joining, and corrosion.

Problems:

- Every energy concept has materials problems critical to engineering or economic feasibility. As examples, fossil and geothermal technologies have severe problems in erosion and corrosion, MHD and gas turbine technologies need higher temperature materials, solar technologies require materials with improved optical and heat transfer properties, and all technologies need materials with improved fracture resistance. Across the board, a more thorough and deeper understanding is needed of the behavior of materials.
- The capabilities of current facilities need augmenting for addressing a number of critical scientific questions involving, for example, the behavior of materials as revealed by scattering

of neutrons and electromagnetic radiation. This translates into the need for new, more complex instrumentation and the construction of new, more intense sources of neutrons and electromagnetic radiation.

Institutional Status and Problems

Status:

- Continuing attention must be given to assure adequate levels of interaction between basic and applied researchers in different, as well as within, performing institutions. Special attention is needed on interactions with workers in fossil, geothermal and solar energy and energy conservation programs. Materials sciences research is performed in large part in multidisciplinary laboratories. They uniquely have extensive breadth and depth in scientific talent, back-up services, and facilities which enable them to perform research on complex problems which cannot be effectively performed elsewhere.
- Support of research projects at universities will remain an important part of this program, both for the oustanding research contributed by these projects and for the important linkages provided, for example, by the graduate students employed on these projects who later enter into applied energy research and development. Industrial and not-for-profit institutions have not played a significant role in the basic materials sciences except in limited, narrowly defined areas because of shorter-term motives.

Problems:

- A significant fraction of the developmental activities in the nuclear technologies take place in the national laboratories contiguous to and coupled with basic materials sciences research. Transfer of information about technological needs and new scientific findings and techniques is thereby facilitated. As the focus of the development of other energy technologies is directed into other institutions not as adequately equipped to pursue and appreciate basic science, other means to facilitate this information transfer process will require strengthening, and it will be necessary to identify and support meritorious basic research talent at these institutions.

Program Implementation

Energy Research and Development Administration

Lack of understanding of certain important materials phenomena and properties limits essentially all energy technologies. This subprogram is concerned with understanding the critical phenomena and properties and approaches to overcome both presently known problems and those now unanticipated. It is oriented toward science rather than technology. Specialties identified of particular importance to development of advanced energy systems include: high temperature materials and thermodynamics, strength and fracture, structure-property relationships, neutron scattering as a probe for studying materials properties, superconductivity, interaction of radiation and matter, erosion and corrosion, the chemistry and physics of surfaces, diffusion, optical, magnetic, electronic, and thermal properties. The Materials Sciences subprogram provides guidance and input to ongoing applied materials programs, a strengthened foundation for planning future materials development programs, tentative solutions or models for unanticipated materials problems, and new materials for future applications.

Close cooperation with the applied programs is essential so that engineers will be aware of the latest findings in materials sciences research and research, and research scientists will be aware of applied problem areas and how they may contribute to solutions. To the extent possible, research will be conducted contiguous to applied efforts to maximize the two-way transfer of information. Basic materials sciences research will be supported in large multidisciplinary laboratories, universities, not-for-profit institutions and industry—wherever outstanding basic science talent can be identified.

Research results will be broadly disseminated by means of reports, open literature publications, and topical and program information meetings. Joint meetings will be sponsored frequently by this subprogram on topics such as fusion, ceramics, radiation damage and superconductivity to examine applied materials problem areas and assist in developing subprograms. One on stress corrosion cracking is planned for 1976. Additional work in scientific areas of importance to fossil, solar, and geothermal energy development and to energy conservation is needed to provide a balanced research program. Emphasis on new non-nuclear areas must be weighed carefully against the needs of continuing efforts, including the strong need for materials research supportive to fission and fusion concepts.

Department of Interior

Within the DOI, the Geological Survey conducts research on the geologic availability of materials necessary for energy development. Research programs on materials availability include 1) resource assessment, 2) commodity estimation and analysis, 3) mineral resource technology development, and 4) mineral resource information analysis systems. The efforts are being implemented to provide the following:

Resource Assessment. To obtain up-to-date systematic geologic information on identified and potential mineral resources on federal lands of immediate legislative concern as well as on non-federal lands, three levels of resource assessment—ranging from general inventory of existing knowledge to broad area reconnaissance field examination, to detailed mining districts studies—are designed to meet required information needs. Near-term emphasis is on the search for new sources of non-energy minerals required for energy production and uranium as a fuel.

Commodity Estimation and Analysis. The program obtains knowledge about geologic availability and location, distribution, quantity and quality of specific minerals on both an aggregate as well as disaggregated basis. Primary emphasis has been on the following mineral commodities: Al, Cr, Pt, Fe, Ni, Mn, Zn, Sn, Ti, Co, Hg, W, Nb, U, F, and Cu. Mineral specialists maintain and analyze the world commodity resource files, make periodic estimates of mineral availability, develop and update new concepts for assessment and identification of domestic and overseas sources of those materials.

Mineral Resource Technology Development. The program provides backup R&D support that is required to improve present competence as well as to improve resource assessments, commodity estimations, and to locate new ore deposit targets.

Mineral Resource Information Analysis Systems. Research is underway to develop automatic data processing programs and techniques to store, retrieve, and process large amounts of resource information, to use mathematical models for complex interactions of geology and economics, and to determine their continuing impact on mineral supply and demand as well as search and occurrence prediction. For instance, the critial resource data file (CRIB) has been international in scope and is growing; it soon will be publicly available through the University of Oklahoma and other supporting computer programs provide access to geologic data and the effective use of mathematical models.

Other Federal Agencies

Research in materials sciences related in part to the ERDA and DOI programs described here is carried out by a number of other federal agencies, especially DOD, NSF, and NASA. The efforts are coordinated through the Committee on Materials, a standing committee of the Federal Council for Science and Technology.

MATERIALS SCIENCES

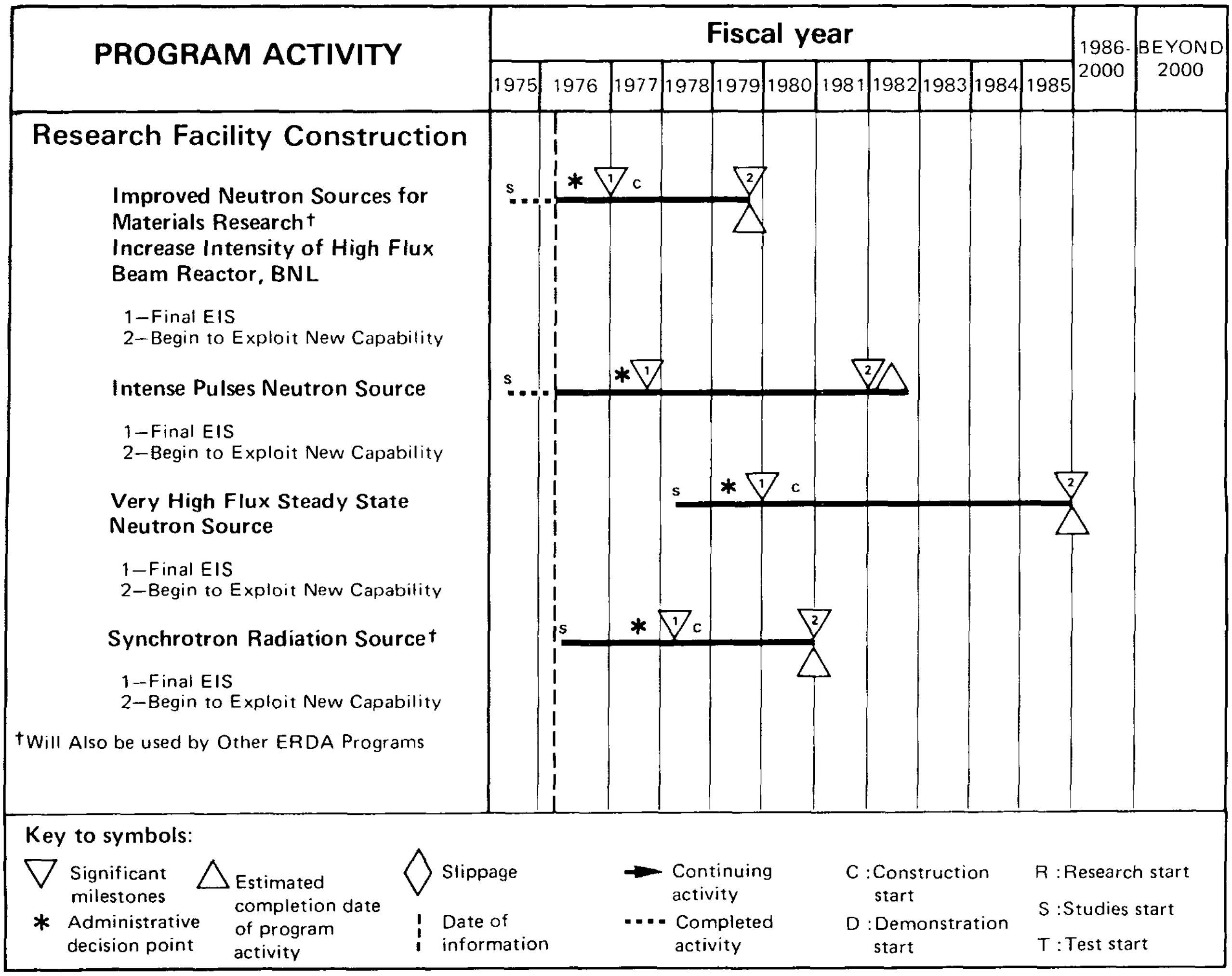
Federal Energy RD&D Budget **($ Millions)**

	FY 1975		FY 1976*		FY 1977	
Agency	BA	BO	BA	BO	BA	BO
ERDA						
Operating Expenses	40.9	39.8	46.3	44.0	51.1	48.7
Plant and Capital Equipment	7.0	4.6	6.6	5.8	26.6	9.3
Total	47.9	44.4	52.9	49.8	77.7	58.0
NSF	21.7	14.2	23.1	15.1	26.6	23.1
Total	69.6	58.6	76.0	64.9	104.3	81.1

* Does not include funds for FY 1976 Transition Quarter.

ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION

MATERIALS SCIENCES



BASIC ENERGY SCIENCES

Molecular, Mathematical and Geo-sciences

Objectives

Near-Term (–1985), Mid-Term (–2000) and Long-Term (Beyond 2000):

Molecular Sciences:

- Develop basic understanding, new empirical and theoretical insights, new concepts and innovations in molecular, atomic and ionic processes pertinent to all energy development programs, especially those in which processes are important.
- Identify and resolve deficiencies in knowledge of chemical structure, reaction mechanisms and catalytic and other phenomena that limit options in fossil, geothermal, fusion and solar energy technologies.
- Conduct engineering sciences programs to improve the transition from scientific advances to technological applications in energy processes.
- Collect scientific data and conduct laboratory scale demonstrations of new energy technology-related processes.

Mathematical Sciences:

- Develop new and improved methods for solving mathematical problems which arise in energy research and for increasing the usefulness, efficiency and reliability of computer systems.

Geo-Sciences:

- Improve understanding of geologic systems and behavior relevant to large-scale energy operations in the earth and on its surface.
- Develop and field test geophysical techniques and instrumentation to increase the knowledge for assessment of geothermal energy resources.

Technological Status and Problems

Status:

- These three research areas, the principal process-oriented sciences, have advanced to a level of understanding at which scientists could recently show, for example, the possibility of making absorbers for sulfur dioxide which are easily and quickly renewable, identifying the key hot chemical species and temperature profiles in selected locations in flames, and designing more efficient turbine blades for supersonic operation. Many other advances have been occuring. Thus progress is being made toward the deeper understanding of chemical and physical processes needed in new systems and concepts and in improving efficiencies and environmental cleanliness of energy production, storage and use.

Problems:

- An example of needs for knowledge impacting the energy-environment interface is in coal conversion where the processes are likely to result in highly toxic substances. Their identification, elucidation of their properties, their control and degradtion by chemical and biological means, therefore, must have a stronger basis in the types of understanding that result from these research efforts. Similarly, in order to avoid delays in energy developments caused by insufficient understanding of processes and phenomena, a serious acceleration of research must occur in molecular, atomic, ionic, plasma and geologic processes, engineering sciences and the mathematical and computer sciences. All of these are strongly interwoven in energy process development and the discovery of new concepts.
- The capabilities of existing facilities are in need of augmentation for addressing a number of critical scientific questions. Scientific equipment needs are critical, including both new kinds of capability and upgrading of outdated instruments. Vital to these advanced research efforts is modern research equipment such as mass

spectrometers, ion-microscopes, magnetic resonance spectrometers, scanning electron microsopes, minicomputer systems, lasers, shocktubes, etc. Field work in the geo-sciences calls for drilling many holes to great depths and requires remote instrumentation.

Institutional Status and Problems

Status:

- There are now in use several means of assuring good input by this basic research effort into advancing energy technologies.
- Communication with industrial laboratories and university researchers takes place regularly in the ERDA program. Agency staffs maintain frequent contacts for the same purpose. Basic researchers in the molecular, mathematical and geo-sciences are associated with applied researchers and engineers in the major laboratories, enabling frequent exchanges on new technological opportunities opened by basic research and scientific barriers encountered in technology development programs. Topical conferences and seminars at laboratories and meetings of scientific societies further facilitate this kind of communication.
- All of these channels of comunication raise the possibility of recognizing uses of new scientific discoveries and facilitate the transition from new concepts to technological development. Further, although basic research is not emphasized in most industrial laboratories, some industrial input to these molecular, mathematical and geo-sciences effort is being sought in order to generate future-oriented involvement of the private sector.

Problems:

- Through the above-stated interactions it has become clear that emphasis must be given to those engineering sciences pertinent to transitions from energy-related scientific discoveries to technological development. The facilities and equipment provided earlier for advanced research in these areas become outdated as new scientific concepts and techniques open new opportunities.

Program Implementation

Energy Research and Development Administration

Knowledge and understanding will be pursued by selecting as performers the most capable scientists in the area of molecular, mathematical and geosciences pertaining to energy technologies, located at the most effective research institutions.

Specialties having high priority because of the likelihood of contributing to energy system advances are typified by: photo-chemistry; catalysis; analytical science, characterization and reactions of coal and its conversion intermediates; geochemistry; high-temperature behavior of geologic systems; combustion kinetics; molecular dynamics; thermochemistry; computation in chemistry; behavior of highly ionized atoms, modeling and simulation methods for complex systems; computer networking; new techniques for the separation of materials; fluid dynamics and fluid particle interactions.

Multidisciplinary university research laboratories (such as Ames, Iowa; Berkeley, California; and possible new entities) will be used for elucidating coal chemical structures and working toward basic understanding of catalytic effects having potential for coal conversions. For these, advanced nuclear magnetic resonance spectrometers must be made available.

University and weapons laboratory physicists and chemists will be enlisted in studies of laser characteristics and laser effects to enhance the power output of gas lasers and to understand alternate fuel combustion for better efficiency and cleanliness. It will be necessary to acquire the most modern laser and shock-tube equipment for this work.

Research areas to be brought up to significant levels include efforts toward effective use of computer networks and study of the behavior of ions important to thermonuclear energy and magnetohydrodynamics. These will require major computer systems and high-resolution ultraviolet/X-ray spectrometers.

Participation in an interagency continental drilling program for geo-science knowledge is intended to begin in the early years of the planning period. To satisfy the requirements for drilling equipment for great depths and remote sensing equipment, the weapons laboratories expertise in subterranean operations will be exploited. Research will continue on advanced measurement techniques to include high resolution ultraviolet/X-ray spectrometers.

An engineering sciences activity will be seeded in FY 1977 in specialities related to process design and operation pertinent to a number of energy research and development programs.

New facilities will be provided at sites and for efforts selected on the basis of the most pressing energy-pertinent scientific opportunities.

For best research-technology interactions, much of the molecular, mathematical and geo-sciences subprograms will be implemented in the laboratories where applied energy research and development programs are located when suitable leading scientific experts are also located there. Basic researchers in universities and federal laboratories will be supported and encouraged to broaden their interactions with applied energy researchers. University capabilities will be utilized both to obtain the benefits of their expertise, and to encourage the growth of students energy-related knowledge.

Wide use of the knowledge resulting from this subprogram will be achieved by publications, dissemination of reports, topical meetings and affirmative efforts to bring applicable results to the attention of potential users in energy research and development programs.

Department of Interior

The Geological Survey has lead responsibility for geologic and water surveys of the U.S. Its basic geo-science programs include studies of high and low temperature geologic processes, rock mechanics, regional geologic and geophysical mapping, offshore surveys, earthquakes and deformation of the earth, chemistry and transport of subsurface and surface waters, and interactions of water with the geologic environment.

MOLECULAR, MATHEMATICAL, AND GEO-SCIENCES

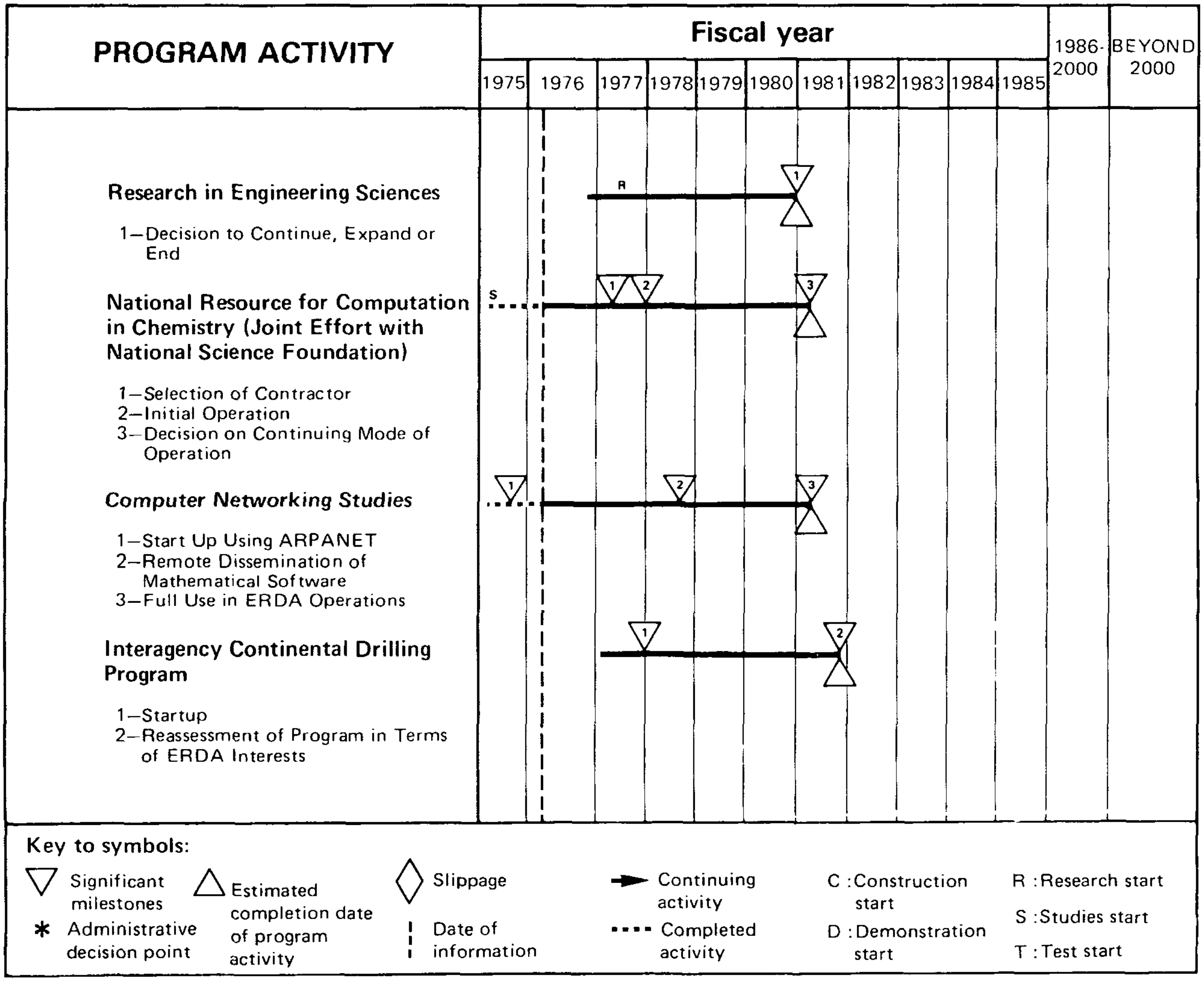
Federal Energy RD&D Budget **($ Millions)**

Agency	FY 1975		FY 1976*		FY 1977	
	BA	BO	BA	BO	BA	BO
ERDA						
Operating Expenses	40.6	39.5	45.3	44.1	50.5	48.0
Plant and Capital Equipment	1.8	1.4	2.7	1.9	2.8	2.3
Total	42.4	40.9	48.0	46.0	53.3	50.3
NSF	60.6	39.8	70.2	46.1	74.4	64.4
Total	103.0	80.7	118.2	92.1	127.7	114.7

* Does not include funds for FY 1976 Transition Quarter.

ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION

MOLECULAR, MATHEMATICAL & GEO-SCIENCES



BASIC ENERGY SCIENCES

Nuclear Sciences

Objectives

Near-Term (–1985), Mid-Term (–2000) and Long-Term (Beyond 2000):

- To increase the understanding of nuclear matter (its properties, structure and interaction) through experimental and theoretical research.
- To pursue that basic research which will provide the informational and conceptual foundation useful to the solution of nuclear problems required for the design of fusion and fission reactors, waste management, safeguards, weapons, biomedical, and environmental programs.
- To develop and operate particle accelerators which are increasingly useful for other sciences and technologies.
- To provide rare elements and enriched isotopes in adequate quantity and purity for the nation's research and development activities.

Technological Status and Problems

Status:

- Many fundamental properties of nuclei and nuclear interactions have been discovered and measured. A firm connection between the fundamentals of nuclear structure and the forces between nucleons is being established.
- A deeper understanding of the structure of nuclei and the nature of nuclear dynamic projectiles provided by a number of new accelerator facilities including the Anderson Mason Physics Facility (LAMPF) at Los Alamos, the Bates Electron Accelerator Facility operated by the Massachusetts Institute of Technology, and the Super HILAC/Bevalac at the Lawrence Berkeley Laboratory. A new heavy ion accelerator facility, designated the Holifield Heavy Ion Facility, is under construction at the Oak Ridge National Laboratory.
- LAMPF has undergone test operation at the full design energy of 800 MeV and 100 microamperes average current. The main meson research area has been upgraded to accept high intensity beams. The polarized ion source and the proton and meson spectrometer systems are being completed.
- The Bates Linac high resolution spectrometer system has been successfully operated to provide electron scattering date of unprecedented high quality.
- The Super HILAC provides heavy ion beams to masses as high as xenon. Very high energy heavy ion beams up to argon are available at the Bevalac. A computer controlled time share operation of the Super HILAC/Bevalac has been completed.
- The contract for procurement of the 25 MV tandem electrostatic accelerator to be located at Oak Ridge has been awarded. Site preparation activities are underway. The building design has been completed.
- The Oak Ridge Electron Linear Accelerator, a major facility for measuring nuclear data needed for design and engineering studies of both fission and fusion reactors, is undergoing upgrading for high current, short pulse capability.
- A national center for the compilation and evaluation of neutron data to serve the fission energy program is in operation at the Brookhaven Laboratory. The center coordinates United States' efforts and cooperates with centers in other countries.
- Research quantities of elements and isotopes are provided both nationally and internationally. Electromagnetic isotope separations are carried out at Oak Ridge. Non-naturally occurring heavy elements are produced and separated using the High Flux Isotope Reactor and the Transuranium Processing Plant also at Oak Ridge.

Problems:

- There continues to exist an incomplete understanding of nuclear properties, nuclear forces and nuclear reactions.
- No accelerator facility in the United States has the capability to accelerate uranium nuclei to sufficient energies to induce nuclear reactions.
- The nuclear data base neded for design and engineering of fusion reactors has yet to be identified, measured, and compiled.
- The basic chemical, physical and nuclear data needed for the technology of actinide waste disposal is lacking.

Institutional Status and Problems

Status:

- Industrial support and involvement in basic nuclear research is minimal. The major effort is carried out by scientists at federal laboratories and universities.
- Formal user group associations exist for LAMPF, Super HILAC/Bevelac, Bates Linac, Brookhaven tandem and the Holifield Heavy Ion Facility.
- Major nuclear theory centers are in operation at a number of universities and federal laboratories.

Problems:

- A number of university accelerator facilities have been closed, resulting in a reduced base for attacking nuclear problems and leading to a potential loss of scientific participation in this area.

Program Implementation

Energy Research and Development Administration

The medium energy nuclear sciences will be carried out by in-house and university-based user groups exploiting the unique capabilities of LAMPF and the Bates Linac. (LAMPF is also involved in numerous important and immediate practical applications in medicine, national defense and radiation damage studies with neutrons with the hope of greatly facilitating this work by using high-energy protons). These facilities will be further developed both to improve the technical capabilities and to better service the user organizations. In particular, a second experimental area is planned at the Bates Linac. This will permit substantially increased research capability at this facility.

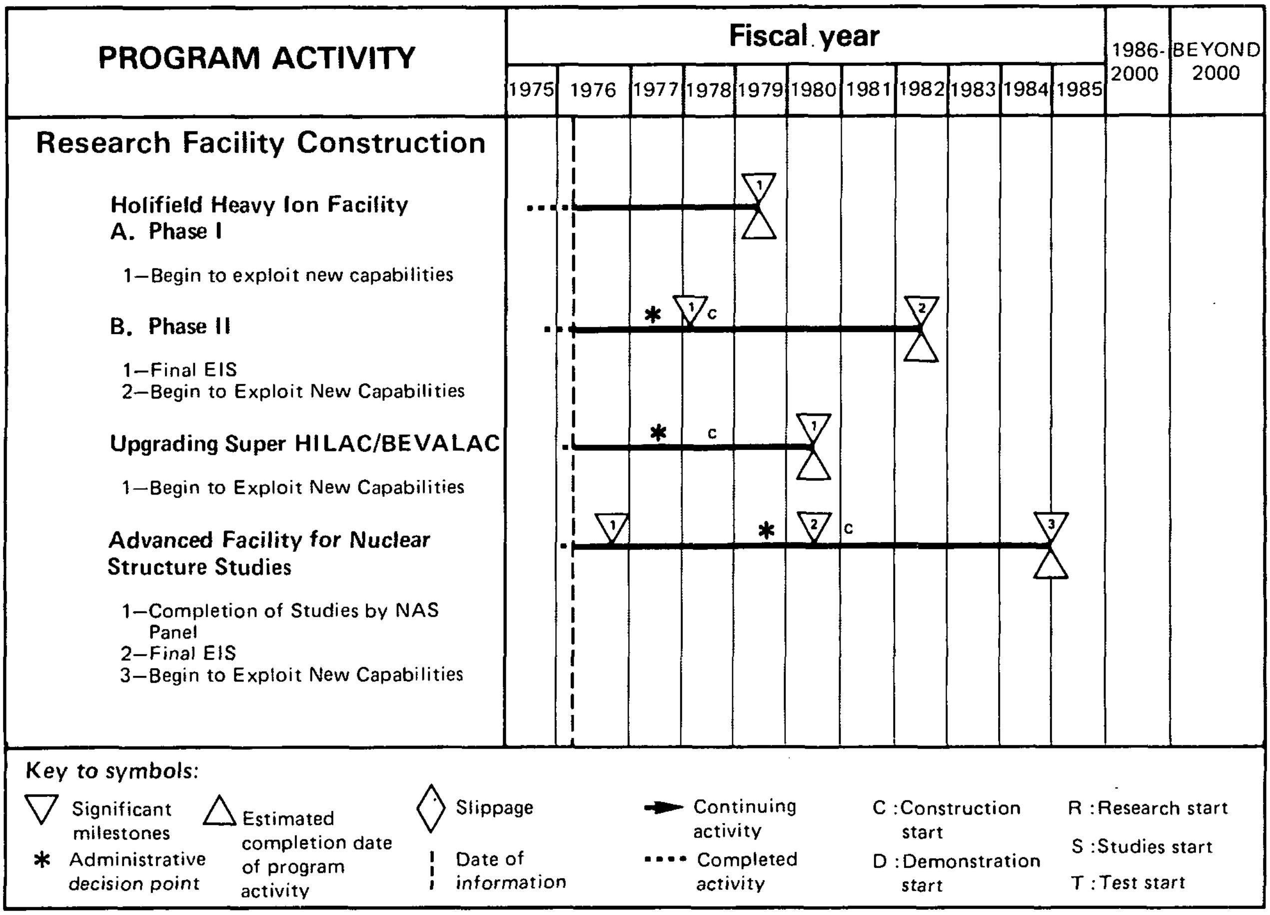
In the heavy ion area, emphasis will be given to continuing development of the Super HILAC/ Bevalac and the Holifield Heavy Ion Facility. Use of high energy heavy ions will be increased for new studies on properties of nuclear matter. The Super HILAC/Bevalac capability will be extended to uranium acceleration. The Holifield Heavy Ion Facility will be expanded into a full-scale national heavy ion laboratory as recommended by a National Academy of Sciences study.

In the low energy nuclear sciences area, research at tandem electrostatic accelerators, cyclotrons and research located at universities and federal laboratories will be carried out to refine the information on classical nuclear properties and reactions. These areas have the closest connection to the applied programs.

In the applied areas, emphasis will be placed upon continuing development of a base of nuclear data for neutron and charged particle interactions between a few hundred keV and 20 MeV, since this energy region will be of prime importance to the fusion reactor program. The Oak Ridge Electron Accelerator will be employed in a major way to provide much of the needed neutron interaction data. The development of the facilities and measuring techniques to provide the nuclear data of required accuracy will be continued. To assist waste management, safeguards, and reactor development programs, compilation and evaluation of radioactive decay data bearing upon after-decay heat and other problems will be pursued. The production of research quantities of heavy elements will be continued in order to permit an extensive study of the chemical and physical properties of the actinide elements which pose special problems in the fission energy program.

ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION

NUCLEAR SCIENCES



NUCLEAR SCIENCES

Federal Energy RD&D Budget **($ Millions)**

Agency	FY 1975 BA	FY 1975 BO	FY 1976* BA	FY 1976* BO	FY 1977 BA	FY 1977 BO
ERDA						
Operating Expenses	74.0	71.8	82.4	79.1	81.2	77.3
Plant and Capital Equipment	25.7	7.2	25.1	11.8	12.0	16.7
Total	99.7	79.0	107.5	90.9	93.2	94.0
NSF	2.3	1.5	2.5	1.6	2.6	2.2
Total	102.0	80.5	110.0	92.5	95.8	96.2

* Does not include funds for FY 1976 Transition Quarter.

PART III — ENERGY-RELATED SUPPORTING ACTIVITIES

INTRODUCTION

The third part of Volume 2 contains six building blocks, grouped into four major program areas:

- Information Services
- General Systems Studies
- General Technology Transfers
- Manpower

The building blocks contain information on the energy RD&D activities of ten federal agencies, namely:

- Department of Agriculture
- Department of Commerce
- Department of Interior
- Department of Labor
- Energy Research and Development Administration
- Federal Energy Administration
- Federal Power Commission
- National Aeronautics and Space Administration
- National Science Foundation
- Nuclear Regulatory Commission

ENERGY–RELATED SUPPORTING ACTIVITIES EXECUTIVE SUMMARY

Broad based support activities associated with each of the previously described energy and supporting technology programs include Information Services, General Systems Studies, General Technology Transfers, Manpower Development, and Education and Training. These activities have been formalized by the federal energy agencies to assure that these programs are integrated and performed with maximum effectiveness. They provide advice, support, and direction to the individual energy technology programs when appropriate, as well as design and implement such activities at the agency level.

The Information Services program goal is to increase public awareness and understanding through the active dissemination of credible information about energy-related problems, options and programs using all forms of communication. Specific current and accurate energy resource technical data is collected, analyzed, organized and published to make it readily available to the R&D and industrial communities.

General Systems Studies are oriented towards providing data, analyses and documentation, and developing techniques to support national energy RD&D planning and program activities. Inherent in these studies are the development and improvement of analytic procedures to support program planning and budget decisions and the identification of policy issues as well as the development and advancement of energy system models.

The main focus of the General Technology Transfers program is the development of methodology for the transfer of energy-related technology developed with public funds into production by private industry for public benefit. The information will be used by program managers in designing demonstration projects to accelerate market penetration of successful technology. The techniques being implemented include the working knowledge of commercialization processes, factors, barriers and mechanisms; identification of new promising energy-related concepts; identification of synergistic program developments; and the identification of federal actions or incentives that may be required for the acceptance of a new technology.

Supporting activities are conducted to ensure that an adequate and qualified source of manpower for energy RD&D will be available. One focus of this effort will be on the development of information to indicate when and where manpower needs will occur for each energy segment. Individual energy technology programs will respond to this information through the development of specific training programs and the sponsorship of mission-oriented educational activities under the coordination of the Office of University Programs.

The program support activities are interrelated. For example, manpower data is needed for systems studies and planning; will be made available to the public for career-planning purposes and to industry and educational institutions via information services activities; and will be used in technology transfer studies to determine whether scarcity of a particular skill could inhibit development or commercialization of a specific technology.

The federal government plays an active role in program support areas, applying its unique national and non-parochial perspective, to fulfill its public responsibility to manage energy technology development which cannot be achieved by industry acting alone.

ENERGY-RELATED SUPPORTING ACTIVITIES (1)

Federal Energy RD&D Budget

($ Millions)

Building Block	FY 1975		FY 1976*		FY 1977	
	BA	BO	BA	BO	BA	BO
Public Awareness	2.6	2.6	2.8	2.7	3.2	3.2
Technical Information Services	6.3	6.8	7.6	7.3	8.6	8.4
General Systems Studies	6.4	3.2	10.7	11.5	11.0	13.0
General Technology Transfers	4.1	3.8	6.0	5.5	2.0	3.4
Manpower Development	5.3	5.2	4.3	4.2	4.9	4.9
Education and Training	3.2	3.2	4.1	3.8	2.8	3.1
Total	27.9	24.8	35.5	35.0	32.5	36.0

(1) These were not included in Volume I of *ERDA 76-1*.
* Does not include funds for FY 1976 Transition Quarter.

ENERGY–RELATED SUPPORTING ACTIVITIES

Information Services

PUBLIC AWARENESS

Objective

Near-Term (–1985), Mid-Term (–2000) and Long-Term (Beyond 2000):

- To increase public awareness and understanding of Federal energy RD&D activities, the nation's energy problems and of the resource and technology options which may be applied to their solution so that the public can make informed choices.

National Energy Technology Goals Supported

Primary

- Perform basic and supporting research and technical services related to energy.

Strategy

Disseminate credible information on energy storage, conservation, technologies and supply systems to the public through mass communication and other media; through schools, museums, and organized public interest and other groups and by direct contact with industry representatives, community leaders and citizens.

Federal Role

The federal government, to carry out its responsibility to set national energy policy, provides the public with factual and timely information about energy sources, usage, and technology options and their implications which will influence future energy consumption patterns.

International Cooperation

The potential for sharing energy-related information for public education is being examined, particularly among those nations which have agreements for technical/scientific information exchange with the United States.

Institutional Status and Problems

Status:

- There is a large amount of information already available on energy sources, usage and technology options.

Problems:

- The large body of energy information now available to the public is generated by many sources with conflicting interests and different perspectives. It is difficult for the public to determine what information is credible.

Program Implementation

U.S. Department of Agriculture (DOA)

The DOA operates a very active information dissemination program, including energy conservation techniques, through its various county extension services and at each of the state land-grant universities, and Puerto Rico, Virgin Islands, and Guam. DOA prepares and distributes fact sheets, brochures and publications, releases for the press, radio and teltvision, slide sets and films, and teacher and student packets. Current literature and educational materials on energy conservation and management in agriculture, rural communities and homes are continually updated to reflect research findings applicable to these areas.

Close working relationships are maintained with other federal and state agencies as well as the private sector to assure a balanced program. Educational and demonstration programs are carried on in all states by specialists in agriculture, community development, home economics and youth work. The purpose of the program is to assure that information on energy conservation and management is made available to and understood by farmers, rural community leaders, homemakers and youth.

Energy Research and Development Administration

The agency develops and disseminates materials on energy RD&D options; coordinates its activities with other federal agencies, industry and user groups; and develops and disseminates school materials.

Energy RD&D policies, plans, programs, accomplishments, decisions, contracts, agreements, etc., are publicized in news releases, fact sheets and articles; and through press briefings, seminars, conferences, interviews and public discussions. Public meetings are conducted on the National Energy RD&D Plan to reach specific regional audiences. Assistance is provided to media representatives in identifying and gaining access to information sources, particularly for environmental impact statement hearings. Information programs will be directed to newspapers and magazines, trade journals, broadcasters, public interest groups, etc., to gain prompt and wide distribution of new information.

ERDA will participate with other federal agencies in strengthening public outreach through cooperative information programs and school programs. Included among these agencies are: FEA, DOA, DOC, DOD, DOT, GSA, HEW, HUD, NASA, NRC, and DOA.

Cooperative programs are being developed with organized groups—civic, labor and management organizations, and environmental, public interest, consumer and youth groups—to provide and obtain information via the active communication channels such groups have with community cross sections throughout the U.S. Seminars will be conducted for organization leaders; publications provided for distribution to increase public understanding and to obtain public views of energy technology options, for example.

Educational materials on energy resources, conservation, technology options, etc., are developed for dissemination through the country's school system—priority attention being given to classroom and teaching materials for elementary, secondary and vocational schools. Booklets, pamphlets, and posters are distributed to increase understanding of energy problems and programs, and to stimulate interest in energy-related careers. In FY 1977 literature will reach about 2.5 million students.

Workshops, conducted under contract with universities, colleges and other institutions, enable representatives of civic organizations and other community leaders to participate in discussions of energy resource and technology options, and their impact on a local or national basis. About 350,000 people a year participate in these workshops.

Exhibits and science demonstrations shown in museums, in mobile vans or trailers, in airports, libraries, shopping malls, etc., provide the public with an opportunity to better understand energy resource technology options, their implications, and the problems inherent to their development. Around 7 million people see these exhibits in each year.

Television, radio and films provide broad, timely dissemination of important developments in ERDA RD&D activities. Public service announcements and news features are produced and distributed to TV and radio stations. Films are produced on a variety of energy-related topics and distributed by a centralized film library which responds to about 100,000 requests a year, primarily from elementary and secondary schools. About 9 million people will see these films and about 20 million people will be reached via television.

Federal Energy Administration

A public service advertising campaign is being conducted through radio, television, print, and other media to (1) make the public aware of the energy crisis facing the United States; (2) alert the public to the benefits of adopting energy conservation measures; (3) stimulate rapid adoption of techniques, methods, and changes in consumption patterns that increase efficient use of energy; and (4) to provide reinforcement and reminders to those who do conserve energy.

A broad range of education strategies is being employed to reach all segments of the American public with in-depth information on the nature of America's energy dilemma, alternative solutions on that dilemma, and instructional material for conservation actions.

Among the programs now in place is an energy conservation youth-training system, which uses the talents and energies of high school students to motivate and train younger children. Underway are a citizens' training program which will employ regional institutes throughout America for community leaders; an energy interpretative model program for use in park and recretation areas; a curriculum on energy conservation for high school science teachers; and energy conservation education materials for use by youth organizations (e.g., 4-H Boy Scouts, Girl Scouts, Future Farmers of America).

PUBLIC AWARENESS

Federal Energy RD&D Budget **($ Millions)**

Agency	FY 1975 BA	FY 1975 BO	FY 1976* BA	FY 1976* BO	FY 1977 BA	FY 1977 BO
ERDA						
Operating Expenses	2.3	2.3	2.6	2.6	3.0	3.0
Plant and Capital Equipment	0.3	0.3	0.2	0.1	0.2	0.2
Total	2.6	2.6	2.8	2.7	3.2	3.2

* Does not include funds for FY 1976 Transition Quarter.

ENERGY–RELATED SUPPORTING ACTIVITIES

Information Services

TECHNICAL INFORMATION SERVICES

Objective

Near-Term (–1985), Mid-Term (–2000) and Long-Term (Beyond 2000):

- To continue to advance energy research and development through the timely dissemination of technical information and current, accurate energy resource data in useful form to the energy RD&D communities; and to foster prompt application and commercialization of new energy technologies by communicating RD&D results to industrial and other potential users.

National Energy Technology Goals Supported

- Perform basic and supporting research and technical services related to energy.

Strategy

Collect, analyze, organize, publish and disseminate scientific and technical information related to energy RD&D.

Develop information services in collaboration with RD&D program managers and utilize external sources of information and services to meet governmental agencies needs. Coordinate services with other public agencies and private organizations to minimize duplication and assure effective service.

Manage and integrate research information on environmental control and effects of energy technology systems.

Federal Role

The government must assure that scientific and technical information on the development of energy resource type and extent, and its efficient extraction, conversion, transmission, and use is collected, organized and disseminated, so as to foster scientific and industrial progress and public understanding of energy resource and technology options.

International Cooperation

International cooperation is being expanded through bilateral arrangements with other countries and information sharing agreements with international organizations; e.g., the International Energy Agency (IEA) and the International Atomic Energy Agency (IAEA). The U.S., represented by ERDA, is a full participant in and beneficiary of IEA's International Nuclear Information System (INIS). Under an agreement with IEA, a World Coal Resources and Reserves Data Bank Service is operated jointly by the U.S. Geological Survey and the British National Coal Board. Also, under NATO, cooperative arrangements are being made to exchange energy conservation, solar, and geothermal energy information.

Technological Status and Problems

Status:

- Modern technical information service depends on computers, communication networking, and distribution and storage of technical documents in mircoform. Various services and printed products are produced from a central store of machine-readable information.

Problems:

- Telecommunication facilities are inadequate to support technical information service demands.
- Computer software flexibility is insufficient to exploit the information services potential of computer hardware.
- Means are needed to (1) accelerate reporting of significant RD&D findings, (2) expedite application and commercialization of new energy-related technology, and (3) provide potential

users prompt and ready access to the full text of R&D documents.

Institutional Status and Problems

Status:

- Well-established organizations and government agencies publish primary journals, provide abstracting and indexing coverage of the scientific and technical literature, and coordinate the compilation and evaluation of scientific data. Some provide reference and research services.

Problems:

- The dissemination and use of resource data and technical information is inhibited by (1) patent, copyright and other proprietary restrictions, (2) incompatibility among computer and telecommunication facilities, (3) inadequate standardization of information formats, technical practices and procedures, (4) delays in reporting results of R&D, (5) noncomparability of various units of energy measurements, and (6) unnecessary duplication due to insufficient subject scope coordination.

Program Implementation

Department of Commerce

Energy data and an information gathering program, as wel as an environmental index and oceanic and atmospheric scientific information system, will be developed by the Department of Commerce beginning in FY 77.

The National Technical Information Service (NTIS) is a central source for the sale of Government-sponsored resource development and engineering reports and other analyses prepared by all Federal agencies, their contractors, or grantees. Newsletters publicize the availablity of new research reports and energy-related inventions. Research summaries are available in magnetic tape form. A variety of periodicals dealing with energy and environmental information are regularly distributed. Over 25 bibliographies of specific energy-related topics are currently prepared. All products and services of NTIS are fully funded from the sales income received.

Energy Research and Development Administration

Energy RD&D programs are supported through (1) development and maintenance of comprehensive information resources for use by federal, state and local agencies and institutions, the private sector, etc., and (2) direct service to producers and consumers of technical information when the information resources and services are not provided by the private sector.

Basic resource development and support functions include: (1) acquiring, organizing, indexing, and abstracting current research in progress and technical literature covering energy R&D, and compiling a standardized data base in machine-readable form; (2) identification, inventorying, compilation, and development of banks of significant physical and technical data together with means of machine exploitation; and (3) development of standard procedures for timely reporting of R&D results. On-going direct services and reprsentative products for producers and consumers of technical information include:

- Publication of announcement and abstracting journals *(ERDA Research Abstracts, Energy Abstracts for Policy Analysis, Solar Energy Update),* technical books *(Handbook on Aerosols, A Manual of Industrial Slot Furnace Operations, Internal Combustion Engine: Combustion, Performance and Emission Characteristics),* technical progress and state-of-the-art reviews *(Nuclear Safety, Particle Transport Simulation),* and conference proceedings *(Cooling Tower Environment);* and contracting for publication by others.

- Providing current and retrospective computer search services of an energy data base covering world-wide RD&D results, including operation of a remotely-accessed computer-based on-line information retrieval network (ERDA/RECON), and selective dissemination of information.

- Supporting scientific and technical conferences whose published proceedings add to the general fund of energy-related knowledge.

- Reproducing and distributing U.S. and foreign energy RD&D reports and translations as a specialized clearinghouse.

The commercialization and application of energy technology is supported by:

- Indentifying, reporting, and disseminating information on energy technologies.

- Identifying user communities supporting workshops and conferences, and developing special publications tailored to their needs.

Department of Interior

U.S. Fish and Wildlife Service

The U.S. Fish and Wildlife Service (FWS) began operating the National Fish and Wildlife Information Transfer Network in FY 1975. The purpose of the Network is to obtain access to existing data and information systems, support research activities, and transmit data and other information to appropriate points within the Department of Interior and outside users.

U.S. Geological Survey

The U.S. Geological Survey (USGS) has developed and is maintaining the following data bases:

- The Petroleum Data System contains 66,000 oil and gas pool records covering location, geology, reservoir engineering, and fluids. Digitizing oil field outlines is presently in process. The system is on-line at the University of Oklahoma on a Time Sharing Option available to all users.
- The American Petroleum Institute/American Association of Petroleum Geologists Well Data System is operational. All exploratory wells from 1954 to the present and all production wells from 1966 to the present are included. Records also include location, status, and classification of wells. Used only by government agencies.
- The Well History Control System contains about 600,000 well records, each detailed as to location, drilling status, texts, geological data, and owner. Used only by government agencies.
- The National Coal Resource Data System contains 12,000 area data entries, 7,000 point-data entries from current coal mapping, and 6,000 geochemical analyses. The system is being built with cooperation of state agencies. Phase I contains data by country and is being prepared for access by all users Phase II, which contains disaggregated point data, will be made available to all users when the file size warrants.
- The Oil Shale Data Analysis Program contains 80,000 data bank entries for preparation of computer-generated resource maps. Presently restricted to government users.
- The Geothermal Resources File contains 140 data bank entries. File build-up is beginning and is presently restricted to participating users. The scope of the file is international.

The systems are upgraded as new data, computational algorithms, techniques of information display and computed hardware become available.

USGS plays an aggressive role in the coordination of its data collection and systems development activities with the activities of other Federal agencies. Through joint agreements with the Bureau of Mines, Forest Service, Bureau of Land Management, and TVA, the Survey is integrating its resource data with economic production, reserve and resource data to provide a comprehensive basis upon which future resource exploitation and land use policy decisions will be made. Coal resource data are obtained in part through cooperative arrangements with the State geological surveys, which also are among the principal users of data compilations.

TECHNICAL INFORMATION SERVICES

Federal Energy RD&D Budget ($ Millions)

Agency	FY 1975 BA	FY 1975 BO	FY 1976* BA	FY 1976* BO	FY 1977 BA	FY 1977 BO
ERDA						
Operating Expenses	6.0	6.0	7.0	7.0	7.9	7.9
Plant and Capital Equipment	0.3	0.8	0.6	0.3	0.7	0.5
Total	6.3	6.8	7.6	7.3	8.6	8.4

* Does not include funds for FY 1976 Transition Quarter.

ENERGY–RELATED SUPPORTING ACTIVITIES

General Systems Studies

Objectives

Near-Term (–1985), Mid-Term (–2000) and Long-Term (Beyond 2000):

- To provide the data, analyses, and documentation required and to develop the techniques to support national energy RD&D planning, decision-making, resource allocation, assessment and program evaluation activities.

National Energy Technology Goals Supported

- Perform basic and supporting research and technical services related to energy.

Strategy

Develop on an agency-wide basis the analysis, program planning, resource allocation, evaluation and documentation system which can provide for uniformity and comparability in assessing energy-related activities. Conduct studies using existing methodology and tools as support for agency-level decision-making activities. Collect and develop accurate, current and appropriate detailed data, new models and analytic resources necessary to reflect changes (economic, social, political) in the operating environment and technological state-of-the-art.

Use universities, non-profit organizations and industry when special capabilities are required which are not available within the federal community.

Federal Role

The federal government performs systems studies to determine the implementation of policy alternatives in managing energy technology development programs and to provide the public with a national perspective and unbiased approach to the energy problem. The systems effort is critical because of the complex inter-dependency inherent to energy and the national economy.

International Cooperation

The U.S. has initiated active cooperation with the International Energy Agency (IEA) and the International Institute for Applied Systems Analysis to exchange ideas, techniques, methodology, and data. The U.S., represented by ERDA, is hosting one international systems analysis team, a major focus of its effort being to develop joint estimates of the cost, time and rate of implementation, and energy contributions of the various energy technologies. Monitoring of analytic studies performed by individual countries in areas of common interest is continuing.

Represented by the Geological Survey in cooperation with the Bureau of Mines, the U.S. is participating in the establishment of the World Coal Resources and Reserves Data Bank Service, a function of the IEA. The data bank and clearinghouse will service the informational needs of the participating nations with respect to qualitative and quantitative information pertaining to coal resources and reserves.

Technological Status and Problems

Status:

- A Reference Energy System and a related optimization model are currently being used in conjunction with an energy-oriented inter-industry model and a macro-growth model to provide the framework for examining the economic, environmental and social implications of various planning options.
- The Energy Model Data Base which supports the Reference Energy System has received CEQ approval for application in environmental impact statements. This data base was developed under interagency sponsorship.
- A constraints model has been developed and is being used for preliminary analysis of the capital, manpower and materials demand implications of various planning options.
- Techniques for assessing the impact of new technologies in major markets have been de-

veloped and are being tested in one market area.

- The Project Independence Evaluation System, composed of an econometric demand model, a collection of supply models, and the integrating framework, has been developed to analyze various energy policy scenarios.
- The International Energy Evaluation System generates planning estimates depicting possible states of the world energy system, recognizing the effects of relative prices, the potential for fuel substitution, and the technological constraints that inhibit expansion of the energy system.
- The International Demand Model, using exogenous inputs of energy prices, gross domestic product and population for each OECD country (other than the United States), forecasts final energy consumption for 27 energy products.
- Specific models of interfuel and inter-factor substitution have been constructed for electricity generation and coal supply/demand modeling to address policy questions relating to specific energy industries.

Problems:

Integration of a national energy RD&D program is inhibited by:

- Difficulty involved in actually integrating economic and engineering models to establish proper constraints and implementation assessments for evaluation of new technologies.
- Lack of commensurate data bases and methodology in areas such as cost-benefit, net energy and risk analyses for application to all technology programs to permit comparisons.
- Lack of proven tools for predicting market penetration of new energy technologies which reflect uncertainties in economics and non-economic considerations.
- Lack of analytical tools and data to assess the regional consequences of the national energy RD&D program.

Institutional Status and Problems

Status:

- Formal arrangements have been established by ERDA with industry, universities and private research organizations for the development of models and data collection and reduction.
- Collaboration among Government agencies such as ERDA, FEA, EPA, CEQ and NSF has been established on studies of energy alternatives and sharing of programmatic information.
- A general framework for analysis, planning, programming and evaluation for energy RD&D programs has been developed with ERDA.

Problems:

- Formal reporting channels for the regular and efficient exchange of reliable and timely information concerning the technical, environmental and economic status of energy activities and RD&D supported by government agencies, industry, academia and non-profit organizations do not exist.
- Efficient channels have not been developed for the incorporation of subjective, non-quantifiable assessments of social and institutional actions and reactions to future energy technologies.
- Appropriate mechanisms have not yet been developed to ensure industry and intergovernmental collaboration on key parameters, data exchange, and interpretations of systems studies at desirable levels.
- The legislation and policies concerned with leasing moratoriums, price regulations, air quality standards, and land use preclude concise statements as to the amount of energy resources that may be available for future needs.
- There are a large number of energy-related forecasts and estimates produced by private organizations and government agencies which are not necessarily consistent.

Program Implementation

U.S. Department of Agriculture (DOA)

The purpose of DOA's program is to determine 1) the energy flow in the food, fiber and forest products systems and 2) effects of alternative energy availabilities and prices in the food and fiber system and the relationship with the rest of the economy. This activity utilizes the Department of Commerce input-output model and estimates of direct energy requirements by type and sector of employment, and product by sector. Energy impacts are analyzed on such variables as: individual sector gross output, final demand levels, employment, GNP, indirect business taxes, property income and trade levels. This permits identification of bottlenecks arising from possible energy contingencies, and evaluation of energy allocation schemes. The activity supports the development, expansion, and modification of the basic model from an 85 sector tableau to the full 367 sector input/output tableau. This would permit assessment of activities in over 65 subsectors of the food, fiber and forest products system, thus permitting the detail required for proper policy evaluation.

Energy Research and Development Administration

Throughout the year, state-of-the-art analytical tools, data and information libraries are employed to perform the following tasks:

- The application of analytic procedures for energy RD&D resource allocation to internal budget decisions and program evaluations to provide a balanced funding array for projects in accordance with their priorities and expected payoffs. This activity is performed annually and keyed to the budget cycle.
- The preparation of planning and program implementation documents to apprise the Congress and the public of ERDA's current plans and the programs designed to accomplish agency goals. This activity is performed annually and keyed to the planning cycle.
- The initiation of policy issue and special studies for policy or legislative proposals, for items of high public concern and for topic areas that transcend a number of technologies for which comprehensive integrated information is needed for Administration decision-making.

In addition, in order to implement the above tasks, ERDA maintains and improves the following analytical tools on a continuous basis:

- Energy / Economic / Environmental Modeling and Interfuel Substitution Studies which evaluate responses to alternative policies and RD&D efforts, and project energy supplies and demands by energy type and by end use under a number of alternative policy scenarios. Specific on-going projects include energy systems analysis and technology assessment, an energy model data base, and an electricity supply-demand model. Specific plans for significant advancements include the development of an input/output energy systems model, a dynamic optimization model based upon the national reference energy system, a comprehensive integrated engineering-economic model of the national energy system, a consistent framework for microeconomic analysis of supply technologies, and refined supply models for natural energy resources.
- Impact studies to examine the underlying causal factors and the magnitude of response to changes in these factors as they relate to energy supply technologies, energy demand patterns, and the effects of RD&D spending on economic lifestyles, helping to understand the socio-economic reactions to new energy development. Existing energy systems models can only provide rough estimates of some of these important impacts. Specific plans for significant improvements include development of an analytical model for assessing inflationary impacts, analytical tools to disaggregate environmental impact information generated by existing systems models, and an analytical framework for assessing social costs and benefits of program implementation.
- Regional Studies to define those actions that can be implemented uniformly across the country versus actions that should take distinguishing regional characteristics into account. The projects include development of a methodology for consistent regional studies and some actual studies and analyses as related to energy and environmental options. Appropriate regional groups will participate in this activity.
- Constraint Analysis to assess potential problems of other resource inputs associated with energy technology implementation and create data bases of resource requirements including capital, manpower, materials and equipment. The existing constraints model will be extended to include additional types of energy facilities and to account for additional materials impacts. It will be complemented by a parallel resource availability study.
- Venture Analyses which define the generic conditions for commercialization of developing energy technologies and provide a consistent evaluation of the social return that can be captured from a contemplated technological development, the probability that the private sector will develop the technology spontaneously, the government role required and the ERDA role required. The studies should produce a commensurable basis to be used for establishing energy system priorities. Several specific analyses are planned to demonstrate a generic methodology which is appropriate for ERDA's candidate technologies.
- Major end use markets studies to (1) assess the market potential for the technologies being developed by ERDA; (2) determine program

requirements for commercialization of these technologies; and (3) establish a fact base concerning technology tradeoffs for a given end use to strengthen integrated ERDA program response to specific market needs. The market studies currently underway or being initiated in FY 1976 cover electric utilities (preliminary study completed), gas utilities, buildings, industry, and transportation.

- Net Energy Analysis projects to identify the role of net energy within the decision making framework, and to make comparisons of entire energy trajectories from extraction to end use with respect to net energy. Specific plans for extending the state-of-the-art include the application of fairly conventional methodology to the analysis of the major source and end use technologies and the application of more comprehensive "energetics" methodology to several representative major technologies.

Federal Energy Administration (FEA)

FEA's systems studies activities are performed to support energy policy analyses that surface energy problems which could endanger the general welfare, common defense and security of the Nation in the near, mid, and long term. The modeling techniques and data being used and developed are continuously improved and updated.

Forecasts for beyond 1990 are constructed to provide basic information concerning the supply, demand, and imports of energy needed to analyze many policy issues. Additional areas of particular interest are state and national conservation analyses (for the Energy Policy and Conservation Act), energy facilities siting analyses, economic and environmental impact analyses, and general regulatory policy (such as energy taxation alternatives). Regulatory impacts and medium range (1980–1990) policy analyses are also addressed.

To support these activities, FEA is developing an additional modeling system and two data bases.

The Regional Energy Activity and Demographic Modeling System (READ), is being designed to provide state level forecasts of shifts in energy demand as a function of: 1) changes in industrial location, 2) population redistribution, and 3) changes in the expenditure patterns of state and local governments. Particular attention is given to the effects of national energy policy decision and exogenous shocks to the U.S. energy system. The READ model is a system of simultaneous econometric equations which model industrial location, population, and state and local government activity as explicit functions of energy prices and availability and other traditional economic variables.

The two data bases being developed are:

- The National Consumption Data Base to reflect end-use consumption of energy by each of the consuming sectors (household, commercial, industrial, transportation) on a regional basis. The effort will be expanded to acquire data on a state-by-state basis if feasible to further support the State/Federal conservation program.
- International Energy Accounts to provide a complete energy flow system from origins to disposition by product for each of the OECD nations and other major energy consuming countries. Data on production, trade, and consumption of energy products, including prices of energy products paid by industrial and domestic users and macro-economic and demographic data which affect energy consumption is being collected and maintained.

Federal Power Commission (FPC)

As part of its regulatory activities, FPC provides current reliable information on energy issues involving public utilities through publication of the National Power Survey and the National Gas Survey. The agency is assisting state regulatory agencies in making more effective use of electronic data processing in the analysis of data and the reduction of regulatory lag. In addition, the following studies and analyses are in progress:

- Residential space heating using electricity or direct combustion of fossil fuels.
- Effectiveness of using off-peak electricity for residential space heating.
- Alternative methods to incorporate incentives for energy conservation into the rate base of electric utilities.
- Interaction between economic considerations and the technical operating efficiencies of electric utility companies.
- Prospects for new gas under regulated prices.
- Alternative rate design proposals for regulated utilities.

Models are being developed to:

- Simulate the cost of on-peak and off-peak electric service.
- Simulate energy supply and demand balances and comparative efficiencies of energy systems.

- Forecast the demand for natural gas, both regionally and nationally.

Regional energy flow diagrams incorporating all uses and sources of energy are also being developed.

Department of Interior

The *Bureau of Mines* Fuels program is related directly to ERDA's national energy technology goals; it provides data and analyses which define the areas and quantities of fuels and energy needs which serve energy R&D planners. The Bureau of Mines Fuels Availability System (FAS), an automatic fuels and energy data and retrieval system, provides detailed historic and current, aggregated and disaggregated, fuels data for determining energy supply-demand balances. It is the most comprehensive fuels and energy information source available in the U.S. In addition, analytical capabilities are available which encompass such fuel commodities as coal, petroleum, natural gas and their products; domestic and international energy trades; energy supply-demand relationships; short and long range energy forecasting; and assessment of alternative energy sources.

The *Geological Survey* assesses the types and amounts of non-energy minerals required by the energy industries for accelerated or alternative modes of energy production, evaluates that anticipated demand against all sources of supply, and attempts to expand the United States' supply of those minerals most in demand for increased energy production. See the Milestone chart for detailed description of the studies and their respective schedules. Additional information on USGS activities which is used in performing systems studies is presented in the Technical Information Services Implementation section.

The *Office of Water Research and Technology* performs water resource assessments relative to energy development. Development of an energy technology could have major impacts on water and related land resources, particularly in the West. Demands for water supply will increase substantially, not only for mining and processing, but also for expanding community growth and new towns. Problems of water allocation, water quality, and adverse environmental and social impacts could occur. Research directed to resolving these and similar problems is important for the orderly development of the Nation's energy resources. The research program is conducted by contracts, grants and others in the following areas:

(a) Water resources research into the impact of coal mining and oil shale development on local and regional water resources;

(b) Water resources research into strip spoil reclamation for reuse and water quality protection;

(c) Methodology to minimize and achieve water-related consequences—social, economic, and environmental—resulting from fossil fuel development in the Western states and Appalachia;

(d) Analytical modeling of water supply allocation;

(e) Acid mine drainage control;

(f) Cooling and process water needs and conservation;

(g) Water recycling and water reuse, and

(h) Water conservation, including substitution of low quality water for high quality water for high quality water in development activities.

National Science Foundation (NSF)

The Energy System Studies and Analysis Program evaluates all aspects of selected problems through analysis of the technological, economic, social, environmental and institutional factors, and will include the following tasks:

(1) *Energy Resource Analysis*

The adequacy of presently available domestic energy resources (oil, natural gas, coal, uranium, etc.), given the current demand projections, and the impact on world energy resources will be evaluated. The capability for expanding energy resource extraction (e.g. coal) and processing to meet the long term needs will be assessed.

The need for new exploration and development techniques for improved extraction of fuels and processing efficiency will be determined and the social, economic, and technical impediments, if any, that may arise in expanding energy resource processing and utilization; and the impact of accelerated depletion of nonrenewable energy resources on the environment, employment, and income patterns, factor productivity, and industry outputs (e.g. steel, aluminum, and turbine manufacturers; the electric utilities) will be identified.

(2) *Comparative Systems Analysis*

The technical and economic options available in the electric energy system will be identified and evaluated and the systems impact of alternative pricing policies in the energy sector will be examined from a multidisciplinary, systems analytic perspective, and the technical, economic, and structural efficiency will be assessed. Methodology to conduct risk/benefit analysis for the technical options available to the energy sector will be developed.

(3) *Energy Data Base/System Modeling*

A methodology for more comprehensive and useful energy data accumulation, utilization, and evaluation will be developed and the needed types of energy data and models will be identified. Appropriate energy data accounting and modeling methodologies for regional, national, and international will be determined and applied to representative areas.

(4) *Energy Policy/Regulatory Research*

The effectiveness of regulatory policy for the energy sector will be assessed and criteria and methodologies for evaluating alternative energy policies will be developed. The domestic and international systems impacts of alternative energy policies will be evaluated in order to identify policy implications of increased domestic and international depletion rates of energy resources. The systems impact of alternative energy regulatory policies will be evaluated.

Tennessee Valley Authority (TVA)

TVA performs studies to ascertain the feasibility and economics of advanced energy conversion devices and synthetic fuel processes for their potential application to the TVA power system. The agency has an active program, particularly in the nuclear area, in power plant design, engineering and operation.

GENERAL SYSTEMS STUDIES

Federal Energy RD&D Budget ($ Millions)

Agency	FY 1975		FY 1976*		FY 1977	
	BA	BO	BA	BO	BA	BO
ERDA						
Operating Expenses	2.1	2.1	9.2	9.2	11.0	11.0
Plant and Capital Equipment	0	0	0	0	0	0
Total	2.1	2.1	9.2	9.2	11.0	11.0
NSF	4.3	1.1	1.5	2.3	—	2.0
Total	6.4	3.2	10.7	11.5	11.0	13.0

* *Does not include funds for FY 1976 Transition Quarter.*

ENERGY—RELATED SUPPORTING ACTIVITIES

General Technology Transfers

Objective

Near-Term (–1985), Mid-Term (–2000) and Long-Term (Beyond 2000):

- To assure that technology developed with Federal support can be rapidly utilized by the private sector for public benefit.

National Energy Technology Goals Supported

Primary

- Perform basic and supporting research and technical services related to energy.

Strategy

- To develop and maintain a working knowledge of the commercialization process, production factors and market acceptance mechanisms which will be considered by Federal program managers in designing energy-related technology demonstrations.
- To identify promising concepts originating with small businesses and individuals outside of the Federal R&D establishment which could provide beneficial results to energy-related technology development.
- To identify technology developed with Federal funds which has potential applications outside its original programmatic field.
- To identify the unusual barriers inhibiting private industry from introducing a technology into the marketplace and analyzing the effectiveness of various incentives in overcoming these barriers.
- To select a Federal action or appropriate incentive option that can be used when it has been determined that a technology has not been introduced by the private sector due to market failure and that this is detrimental to the public interest.

Federal Role

The role of the Government is to supplement what cannot otherwise be done by the private sector in a timely manner. The Government can eliminate obstacles, share risks and conduct its own RD&D program to maximize the benefit to the public.

International Cooperation

The potential for international cooperation consists of exchanging information, trading technology and products, and sponsoring joint projects.

Technological Status and Problems

Status:

- The energy related technologies now receiving Federal support are in phases of development ranging from study and laboratory research to demonstration projects.

Problems:

- Barriers to commercialization are unique for each technology.
- It is difficult to measure the value of social benefits when determining an appropriate kind or level of Federal support.

Institutional Status and Problems

Status:

- Formal programs to study the generic process of technology transfer have been established.

Problems:

- All of the institutional barriers—such as fragmented industry structure, inconsistent government regulation of fuel prices, conflicting regulations among state, local, and federal agencies for different regions of the country—which inhibit commercialization of individual technologies have not been identified yet.

Program Implementation

Energy Research and Development Administration

The major mechanism for general technology transfer is the dissemination of RD&D results to private industry. This program is described in two preceding sections, Public Awareness and Technical Information Services.

ERDA has established the Task Force on Demonstration Projects to advise the agency on how to design and conduct demonstration projects to the accelerate market peneration of successful technology. The demonstration phase is the crucial link for commercialization for it is at this stage that the results of publicly-funded R&D efforts are perfected and presented to the private sector for evaluation against existing, competing technology.

Studies are being conducted to establish viable incentives for industry, identify governmental policy constraints and determine the extent to which incentives for conservation technology need differ from production incentives. As incentive programs are implemented, evaluation studies will be performed to guide future applications of the incentives.

Technology Utilization (TU) representatives are located at six ERDA laboratories to serve as points of contact and assist industry and state and local government officials seeking to implement new technology and to utilize Federally developed methodology. As transfer of programmatic technology often requires adaptive engineering, funds have been designated specifically for such projects to be conducted at the laboratories.

National Bureau of Standards

The National Bureau of Standards (NBS) performs the initial screening and evaluation for ERDA of energy-related invention proposals received from the private sector. Those that are recommended to ERDA are validated and then: a) tested for supportability in the private market; b) if proven unsupportable due to technical uncertainty, considered for normal RD&D support by the appropriate ERDA program manager. It is estimated that between twenty-five and fifty inventions will be forwarded to ERDA each year.

National Aeronautics and Space Administration (NASA)

NASA's program to identify technology within its program activities which have potential energy-related application consists of: 1) properly relating these technologies to energy research and technology needs, 2) validating potential candidates by selected experimentation; and 3) formulating, where appropriate, technology advancement plans for other agencies having primary responsibility for meeting national needs. The broad areas covered are: ground propulsion, stationary power, fuel cells, solar energy and solar energy derivatives, hydrogen, gas turbines, and coal energy extraction.

GENERAL TECHNOLOGY TRANSFERS

Federal Energy RD&D Budget ($ Millions)

Agency	FY 1975		FY 1976*		FY 1977	
	BA	BO	BA	BO	BA	BO
ERDA						
Operating Expenses	0.5	0.5	1.8	1.8	2.0	2.0
Plant and Capital Equipment	0	0	0	0	0	0
Total	0.5	0.5	1.8	1.8	2.0	2.0
NASA	3.6	3.3	4.2	3.7	0	1.4
Total	4.1	3.8	6.0	5.5	2.0	3.4

* Does not include funds for FY 1976 Transition Quarter.

ENERGY—RELATED SUPPORTING ACTIVITIES

Manpower

MANPOWER DEVELOPMENT

Objective

Near-Term (–1985), Mid-Term (–2000) and Long-Term (Beyond 2000):

- To develop manpower information that will indicate when, where, and to what extent manpower needs will occur by occupation for each energy segment.

National Energy Technology Goals Supported

Primary

- Perform basic and supporting research and technical services related to energy.

Strategy

- Develop a data base on the utilization and characteristics of manpower engaged in energy-related activities.
- Disseminate supply-demand information to producers and users of energy-related manpower.
- Develop a mechanism for national planning and mobilization of existing manpower resources to meet energy-related needs.

Federal Role

Only the federal government is in the position to identify and assess long-range manpower requirements to support the overall national energy RD&D goals.

Institutional Status and Problems

Status:

- There are extant manpower data bases by occupation and specialty.

Problems:

- There are gaps both in data and currency of information in existing data banks.
- Existing data bases are not structured to extract meaningful energy-related manpower information.

Program Implementation

Energy Research and Development Administration

Cooperative relationships shall be established with other federal agencies and other public and private organizations to establish and maintain a data base to provide numbers of people employed by occupation in each of the energy categories. This data base will permit the projection of manpower supply and demand for any occupation in any energy segment (fossil, solar, nuclear, etc.). Periodic validation of projections will suggest need for change in projection techniques used. The data base will be modified and updated to incorporate new skill requirements of emerging technologies. Information in the data base and projections will be made available to public and private organizations and individuals. Effort to design the data base was initiated early in FY 1976 and the system development work is scheduled for completion at the end of FY 1977.

The data base is used to provide guidance and support to educational institutions and others on the national energy effort for assistance in defining their role and responsibilities in making the changes necessary for producing the diversity of skills and technical expertise needed to pursue energy goals.

Interagency agreements will be established with the National Science Foundation, Department of Labor, Environmental Protection Agency and Department of Health, Education and Welfare and others to identify and lay out a plan of action to achieve common manpower goals and objectives.

A new Office of University Programs has been established to assure that allocation of resources reflect the training priorities of fossil, nuclear, solar-geothermal and advanced systems, environment and safety, conservation and safety programs.

Department of Labor

The Employment and Training Administrator will initiate a project in FY 1977 to study manpower shortages in many fields, including the electric power and chemical industries.

MANPOWER DEVELOPMENT

Federal Energy RD&D Budget ($ Millions)

Agency	FY 1975		FY 1976*		FY 1977	
	BA	BO	BA	BO	BA	BO
ERDA						
Operating Expenses	0.2	0.2	0	0	0.7	0.7
Plant and Capital Equipment	0	0	0	0	0	0
Total	0.2	0.2	0	0	0.7	0.7
NSF	5.1	5.0	4.3	4.2	4.2	4.2
Total	5.3	5.2	4.3	4.2	4.9	4.9

* Does not include funds for FY 1976 Transition Quarter.

ENERGY—RELATED SUPPORTING ACTIVITIES

Manpower

EDUCATION AND TRAINING

Objective

Near-Term (–1985), Mid-Term (–2000) and Long-Term (Beyond 2000):

- To assist in developing a solid base of skilled and professionally-trained manpower to support the energy RD&D effort.

National Energy Technology Goals Supported

Primary

- Perform basic and supporting research and technical services related to energy.

Strategy

The startegy is to (1) sponsor faculty training workshops; graduate traineeships; research participation assignments to ERDA laboratories, energy centers and contractor facilities; short-term training courses on specific energy-related topics; visiting lecturers; conferences; (2) assist curricula development to supplement and stimulate the normal education process in meeting requirements for appropriately trained personnel; and (3) conduct programs designed to motivate and encourage qualified individuals to choose careers in the energy-related disciplines at both the professional and non-professional levels.

ERDA will establish and maintain liaison with other federal agencies for the purpose of coordinating energy-related education and training activities.

Federal Role

Colleges and universities, aided by industry support and on-the-job training programs, are the main source of trained manpower. The federal government augments those efforts to help shorten the lead times involved in the usual educational cycle when a quick response to changing national priorities is required.

International Cooperation

A special energy and environmental training project has been initiated in conjunction with the International Atomic Energy Agency (IAEA) to train managers from developing countries for nuclear power project planning.

Institutional Status

Status:

- Some federally-sponsored programs for training in selected areas currently exist.
- Interagency agreements are being established with the National Science Foundation, Federal Energy Administration, Department of Labor, Environmental Protection Agency, and Department of Health, Education and Welfare and others to create a uniform and cooperative framework for the federal support of educational programs.

Program Implementation

Energy Research and Development Administration

A major study to develop a comprehensive non-nuclear education and training program is under way, and will be completed in September, 1976.

On-going faculty training of high school and community college teachers is pursued through workshops on selected topics.

Graduate traineeships will be sponsored in the disciplines that support all energy technology research and development, and environmental, health and safety areas.

Research participation assignments will continue to be made for university-based faculty and students at ERDA laboratories and contractor facilities.

Support is also provided for the acquisition of fuel for university-owned reactors to provide a nuclear training capability for the host university and other participants.

The Puerto Rico Nuclear Center has been reorganized as the Puerto Rico Center for Energy and Environmental Research under the direction of the University of Puerto Rico. This center will carry out programs for training scientists, engineers, and other professionals, and will offer research-sharing opportunities for stateside scientists to work on energy research and development projects performed at the Center.

The responsibility for managing this program has been transferred from the Divisions of Biomedical and Environmental Research and Physical Research to the Office of University Programs.

EDUCATION AND TRAINING

Federal Energy RD&D Budget ($ Millions)

Agency	FY 1975		FY 1976*		FY 1977	
	BA	BO	BA	BO	BA	BO
ERDA						
Operating Expenses	2.9	2.9	3.5	3.2	2.2	2.5
Plant and Capital Equipment	0.3	0.3	0.6	0.6	0.6	0.6
Total	3.2	3.2	4.1	3.8	2.8	3.1

* Does not include funds for FY 1976 Transition Quarter.

PART IV
SPECIAL ANALYSES

Table 1

BB's Versus National Energy Technology Goals Supported

I Expand the domestic supply of economically recoverable energy-producing raw materials.

II Increase the use of essentially inexhaustible domestic energy resources.

III Efficiently transform fuel resources into more desirable forms.

IV Increase the efficiency and reliability of the processes used in energy conversion and delivery systems.

V Transform consumption patterns to improve energy use.

VI Increase end-use efficiency.

VII Protect and enhance the general health, safety, welfare and environment related to energy.

VIII Perform basic and supporting research and technical services related to energy.

Building Blocks	National Energy Technology Goals							
	I Expand Domestic Supply	II Increase Use of Inexhaustible Resources	III Efficiently Transform Fuel Resources	IV Increase Energy Conversion Efficiency	V Transform Consumption Patterns	VI Increase End-Use Efficiency	VII Protect Health, Safety, Welfare, & Environment	VIII Perform Basic, Supporting Research
Energy Technology Programs								
Fossil Energy								
Coal								
Liquefaction			P	S				
High BTU Gasification			P	S				
Low BTU Gasification			P	S	S			
Advan. Power Systems				P				
Direct Combustion	P			S				
Adv. Res. & Supp. Tech.							S	P
Demo. Plants			P	S				
Magnetohydrodynamics			S	P				
Pet. and Nat. Gas								
Gas & Oil Ext.	P							
Supp. Research	S			S			S	P
In-Situ Technology								
Oil Shale	P							
In-Situ Coal Gas.	P		S	S				
Supp. Research								P
Extraction Tech.	P							
Resource Appraisal	P		S				S	S

P — Primary
S — Secondary

Table 1

BB's Versus National Energy Technology Goals Supported (Cont'd)

Building Blocks	National Energy Technology Goals							
	I Expand Domestic Supply	II Increase Use of Inexhaustible Resources	III Efficiently Transform Fuel Resources	IV Increase Energy Conversion Efficiency	V Transform Consumption Patterns	VI Increase End-Use Efficiency	VII Protect Health, Safety, Welfare, & Environment	VIII Perform Basic, Supporting Research
Solar Energy								
Thermal Applications								
Solar Heat. & Cool.		P			S	S		
Agric. & Indust. Proc. Heat		P			S			
Tech. Supp. & Util.								
Envir. & Res. Assess.		P		S			S	S
Solar Energy Res. Inst.		P	S		S		S	S
Inform. Diss. & Commer.		P		S				S
Solar Electric Appl.								
Solar Thermal Energy		P		S				
Photovoltaic Energy		P		S				
Wind Energy		P						
Ocean Thermal Energy		P	S	S				
Fuels From Biomass		P	S					
Geothermal Energy Program								
Envir. Cont. & Inst. Std.	P	S					S	
Resource Expl. & Assess.	P	S					S	
Hydrothermal Projects	P	S					S	
Demonstration Projects	P	S					S	
Advan. Tech. Applic.	P	S					S	
Engineering R&D	P	S					S	
Geothermal Res. Dev. Fund	P	S					S	
Conservation								
Elec. Energy Sys. & Energy Stor.								
Electric Energy Sys.				P	S			
Energy Storage				P	S	S		
Tech. to Improve Eff.								
Industry Conservation					S	P		S
Buildings Conservation			S		S	P	S	S
Trans. Energy Conser.					S	P	S	S
Energy Conversion				P	S	S		
Fusion Power R&D								
Magnetic Fusion								
Confinement Systems		P						
Reactor Projects		P						
Dev. & Technology		P						
Applied Plasma Physics		P						

P — Primary
S — Secondary

Table 1

BB's Versus National Energy Technology Goals Supported (Cont'd)

Building Blocks	National Energy Technology Goals							
	I Expand Domestic Supply	II Increase Use of Inexhaustible Resources	III Efficiently Transform Fuel Resources	IV Increase Energy Conversion Efficiency	V Transform Consumption Patterns	VI Increase End-Use Efficiency	VII Protect Health, Safety, Welfare, & Environment	VIII Perform Basic, Supporting Research
Laser Fusion		P						S
Nuclear Fuel Cycle R&D & Safe. Uranium Res. Assessment	P							S
Support of Nuc. Fuel Cyc.		P		S			S	
Waste Management (Comm)							P	S
Nuclear Mats. Sec. & Safe.							S	P
Uran. Enrich. Process Dev.			P	S				S
Adv. Iso. Sep. Tech.			P					S
Fission Power Liq. Metal Fast Breed. Reactor Base Program R&D		P	S	S				S
Clinch River B.R.P. Proj.	S	P		S				
Reactor Safety		S	S				P	
Advanced Fuels		P	S	S				
Water Cooled B.R.	S	P	S	S				
Gas Cooled Reactors Thermal Reactors	S			P			S	
Fast Breeder Reactor	S	P		S				
Reactor Safety			S				P	
Light Water Technology				P			S	
Supporting Activities		S	S	S			S	P
Reactor Safety Facilities							S	P
Envir. Cont. Tech. Envir. Control Technology				S			P	
Synthetic Fuels Comm. Demo. Prog. Synthetic Fuels Comm. Demo.	S		P	S				
Supporting Technology Programs Biom. & Envir. Res. Program Health Studies							P	S
Biological Studies							P	S
Environmental Studies							P	S
Physical & Tech. Stud.							P	S
Assessments							P	S
Basic Energy Sciences Program Materials Sciences								P
Mole., Math. & Geo-sciences								P
Nuclear Sciences								P

P — Primary
S — Secondary

Table 1

BB's Versus National Energy Technology Goals Supported (Cont'd)

Building Blocks	National Energy Technology Goals							
	I Expand Domestic Supply	II Increase Use of Inexhaustible Resources	III Efficiently Transform Fuel Resources	IV Increase Energy Conversion Efficiency	V Transform Consumption Patterns	VI Increase End-Use Efficiency	VII Protect Health, Safety, Welfare, & Environment	VIII Perform Basic, Supporting Research
Energy-Rel. Supp. Act. Information Services Public Awareness								P
Tech. Information								P
General Systems Studies								P
General Tech. Transfers								P
Manpower Manpower Development								P
Education and Training								P

P — Primary
S — Secondary

Table 2
BB's Versus Volume 1 Technologies

Volume 1 Energy RD&D Technologies

Building Blocks	Oil and Gas-Enhanced Recovery	Oil Shale	Geothermal	Solar Electric	Breeder Reactors	Fusion	Coal – Direct Utilization in Utilities/Industry	Waste Materials to Energy	Gaseous and Liquid Fuels from Coal	Fuels from Biomass	Nuclear Converter Reactors	Electric Conversion Efficiency	Energy Storage	Electric Power Transmission and Distribution	Solar Heating and Cooling	Waste Heat Utilization	Electric Transport	Hydrogen in Energy Systems	Transportation Efficiency	Industrial Energy Efficiency	Conservation in Buildings and Consumer Products	Basic Research	Biomedical and Environmental Research	Systems Studies	Information Dissemination	Manpower Development	Safety	Exploration and Resource Assessment	Mining and Beneficiation	Environmental Control Technology	Nuclear Safeguards	Support of the Nuclear Fuel Cycle	Uranium Enrichment	Fossil Fuel Transportation	Waste Management
Energy Technology Programs																																		
Fossil Energy																																		
Coal																																		
Liquefaction										X																									
High BTU Gasification										X																									
Low BTU Gasification								X																											
Advan. Power Systems								X		X				X																						
Direct Combustion								X																											
Adv. Res. & Supp. Tech.								X		X				X																						
Demo. Plants								X		X																									
Magnetohydrodynamics								X					X																						
Pet. and Nat. Gas																																		
Gas & Oil Ext.	X																																	
Sup. Research	X																																	
In-Situ Technology																																		
Oil Shale		X																																
In-Situ Coal Gas.										X																									
Supp. Research		X								X																									
Extraction Tech.		X						X		X																				X					
Resource Appraisal																													X	X					
Solar Energy																																		
Thermal Applications																																		
Solar Heat. & Cool.																X																			
Agric. & Indust. Proc. Heat																X																			
Tech. Supp. & Util.																																		
Envir. & Res. Assess.				X												X																			
Solar Energy Res. Inst.				X												X																			
Infor. Diss. & Commer.				X												X										X									
Solar Electric Appl.																																		
Solar Thermal Energy				X																														
Photovoltaic Energy				X																														
Wind Energy				X																														
Ocean Thermal Energy				X																														
Fuels from Biomass											X																								
Geothermal Energy Program																																		
Envir. Cont. & Inst. Std.			X																										X	X					
Resource Expl. & Assess.			X																															
Hydrothermal Technology			X																															
Demonstration Projects			X																															
Advan. Tech. Applic.			X																															
Engineering R&D			X																															
Geothermal Res. Dev. Fund			X																															

Table 2
BB's Versus Volume 1 Technologies (Cont'd)

Volume 1 Energy RD&D Technologies

Building Blocks	Oil and Gas-Enhanced Recovery	Oil Shale	Geothermal	Solar Electric	Breeder Reactors	Fusion	Coal – Direct Utilization in Utilities/Industry	Waste Materials to Energy	Gaseous and Liquid Fuels from Coal	Fuels from Biomass	Nuclear Converter Reactors	Electric Conversion Efficiency	Energy Storage	Electric Power Transmission and Distribution	Solar Heating and Cooling	Waste Heat Utilization	Electric Transport	Hydrogen in Energy Systems	Transportation Efficiency	Industrial Energy Efficiency	Conservation in Buildings and Consumer Products	Basic Research	Biomedical and Environmental Research	Systems Studies	Information Dissemination	Manpower Development	Safety	Exploration and Resource Assessment	Mining and Beneficiation	Environmental Control Technology	Nuclear Safeguards	Support of the Nuclear Fuel Cycle	Uranium Enrichment	Fossil Fuel Transportation	Waste Management
Conservation																																			
Elec. Energy Sys. & Energy Stor.																																			
Electric Energy Sys.														X																					
Energy Storage Sys.													X					X																	
Tech. to Improve Eff.																																			
Industry Conservation																				X															
Buildings Conservation								X								X					X														
Trans. Energy Conser.																	X	X	X															X	
Energy Conversion												X																							
Fusion Power R&D																																			
Magnetic Fusion																																			
Confinement Systems						X																													
Reactor Projects						X																													
Dev. & Technology						X																													
Applied Plasma Physics						X																													
Laser Fusion						X																													
Nuclear Fuel Cycle R&D & Safe.																																			
Uranium Res. Assessment																												X	X						
Support of Nuc. Fuel Cyc.																																X			
Waste Management (Comm)																																			X
Nuclear Mats. Sec. & Safe.																															X				
Uran. Enrich. Process Dev.																																	X		
Adv. Iso. Sep. Tech.																																	X		
Fission Power																																			
Liq. Metal Fast Breed. Reactor																																			
Base Program R&D					X																														
Clinch River B.R.P. Proj.					X																														
Reactor Safety																											X								
Advanced Fuels					X																														
Water Cooled B.R.					X																														
Gas Cooled Reactors																																			
Thermal Reactors											X																								
Fast Breeder Reactor					X																														
Reactor Safety																											X								
Light Water Technology											X																								
Supporting Activities					X																														
Reactor Safety Facilities																											X								
Envir. Cont. Tech.																																			
Envir. Control Technology																														X					
Synthetic Fuels Comm. Demo. Prog.																																			
Synthetic Fuels Comm. Demo.		X							X	X																									

Table 2
BB's Versus Volume 1 Technologies (Cont'd)

Volume 1 Energy RD&D Technologies

Building Blocks	Oil and Gas-Enhanced Recovery	Oil Shale	Geothermal	Solar Electric	Breeder Reactors	Fusion	Coal—Direct Utilization in Utilities/Industry	Waste Materials to Energy	*Gaseous and Liquid Fuels from Coal*	Fuels from Biomass	Nuclear Converter Reactors	Electric Conversion Efficiency	Energy Storage	Electric Power Transmission and Distribution	Solar Heating and Cooling	Waste Heat Utilization	Electric Transport	Hydrogen in Energy Systems	Transportation Efficiency	Industrial Energy Efficiency	Conservation in Buildings and Consumer Products	Basic Research	Biomedical and Environmental Research	Systems Studies	Information Dissemination	Manpower Development	Safety	Exploration and Resource Assessment	Mining and Beneficiation	Environmental Control Technology	Nuclear Safeguards	Support of the Nuclear Fuel Cycle	Uranium Enrichment	Fossil Fuel Transportation	Waste Management
Supporting Technology Programs																																			
Biomed. & Envir. Res. Program																																			
Health Studies																							X												
Biological Studies																							X												
Environmental Studies																							X												
Physical & Tech. Stud.																							X												
Assessments																							X	X			X			X					
Basic Energy Sciences Program																																			
Materials Sciences																						X													
Molec., Math & Geo-sciences																						X													
Nuclear Sciences																						X													
Energy Rel. Supp. Act.																																			
Information Services																																			
Public Awareness																									X										
Tech. Information																									X										
General Systems Studies																								X											
General Tech. Transfers																								X											
Manpower																																			
Manpower Development																										X									
Education and Training																										X									

Table 3
Federal Agency Involvement(1)

Building Blocks	DOA (USDA)	DOC	DOD	DOI	DOL	DOT	EPA	FEA	FPC	GSA	HEW	HUD	NASA	NRC	NSF	TVA	USPS	WRC
Energy Technology Programs																		
Fossil Energy																		
Coal																		
Liquefaction																		
High BTU Gasification																		
Low BTU Gasification																		
Advan. Power Systems																		
Direct Combustion																		
Adv. Res. & Supp. Tech.																		
Demo. Plants																		
Magnetohydrodynamics																		
Pet. and Nat. Gas																		
Gas & Oil Ext.																		
Supp. Research		✓		✓														
In-Situ Technology																		
Oil Shale				✓														
In-Situ Coal Gas.																		
Supp. Research																		
* Extraction Tech.				✓														
* Resource Appraisal				✓														
Solar Energy																		
Thermal Applications																		
Solar Heat. & Cool. of Bldgs.		✓	✓					✓		✓		✓	✓					
Agric. & Indust. Proc. Heat	✓																	
Tech. Supp. & Util.																		
Envir. & Res. Assess.		✓	✓												✓			
Solar Energy Res. Inst.																		
Inform. Diss. & Commer.												✓						
Solar Electric Appl.																		
Solar Thermal Energy																		
Photovoltaic Energy								✓					✓		✓			
Wind Energy	✓		✓					✓					✓					
Ocean Thermal Energy			✓						✓									
Fuels from Biomass	✓		✓															
Geothermal Energy																		
Envir. Cont. & Inst. Std.															✓			
Resource Expl. & Assess.				✓											✓			
Hydrothermal Technology Appl.				✓														
Demonstration Projects																		
Advan. Tech. Appl.																		
Engineering R&D				✓											✓			
Geothermal Res. Dev. Fund																		
Conservation																		
Elec. Energy Sys. & Energy Stor.																		
Electric Energy Sys.		✓		✓			✓	✓										
Energy Storage Sys.			✓	✓		✓							✓		✓	✓	✓	
Tech. to Improve Eff.																		
Industry Conservation	✓	✓						✓										
Buildings Conservation	✓	✓	✓					✓		✓	✓	✓				✓		
Trans. Energy Conser.	✓	✓	✓	✓		✓	✓	✓		✓			✓		✓		✓	
Energy Conversion																		

(1) All Building Blocks listed contain ERDA programs except those marked with an asterisk (*).

Table 3
Federal Agency Involvement (Cont'd)[1]

Building Blocks	DOA (USDA)	DOC	DOD	DOI	DOL	DOT	EPA	FEA	FPC	GSA	HEW	HUD	NASA	NRC	NSF	TVA	USPS	WRC
Fusion Power R&D																		
Magnetic Fusion																		
Confinement Systems																		
Reactor Projects																		
Dev. & Technology																		
Applied Plasma Physics																		
Laser Fusion		✓	✓															
Nuclear Fuel Cycle R&D & Safe.																		
Uranium Res. Assessment				✓														
Support of Nuc. Fuel Cyc.														✓				
Waste Management (Comm)				✓										✓				
Nuclear Mats. Sec. & Safe.			✓											✓				
Uran. Enrich. Process Dev.																		
Adv. Iso. Sep. Tech.		✓	✓											✓				
Fission Power																		
Liq. Metal Fast Breeder Reactors																		
Base Program R&D																		
Clinch River B.R.P. Proj.																✓		
Reactor Safety														✓				
Advanced Fuels																		
Water Cooled B.R.																		
Gas Cooled Reactors																		
Thermal Reactors													✓					
Fast Breeder Reactor																		
Reactor Safety														✓				
Light Water Technology														✓		✓		
Supporting Activities		✓	✓	✓														
Reactor Safety Facilities														✓				
Envir. Cont. Tech.																		
Envir. Control Technology	✓			✓			✓									✓		
Synthetic Fuels Comm. Demo.																		
Synthetic Fuels Comm. Demo.																		
Supporting Tech. Programs																		
Biomed. & Envir. Res. Program																		
Health Studies							✓				✓			✓				
Biological Studies							✓				✓				✓	✓		
Environmental Studies	✓	✓		✓			✓				✓			✓	✓	✓		
Physical & Tech. Stud.		✓		✓			✓		✓						✓	✓		
Assessments	✓	✓		✓			✓		✓							✓		✓
Basic Energy Sciences Program																		
Materials Sciences			✓	✓									✓		✓			
Molec. Math & Geo-sciences				✓											✓			
Nuclear Sciences															✓			
Energy Related Supp. Activities																		
Information Services																		
Public Awareness	✓							✓										
Tech. Information Services		✓		✓														
General Systems Studies	✓			✓				✓	✓						✓	✓		
General Tech. Transfers													✓					
Manpower																		
Manpower Development					✓													
Education and Training																		

[1] All Building Blocks listed contain ERDA programs except those marked with an asterisk (*).

PART V
APPENDIX

ACRONYMS

AAPS —Advanced Automotive Power System
ACDA —Arms Control and Disarmament Agency
ACES —Annual Cycle Energy System Program
AEC —Atomic Energy Commission
AECS —Annual Energy Cycle System
AETF —Advanced Equipment Test Facility
AGA —American Gas Association
AGS —Alternating Gradient Synchrotron
AGARD —Advisory Group for Aerospace Research and Development
ANL —Argonne National Laboratory
AR&T —Advanced Research and Technology
ARAC —Atmospheric Release Advisory Capability
ARMS —Aerial Radiological Monitoring System
ARPA —Advanced Research Projects Agency
ARS —Agricultural Research Service
ASEAN —Association of Southeast Asian Nations
ASTM —American Society of Testing Materials
ATMES —Advanced Technology Mix Energy Systems
AWBA —Advanced Water Breeder Applications

BA —Budget Authority
BB —Building Block
BER —Biomedical & Environmental Research
BES —Basic Energy Sciences
BLM —Bureau of Land Management
BNL —Brookhaven National Laboratory
BO —Budget Outlays
BRC —Breeder Reactor Corp.
BuM —Bureau of Mines
BuRec —Bureau of Reclamation

CCIUS —Campus Community Integrated Utility System Project
CCMS —Committee for the Challenges of Modern Society, NATO
CEQ —Council on Environmental Quality
CEUS —Community Utility/Energy Program System
CFR —Code of Federal Regulations
CFTL —Core Flow Test Loop
CIB —International Center for Buildings
CIP —Cascade Improvement Program
CNRS —French National Center of Scientific Research
COED —Char-oil Energy Development
CPDF —Centrifuge Plant Demonstration Facility
CPL —Component Preparation Laboratories
CRBR —Clinch River Breeder Reactor
CRBRP —Clinch River Breeder Reactor Plant Project
CTIU —Component Test and Integration Unit
CTF —Component Test Facility
CUP —Cascade Uprating Program
CVT —Continuously Variable Transmissions

DARPA —Defense Advanced Research Projects Agency
DGE —Division of Geothermal Energy
DOA* —Department of Agriculture
DOC —Department of Commerce
DOD —Department of Defense
DOI —Department of Interior
DOT —Department of Transportation
DP —Data Processing
DSE —Division of Solar Energy

EACT —Emergency Action and Coordination Team
EBFF —Electron Beam Fusion Facility
EBR-II —Experimental Breeder Reactor-II
ECAS —Energy Conversion Alternatives Study
ECCS —Emergency Core Cooling System
EDP —Environmental Development Plan
EIA/EIS —Environmental Impact Assessment/Environmental Impact Statement
EIS —Environmental Impact Statement
E/M —Electromagnetic
EPA —Environmental Protection Agency
EPCA —Energy Policy Conservation Act
EPIC —Energy Conservation Program Guide for Industry and Commerce
EPR —Experimental Power Reactors
EPRI —Electric Power Research Institute
ER —Environmental Report
ERC —Energy Research Center
ERDA —Energy Research and Development Administration
ES&H —Environment, Safety and Health
ETR —Engineering Test Reactor
ETF —Engineering Test Facilities

FAA —Federal Aviation Administration
FAS —Fuels Availability System
FBI —Federal Bureau of Investigation
FEA —Federal Energy Administration
FERF —Fusion Engineering Research Facility
FFTF —Fast Flux Test Facility
FMEF —Fuels and Materials Examination Facility
FPC —Federal Power Commission
FRA —Federal Railroad Administration
FRG —Federal Republic of Germany
FSAR —Final Safety Analysis Report
FTC —Federal Trade Commission
FWS —Fish and Wildlife Service

* Also: USDA.

GA —General Atomic Company
GASSAR —General Atomic Company Standard Safety Analysis Report
GBR —Gas Breeder Reactor Associates
GCFR —Gas Cooled Fast Breeder Reactor
GCR —Gas Cooled Reactor
GESMO —Generic Environmental Statement on the use of Recycle Plutonium in Mixed Oxide Fuel in LWRs.
GOCO —Government-Owned Contractor-Operated
GRID —National Geothermal Resource Information Data Bank
GRIST —Gas Reactor In-Pile Safety Test
GSA —General Services Administration

HEGLF —High Energy Gas Laser Facility
HELF —High Energy Laser Facility
HEW —Department of Health, Education and Welfare
HRDF —HTGR Recycle Demonstration Facility
HTGR —High Temperature Gas Cooled Reactor
HUD —Department of Housing and Urban Development
HYGAS —High Btu Gasification Process

IAEA —International Atomic Energy Agency
IAEA/UN —International Atomic Energy Agency/ United Nations
ICE —Internal Combustion Engine
ICRP —International Commission on Radiological Protection
ICRU —International Commission on Radiation Units
ICSP —The International Committee on Standards Policy
IEA —International Energy Agency
IEA/OECD —International Energy Agency/Organization of Economic Cooperation and Development
INIS —International Nuclear Information Systems
INS —Intense Neutron Source
IPTASE —Inter-agency Panel on Terrestrial Applications of Solar Energy
IUS —Integrated Utility System

KGRA —Known Geothermal Resources Areas

LAMPF —Anderson Meson Physics Facility at Los Alamos
LASL —Los Alamos Scientific (National) Laboratory
LBL —Lawrence Berkeley (National) Laboratory
LCC —Life Cycle Cost
LIS —Laser Isotope Separation
LLL —Lawrence Livermore (National) Laboratory
LMFBR —Liquid Metal Fast Breeder Reactor
LNG —Liquified Natural Gas
LOCA —Loss of Coolant Accident
LOFT —Loss of Fluid Test
LWBR —Light Water Breeder Reactor
LWR —Light Water Reactor

MAP3S —Multistate Atmospheric Power Production Pollution Studies Program
MFE —Magnetic Fusion Energy
MHD —Magnetohydrodynamics
MIUS —Modular Integrated Utility System

NATO —North Atlantic Treaty Organization
NAHB —National Association of Homebuilders
NASA —National Aeronautics and Space Administration
NBS —National Bureau of Standards (under the Department of Commerce)
NCA —National Coal Association
NCI —National Cancer Institute
NEA —Nuclear Energy Agency
NEG —Net Energy Gain
NEPA —National Environmental Policy Act
NHTSA —National Highway and Traffic Safety Administration
NIEHS —National Institute of Environmental Health Sciences
NOAA —National Oceanic and Atmospheric Administration
NRC —Nuclear Regulatory Commission
NRDS —Nuclear Rocket Development Station
NSF —National Science Foundation
NTS —Nevada Test Site
NTIS —National Technical Information Service
NURE —National Uranium Resource Evaluation Program

OCS —Outer Continental Shelf
OEA —Office of Environmental Affairs
OECD —Organization for Economic Cooperation and Development
ORNL —Oak Ridge National Laboratory
OS —Operational Safety
OTEC —Ocean Thermal Energy Conversion

PAD —Program Approval Document, ERDA
PBF —Power Burst Facility
PCRV —Pre-Stressed Concrete Reactor Vessel
PCTF —Plant Component Test Facility
PEP —Positron Electron Project
PFE —Plenum Filling Experimental Facilities
PLBR —Prototype Large Breeder Reactor
PLT —Princeton Large Torus
PMC —Project Management Corporation
PNE —Peaceful Nuclear Explosives
PNL —Pacific Northwest Laboratory (of Batelle)
PON —Program Opportunity Notice
PPPL —Princeton Plasma Physics Laboratory
PSAR —Preliminary Safety Analysis Report
PWR —Pressurized Water Reactors

R&D —Research and Development
RD&D —Research, Development and Demonstration
RDF —Refuse-Derived Fuel
RERF —Radiation Effects Research Foundation
RFP —Request for Proposal
RIA —Request for Implementation Applications
RSR —Reactor Safety Research
RTNS —Rotating Target Neutron Source

SAES —State Agricultural Experiment Station
SAREF —Safety Research Experiment Facility

SASOL —Sasolburg, South Africa Coal Liquefaction Plant
SBE —Scientific Breakeven
SERI —Solar Energy Research Institute
SFB —Significant Fusion Burn
SLAC —Stanford Linear Accelerator Center
SNG —Substitute (Synthetic) Natural Gas
SNM —Special Nuclear Materials
SOA —state-of-the-art
SOLFRAC —Solvent Fracturing
SPC —Solar Photovoltaic Conversion
SPEAR —Stanford Positron Electron Asymmetric Ring
SPS —Space-based Power Systems
SRC —Solvent Refined Coal
SuperHILAC/Bevalac —Heavy Ion Linear Accelerator Facility in Calif.

TES —Total Energy Systems
TFTR —Tokamak Fusion Test Reactor
TIES —Total Integrated Energy System
TREAT —Transient Reactor Test Facility
TVA —Tennessee Valley Authority

UK —United Kingdom
UMTA —Urban Mass Transit Administration
UNEP/GEMS —United Nations Environmental Program/Global Environmental Monitoring System
UNSCEAR —United Nations Scientific Committee on Effects of Atomic Radiation
USDA* —United States Department of Agriculture
USFS —United States Forest Service
USGS —United States Geological Survey
USPS —United States Postal Service
USSR —Union of Soviet Socialist Republics

VHTR —Very High Temperature Gas Cooled Reactor

WEC —Wind Energy Conversion
WECS —Wind Energy Conversion Systems
WRC —Water Resources Council

ZGS —Zero Gradient Synchrotron

* Also: DOA.

ABBREVIATIONS

ac —alternating current
amps —amperes

BPDE —barrels per day equivalent
Btu —British thermal unit
Btu-SCF —Btu/Standard cubic foot (feet)

°C —degree centigrade
CO_2 —carbon dioxide
cm —centimeter

dc —direct current

°F —degree Fahrenheit
ft —foot
FY —fiscal year

GW —giga watt electric
G_eV —gigaelectronvolt
GNP —gross national product
GPD —gallons per day
GPM —gallons per minute

H_2S —hydrogen sulfide
h.p. —horsepower

kW —kilowatt
kW_eh —kilowatt hour
kgm —kilogram

kV —kilovolt
KVDC —kilovolt direct current
KVAC —kilovolt alternating current

MJ —mega joule
MW —megawatt
MTU —metric tons uranium
MW_e —megawatts electric
MWD/t —megawatt days thermal
MeV —million electron volts
mV —millivolt
MWt —megawatts thermal

NO_X —nitrogen oxides

PDU —Process Development Unit
Psi —pounds per square inch
ppm —parts per million

quad —10^{15} British Thermal Units

SCF —standard cubic feet
SO_X —sulfur oxides
SO_2 —sulfur dioxide
SWU —Separative Work Unit

T/D —tons per day

UF_6 —uranium hexafluoride