ENERGY RESEARCH: ALTERNATIVE STRATEGIES FOR DEVELOPMENT OF NEW ENERGY TECHNOLOGIES AND THEIR IMPLICATIONS FOR THE FEDERAL BUDGET

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PREFACE

Energy Research analyses and provides background information about federal efforts in research, development, and demonstration of new and emerging energy technologies. The analysis was performed in response to requests from the House and Senate Budget Committees. In keeping with the Congressional Budget Office's mandate to provide non-partisan analysis of policy options, the report contains no recommendations. This paper was prepared by Richard M. Dowd, Nicolai Timenes, Jr., and Kendrick W. Wentzel, with contributions from Mary Ann Massey and editorial assistance from Melinda Upp, under the direction of Douglas M. Costle.

The authors wish to express their appreciation to numerous reviewers who provided very helpful comments.

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SUMMARY

The Congress has long been concerned with energy issues; in recent years that concern has increased markedly, paralleling an increasing national awareness of energy problems.

Recognizing the important contribution that research can make to the solution of both short and long range energy problems, Congress has expanded and redirected federal policies and programs in energy research, development, and demonstration (R,D,&D). It has directed the Energy Research and Development Administration (ERDA) to design a national energy research and development plan and a program for implementing it.

In response to such changing priorities, ERDA in its national plan has described varying potential energy futures for the United States; other groups have also formulated alternative futures.

While the U.S. energy future could take any of these shapes, a consensus seems to exist that the most desirable future would have at least three characteristics: (1) a reasonable balance between total demand and domestic supply, resulting in reduced dependence on imports; (2) minimal adverse environmental impacts; and (3) a phased transition from the dominance of oil and gas from traditional sources to a much greater role for a broad variety of new technologies.

To achieve such a future, the United States would have to rely heavily on: (1) conservation or demand management, (2) important contributions from all major near-term technologies, and (3) dependence, in the long run, on some sort of "ultimate" technology using a virtually inexhaustible source.

The impediments--technical, environmental, economic, or institutional--to implementation of new or expanded technologies are of two types: those due to uncertainties (e.g., technical feasibility) and those due to other factors (e.g., prohibitive costs). -A strategy for R,D,&D can be designed to gather information that can reduce uncertainties. Such a strategy can also help develop methods to overcome other impediments, should this be

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judged desirable. However, other mechanisms, such as financial incentives, may be more appropriate in certain instances.

The criteria for designing research strategies may be grouped into three categories: support of desirable futures, insurance against failure, and cost.

The degree to which a given research strategy supports desirable futures depends on: its consistency with Congressional mandates emphasizing energy conservation, renewable resources, and environmental technologies; its support for an energy future not limited to a few sources but drawing from a wide diversity of types; and the balance it achieves among technologies that could provide energy over three timeframes: near-, mid-, and long-term.

Providing insurance against failure minimizes the chance that all or many technologies will prove infeasible (as some surely must). The degree to which a strategy satisfies this criterion depends on: its adequacy of attention to basic (as distinct from applied) research; the pursuit of diverse technical approaches to any one source (e.g., supporting both centralized and localized conversion of solar energy so that technical risks are hedged); balance in the scale of research, so that large costly demonstration projects do not crowd out earlier stages; and proper pacing, so that the program does not proceed so quickly that problems and failures raised in one stage are incorporated into the next.

Finally, cost is a criterion because federal financial support for any endeavor must generally be limited. Cost could therefore become the determining factor in choosing between alternative strategies where other considerations were equal or similar.

Alternative Research Strategies

To illustrate the application of these criteria, five potential alternative research strategies have been evaluated. Each strategy differs in the degree to which it satisfies the criteria. The five strategies are:

(1) A strategy of continuing ERDA's present programs, completing ongoing projects and allowing modest real growth, but not allowing major new starts.

This is referred to as the "base program completion" strategy,

(2) A "full funding" strategy, including the elements of the base program completion strategy and carrying out all major additional R,D,&D projects identified in ERDA's national plan.

(3) A strategy emphasizing long-term nuclear fission technologies and downplaying all others.

(4) A strategy downplaying the fission programs but emphasizing all other long-term technologies.

(5) A strategy emphasizing near- and mid-term technologies and deferring all major long-term technology demonstration projects not already underway.

The base program completion strategy uses the President's fiscal 1977 budget request, with its five-year projections, as a base. Modest growth rates were incorporated and completion of projects already begun was assumed. However, no new projects would be initiated beyond 1977; it is very close to a "no new starts" strategy.

Consistency of this strategy with desirable futures is impaired by its reliance upon past projects and priorities. It would not respond to recently articulated priorities in solar energy, conservation, and environmental protection, nor would it permit pursuit of diverse technical approaches within any one source. While its pace of development would not be excessive, its lack of diversity would not provide insurance against the likelihood of future failures. This strategy would total $40.5 billion in budget authority over the next decade; it would reach its one-year peak of $4.7 billion in 1986.

The full funding strategy would add to the base program completion strategy all of the demonstration projects identified in ERDA's national plan in all program areas.

This strategy could be consistent with a desired energy future, including ERDA's preferred future, in that all program areas would be supported, providing diversity within each source and across all timeframes. Its weakness steins from the scale of effort and the pace. So much of its effort is devoted to large demonstration projects that budget constraints could imperil initiatives in the vital pre-demonstration stages of research and development. The full funding strategy would cost $63.7 billion in budget authority over the next decade; its one-year peak of $7.9 billion would occur in 1984.

The fission strategy would emphasize long-term solutions, especially the nuclear breeder reactor. It would add to the base program completion level all the demonstrations in nuclear fission programs but would not include demonstrations of other technologies.

This neglect of important nonfission sources, conservation, and the environment would be inconsistent with ERDA's desired future. It might not insure against failure, because it focuses only on one technology, even though all timeframes are covered. Pacing might also be a problem, because of its heavy emphasis on a single technology. This strategy would cost $51.3 billion in budget authority; its one-year peak of $6.1 billion would occur in 1981.

The fourth strategy would also emphasize long-term solutions; it would rely on nonfission technologies. It would add to the base program completion all of ERDA's suggested nonfission demonstrations, particularly for nuclear fusion and solar sources, but would not include new demonstrations for nuclear fission.

This strategy would also be inconsistent with ERDA's desired future because it would not assign an important role to the breeder. However, its support for a wide diversity of sources (other than the breeder) would help insure against failure. This strategy would cost $51.6 billion in budget authority; its one-year peak of $6.7 billion would occur in 1984.

The fifth strategy would emphasize near- and mid-term technologies. It would include all components of the base program completion strategy, to which would be added those projects identified in ERDA's national plan from which results could possibly be implemented in the near- or mid-term.

This strategy would not be completely consistent with desired futures, because demonstration projects for long-term technologies would be deferred. However, support of long-term processes at pre-demonstration levels would preserve some diversity among sources, including conservation and renewable resources. This strategy would cost $48.0 billion in budget authority in the next decade; its one-year peak of $5.4 billion would occur in 1983.

The total costs for these strategies over the next decade range from over $40 billion for completion of the base program to nearly $64 billion for the full funding strategy. The budget impacts of each strategy are summarized in Summary Table I.

SUMMARY TABLE I
FIVE ENERGY R,D,&D BUDGET ALTERNATIVES
(billions of 1977 dollars)

Strategy	Cumulative Ten-Year Budget Auth.	Peak One-Year Budget Auth.	Year of Peak
Base Program Completion	$40.5	$4.7	1986
Pull Funding	63.7	7.9	1984
Fission Emphasis	51.3	6.1	1981
Nonfission Emphasis	51.6	6.7	1984
Near- and Mid-Term Emphasis	48.0	5.4	1983

Each of the strategies implies future budget authority significantly higher than current levels. (The President's fiscal 1977 budget authority request for energy R,D,&D is

$3.1 billion.) While a strategy with a budget lower than current levels could certainly be designed, it would require a major shift in priorities set by Congress since the energy crisis of 1973-74.

Summary Chart 1 shows the budget authority pattern required for each strategy over the next 10 years. With the exception of the base program completion strategy, for which funding increases slowly, the budget authority required for each strategy rises to a maximum and then declines. Because the major projects now planned cannot extend a research program indefinitely, actual budgets after 1980 would depend on intervening decisions about budget levels, on the desirability of planned projects, and on cost requirements for introduction of new projects.

Selection Among Strategies

The desirability of each of these alternative strategies depends in part on a judgment as to which potential energy future is most satisfactory for the United States. If funding constraints are extremely severe or if it is decided that future large-scale demonstrations should be primarily the responsibility of the private sector, then it would be appropriate to select a strategy such as the base program completion strategy.

If, at the other extreme, Congress decides that extensive federal support of demonstrations is appropriate and that an additional $23 billion, beyond the costs of completing the base program, should be made available over the next 10 years for energy R,D,&D, then a full funding strategy could be selected.

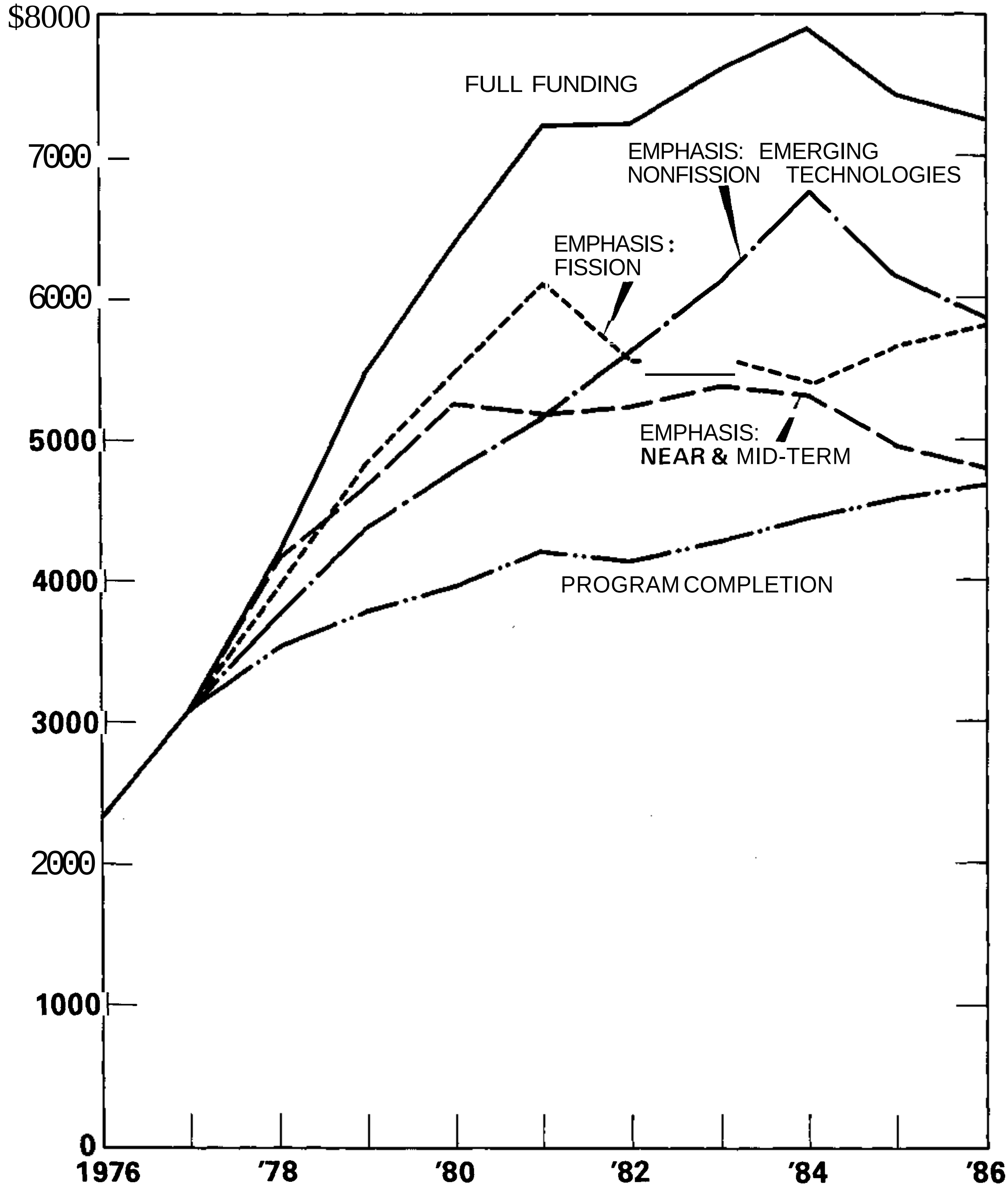
Selection of one of the three middle-cost strategies, which have very similar budget implications, could result from a decision that some intermediate level of funding should be supported. Such a selection could also reflect a Congressional decision that, for budgetary or other reasons, only one of the three major groups of middle-cost demonstration initiatives--near-and mid-term, fission, or nonfission technologies--deserves support.

Other Perspectives on Research Strategies

The five strategies imply quite different mixes of fission and nonfission research during the decade. The range is from about $25 billion--with nearly half of all

summary chart 1 Budget Authority for Alternative Research Strategies, 1976-1986

(In Millions of 1977 Dollars)



funding devoted to fission in that strategy--to about $13 billion, or a quarter of all funding, in the strategy emphasizing nonfission technologies.

The influence of demonstration stages is also quite significant in the choice of strategies. As funding for demonstration projects grows, the total R,D,&D program becomes less flexible. The full funding strategy would devote about 45 percent of all funding over the next decade to demonstration projects, while the strategies emphasizing fission, nonfission, or near- and mid-term technologies would spend about one-fourth of the total on demonstrations. The base program completion strategy would spend about one-tenth on demonstrations.

Final detailed decisions on a research strategy do not have to be made now. The budget paths described above would result from a series of decisions to be made over the next decade. Research is dynamic, and new information becomes available almost daily. That information is useful in itself; it can also be used to help shape those decisions to be made in the future.

Each such decision, however, represents a step along a strategic path. The pattern of those decisions over the next few years, especially with respect to funding major demonstrations, will--whether by conscious design or by piecemeal actions--result in the definition of a U.S. energy R,D,&D strategy. That pattern of decisions will have significant impacts on the federal budget over the next 10 years.

CHAPTER I
INTRODUCTION

Congressional concern about U.S. energy problems has increased markedly in recent years. Briefly, those problems include (1) the finite character of traditional domestic sources of energy, such as oil and gas, whose production has peaked and begun to decline; (2) environmental effects related to energy production, transportation, and use; (3) increasing energy prices in the early 1970s, with attendant increases in unemployment and inflation rates; and (4) the possibility of another embargo that would disrupt U.S. energy imports and harm the economy.

Since the 1973-74 embargo, increasing attention has been focused on the long-range importance of energy technologies that are now only on the drawing boards or in the laboratory. Many such technologies, if developed successfully, promise to permit the exploitation of large, hitherto untapped domestic resources or provide environmental or economic advantages over existing technologies.

Much work remains before such potentials can be realized. For some promising technologies, questions of technical feasibility remain to be resolved; for others, technical feasibility has been established but economic feasibility has not. Other impediments to early introduction include potential environmental problems or institutional constraints.

A research program can investigate such potentials and provide information that reduces uncertainties. Partially in response to recent U.S. energy problems, support for energy research, development, and demonstration (R,D,&D) in recent years has become one of the fastest growing components of the federal budget.

This paper analyses the rationale for a federal energy research program, presents some of the opportunities for investigation of energy technologies, and describes the major criteria for designing an energy research strategy. Five alternative long-run energy research strategies, their long-term budgetary implications, and possible impacts on the fiscal year 1977 budget are outlined.

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The balance of this chapter briefly describes the technical opportunities in energy, discusses Congressional energy concerns and responses (particularly as they affect research and development), describes the national plan for energy research, development, and demonstration prepared by the U.S. Energy Research and Development Administration (ERDA), and outlines some energy issues and options.

Chapter II considers the role of new and emerging technologies in shaping the nation's energy future, the impediments to realization of that potential and, hence, the targets for research. Chapter III discusses the rationale for federal involvement and the criteria for designing a research program. Chapter IV first describes the President's requested energy research budget for fiscal year 1977 with its implicit priorities; it then outlines five alternative long-run research strategies and evaluates each one in terms of the criteria developed in Chapter III. Finally, Appendix A describes the funding history, program content and trends, initiatives and issues for 1977, and future program implications and decisions for each of the major federal energy R,D,&D program components.*

Potential Energy Technologies

The many potential energy technologies that might prove feasible draw on a variety of energy forms. In this paper, energy programs are classified into three broad categories: CD ERDA's direct energy R,D,&D, (2) ERDA's supporting technologies, and (3) direct energy R,D,&D by other agencies.

Direct Energy R,D,&D. ERDA's direct energy R,D,&D programs include four categories of nonnuclear res.earch and three of nuclear research.

Nonnuclear Technologies:

- Fossil energy includes research on direct combustion of coal, conversion of coal and

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*A separate backup paper, detailing methodology and data used in developing the projections in this report, has been prepared for staff use. See Congressional Budget Office CCBO) Technical Staff Working Paper, Federal Energy Research; An Analysis of Fiscal 1977 Program Funding Levels and Alternative Fiscal Budget Paths Through Fiscal 1986, July 1976.

oil shale to clean fuel products and petrochemical feedstocks, advanced power cycles for deriving electric power from coal, and improved techniques for extracting oil and gas from the ground.

- Solar energy includes the direct use of the sun's energy in heating and cooling of buildings, conversion of solar energy to electricity, wind energy, technologies to tap the power of the oceans, and so forth.

- Geothermal energy investigates ways of tapping heat in rocks or fluids far below the surface of the earth.

- Conservation programs address methods to use energy more efficiently.

Nuclear Technologies:

- Fusion power addresses different methods of exploiting the energy released when atoms are combined. These programs may result in the long term in *a* new generation of nuclear energy sources.

- Fission Reactor research investigates the reactions in which the splitting of atoms releases energy. This program addresses both the current generation of once-through converter reactors and a new generation of breeder reactors.*

- Other Nuclear programs investigate those activities which support nuclear fission reactions. Fuel cycle R,D,&D, uranium enrichment, and nuclear materials security and safeguards are included in this category.

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*The breeders are a case of special interest. Ordinary "converter" fission reactors use only a small amount of the potential energy in uranium, most of which then becomes a waste product. "Breeders" use similar amounts of energy but, in the process, also convert more of the otherwise unusable uranium into usable plutonium than do ordinary reactors. Breeders produce more plutonium than is used up in this process, thus "breeding" more fuel and greatly extending the uranium resource base. The considerable controversy surrounding breeder development has focused on potential environmental and safety hazards, as well as on economic considerations.

Supporting Technologies. These include the environmental research, safety research, and basic energy science programs funded by ERDA,

Other Federal Energy R,D,&D. Agencies other than ERDA also conduct direct energy R,D,&D, but are funded more modestly. The largest programs are nuclear safety research in the Nuclear Regulatory Commission, coal mining research in the Bureau of Mines of the Department of the Interior, and the environmental research programs of the Environmental Protection Agency (EPA).

Congressional Concerns With Energy Research

The Congress has long supported federal research at a modest scale on a broad variety of energy forms and technologies. Under the Atomic Energy Act of 1954, research, development, and demonstration of nuclear power has been carried to the point of successful commercialization of fission technologies, such as the current generation of reactors. Until early in the 1970s, however, nuclear power was the only technology annually funded at the level of several hundred million dollars.

In recent years, Congress has mandated--and has increased funding for--aggressive investigation into technical opportunities in other areas. The major Congressional policy statement in regard to nonnuclear R,D,&D is contained in the Federal Nonnuclear Energy Research and Development Act of 1974, P.L. 93-577. That act recognizes a broad spectrum of objectives for the nation's energy research strategy; while a greater degree of self-sufficiency in energy is clearly implied as an objective, the act also calls for a balancing of this and other economic objectives with environmental and social goals.

In the act, Congress broadened the scope of the federal energy research and development program by a commitment to "...a total Federal investment which may meet or exceed $20,000,000,000 over the next decade." Congress wanted to elicit "...the broadest range of energy policy options." To accomplish this, the act directs ERDA to "...establish and vigorously conduct a comprehensive, national program of basic and applied research and development...."

Congress has supported its mandates for broadened energy R,D, &D programs with accompanying increases in funding. In fiscal 1976, for example, outlays for energy R,D,&D were three times the fiscal 1974 level. The President's requested fiscal 1977 budget would represent an increase of more than 30 percent above fiscal 1976 levels.

In addition to development of new energy supply technologies, the act specifically requires energy research to incorporate conservation initiatives, including "... improvement in efficiency of energy production and use, and reduction in energy waste....advance[d] energy conservation technologies...[and] improve[d] techniques for the management of existing energy systems...."

Demonstration and Commercialization

Success of a technology in the laboratory or at the larger "pilot plant" scale does not necessarily ensure its adoption for commercial production. Substantial uncertainties--particularly with regard to reliability, cost, and profitability--can remain in translating that success into production. Two stages remain before R,D,&D can result in actual energy production: (1) demonstration of a technology at a scale of components that approximate commercial size individually (but not necessarily in a commercially viable assembly) in order to gather additional information, and (2) commercialization, the building and operation of a commercial scale plant that demonstrates continuing reliability and produces a product that can be sold at a profit.

Increasingly, as federal energy R,D,&D efforts accelerate and processes are proven at ever larger scales, decisions will be required about the potential expansion of federal participation in R,D,D,&C--research, development, demonstration, and commercialization. Except for certain nuclear energy programs, federal involvement in energy has traditionally focused on basic R&D, leaving demonstration and commercialization largely to private industry. In the past two years, Congress has addressed the demonstration issue and found that previous national efforts and levels of funding had limited the nation's options in these areas. To remedy this, Congress enacted the Solar Heating and Cooling Demonstration Act of 1974, the Geothermal Energy Research, Development, and Demonstration Act of 1974, and the Solar Energy Research, Development, and Demonstration Act of 1974. These bills set a policy of supporting and encouraging federal energy R,D,&D and established large-scale demonstration programs.

Commercialization addresses issues of a different type, such as size of investment and financial Cas opposed to technical) risks. A number of commercialization proposals are now before the Congress, However, commercialization issues are beyond the scope of this paper and are addressed elsewhere.*

ERDA's National Plan For Energy Research, Development, and Demonstration

Concerned with an apparent lack of clear direction for future research, the Congress gave ERDA responsibility for coordinating all federal energy R,D,&D and required the agency to develop comprehensive plans for energy research, development, and demonstration that reflect Congressional policy guidance. ERDA is also responsible for developing a comprehensive program to implement the plan. Both the plan and the program implementation are to be updated annually and submitted to Congress.

Responding to this mandate, in June, 1975, ERDA submitted to Congress its initial plan entitled "A National Plan for Energy Research, Development and Demonstration: Creating Energy Choices for the Future" (ERDA-48). The plan defines ERDA's interpretation of energy policy goals, presents alternative energy technology futures ("scenarios") and identifies one scenario as consistent with a policy goal of energy independence. That scenario requires development of a broad range of technologies for near-, mid-, and long-term use and emphasizes the importance of nuclear power. These results are used to define research priorities.

According to ERDA's plan, near-term supply priorities are direct use of coal, nuclear fission, conversion of waste material to energy, and enhanced recovery of oil and gas. Mid-term priority sources are synthetic fuels from

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*See, for example, Congressional Budget Office Background Paper #3, "Commercialization of Synthetic Fuels: Alternative Loan Guarantee and Price Support Programs," January 16, 1976, and its companion staff analysis, "Financing Energy Development," forthcoming. See also CBO Background Paper #7, "Uranium Enrichment: Alternatives for Meeting the Nation's Needs and Their Implications for the Federal Budget," May 18, 1976.

coal and oil shale. Long-term priority sources are breeder reactors, nuclear fusion, and solar electric. To reduce energy demand, ERDA states that highest priority is to be given to near-term technologies designed to improve efficient use of energy and to reduce waste.

In a separate volume, ERDA outlines its program for implementation of its national plan. The plan and program, together with agency budget requests, define ERDA's research strategy and form the data base for much of the analysis in this paper. In April, 1976, ERDA submitted to Congress the first updated version of its national plan. This update builds on the earlier version; a major revision is its increased priority for conservation technologies. ERDA has emphasized the paramount role of the private sector, particularly with regard to conservation.

R,D,&D Issues and Budgets

The major energy R,D,&D issues addressed in this paper are the level and mix of funding for energy programs. In selecting a level and mix from the many potential alternatives, Congress will in effect resolve a number of other issues, including: the relative balance between fission and non-fission technologies, the impact of large demonstration project costs on the U.S. energy research program, the importance to be accorded to near- and mid-term technologies as distinct from long-term ones, the support to be given to environmental programs and to technologies emphasizing renewable resources. The paper describes the varying degrees of resolution that could be brought to each of these issues by selection among five alternative energy research strategies.

CHAPTER II
TECHNOLOGICAL POSSIBILITIES AND PROBLEMS

To define the objectives of an energy research strategy, to design the strategy, and to measure progress of the resulting research program require an understanding of the broader energy policy context in which the strategy is to be developed. Three questions are pertinent: (1) What can and should the nation's energy future look like? (2) What can and should be the role of new and emerging technologies in shaping that future? And, (3) What are the impediments to development and timely application of those technologies?

What Can and Should the Nation's Energy Future Look Like?

During the last few years, a consensus has evolved about certain characteristics of a desirable energy future. Those characteristics include sharply reduced reliance on imports, improved environmental quality, and a degree of protection of the economy against the effects of precipitate or large sustained increases in energy prices. The consensus extends to selection of the general methods that could be used to achieve such a future; the methods include wise use of available energy (conservation), efforts to accelerate development of domestic resources (particularly those hitherto largely untapped), emphasis on renewable or essentially inexhaustible resources, and an expanded role for new technologies.

Central issues in the energy debate remain, particularly the determination of the level of imports that would be consistent with national security concerns and the acceptability of both the economic and environmental costs associated with a long-range strategy of independence. Research, it is hoped, will develop information and technologies that would permit the exploitation of new resource targets, the more efficient use of traditional sources, and greater ability to reconcile security and economic and environmental imperatives.

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What Can and Should Be the Role of New and Emerging Technologies in Shaping That Future?

Use of energy resources has followed a classical pattern of discovery, understanding, development, exhaustion, and abandonment. In the 19th century, wood supplied the bulk of U.S. energy, accounting for as much as 80 percent of U.S. consumption in the 1860s. Coal then became the dominant fuel for nearly 60 years. The most recent cycle has emphasized oil and natural gas, which overtook coal during World War II and has reached a peak supply of about 75 percent of all energy, while coal has declined to around 20 percent. Each time a change in fuel use has occurred, new technologies for the supply and use of the new sources have come into widespread use.

This rapid passage from one fuel source cycle to another has left the United States with great differences in remaining domestic supplies of some major potential sources. For example, remaining coal sources contain at least 12 times as much thermal energy (expressed in units of common energy content) as do natural gas sources. And some as-yet-untapped sources, such as the uranium -fueled nuclear breeder reactor, could produce more than 10 times as much energy as the remaining coal. Finally, several potential sources, such as solar energy and nuclear fusion, are essentially unlimited. (See Appendix B for estimates of the supply available from all major existing or potential domestic sources.)

Projections of Future Supply and Demand

Several estimates have been made of future levels of domestic energy supply and demand. Most influential in shaping federal research and development are the estimates made by ERDA in its national plan, which are the Administration's basis for planning the nation's energy technology future. In addition, the Ford Foundation Energy Policy Project's "A Time to Choose," the Federal Energy Administration's "Project Independence Report," and the Department of Interior's study "Energy Through the Year 2000" contain independently prepared estimates.* Such projections

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*Energy Research and Development Administration, "A National Plan for Energy Research, Development and Demonstration" ERDA-48, Vol. I, 1975. Energy Policy Project of the Ford Foundation, "A Time to Choose," 1974. Federal Energy Administration, "Project Independence Report," 1974. Department of Interior, Bureau of Mines, "Energy Through the Year 2000" (Revised), 1975.

can be used to evaluate the new technologies in terms of their potential contribution to future supplies.

A Business-as-Usual Future. In describing one potential future that assumed current policy and consumption patterns are continued, all four studies foresaw an energy demand in the year 2000 at more than twice present levels. In addition, all showed substantial reduction in the proportion of that demand that could be met by oil and natural gas. Currently, oil and natural gas supply about 75 percent of U.S. energy; by the year 2000, this proportion would drop to about 40 or 50 percent (even though the nation would be consuming twice the current amount of these fuels).

A Conservation Future. Three of these studies--ERDA's FEA's, and Ford's--estimated the effects of vigorous conservation measures (Table I). All agreed that conservation could significantly reduce demand by as much as 10 percent in 1985 and about 25 percent by 2000. (This reduction would be equivalent to lowering the nation's annual energy growth rate to 2.6 percent from the average 3.4 percent since World War II.)

ERDA's estimate assumed a conservation strategy that would improve end-use efficiency for heating and cooling, for industrial uses, and for transportation. Its strategy would reduce 1985 consumption by 10 quads* (from 107 to 97), or nearly 10 percent. The Ford Foundation, in its "Technical Fix" scenario, found that 1985 energy demand could be reduced from 115 to 92 quads. Similarly, FEA projected that 1985 demand could be reduced from 103 to 94 quads.

The conservation scenarios for the year 2000 are also close, ERDA estimated a demand of 122.5 quads, down from a business-as-usual 165 quads; the Ford study estimated 123-124 quads; and FEA estimated 120 quads. This would be a 25 percent reduction from the demand projected without a conservation strategy. Application of such a strategy would therefore contribute significantly toward balancing supply and demand.

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*Quad is defined in Table *I.*

TABLE I. THREE PROJECTIONS OF ENERGY DEMAND[a]
(in quads)[b]

	with conser.		without conser.	
	1985	2000	1985	2000
ERDA Conservation Scenario[c]	97	122.5	107	165
Ford Foundation's Energy Policy Project[d]	92	123-124	115-116	187-188
Federal Energy Administration's Project Independence Report[e]	94	120	103	145

a. All three projections incorporated reductions in demand estimated to be achieved through conservation.

b. Domestic energy consumption is often tabulated in quads of energy. A quad is quadrillion (10^{15}) British thermal units (BTU). One quad is equivalent to the energy produced by burning half a million barrels of oil per day for one year. In 1974, the nation consumed about 73 quads.

c. This scenario is ERDA's Scenario I. It is not ERDA's choice for the future; however, many of its conservation resources are incorporated in ERDA's preferred Scenario V.

d. This scenario is called the "Technical Fix" scenario.

e, FEA assumes a price of $11 per barrel for oil (in 1974 dollars).

Supply Sources, in addition to a scenario for a business-as-usual energy future and one for a conservation-oriented future, ERDA postulated four other scenarios based on different sets of assumptions about future energy uses and different mixes of sources. ERDA's six scenarios are:

Scenario O, the baseline scenario that extends present trends. It involves no initiatives in developing alternative energy sources or in adopting conservation measures. (This is the business-as-usual case.)

Scenario I, which calls for some increases in supply from alternative sources and for greatly improved efficiencies in energy end-use, including conservation in the industrial, residential, and transportation sectors and in electricity production and consumption. (ERDA treats this as its conservation scenario.)

Scenario II, which relies on achieving major synthetic fuels production capability from coal and oil shale.

Scenario III, which envisions intensive electrification using new sources of generation, widespread use of electric cars, and improved electric efficiencies, e.g., in transmission and storage.

Scenario IV, which calls for "limited" nuclear power (no more than the equivalent of 200 plants each producing 1,000 megawatts), production of synthetic fuels, and improved industrial efficiency.

Scenario V, which combines production from all potential technologies at maximum or near-maximum levels. It calls for all the conservation improvements included in Scenario I, as well as for the electric car usage projected in Scenario III.

ERDA concluded that only Scenario V is an acceptable future: Although several scenarios would limit imports, only Scenario V would eliminate them in the year 2000. The import criterion thus appeared to override other considerations in ERDA's choice of an acceptable and desired energy future.

If, however, the import criterion were relaxed somewhat to allow small but still significant imports of oil, other futures would be both possible and acceptable. For example, if the conservation features of Scenario I were combined with features of other supply-oriented scenarios, then considerably more flexibility could be obtained for contributions from various future energy sources than is provided by Scenario V. If some imports were allowed, none of the new sources and technologies would be forced to provide as much energy as now seems necessary, and failure or reduced success of any given new technology could be more easily accommodated. Much turns, then, on the notion of an "acceptable" level of imports. Clearly, the price and embargo risks of some modest level of imports could be tolerated, especially considering the potentially extreme costs of achieving full independence; yet the analysis which would permit selecting such a level has not been done. For the present, selection of an acceptable level remains a policy judgment.

The Need for New Technologies

Depletion of traditional sources of domestic oil and gas, along with an annual growth rate in energy demand generally estimated to be at least 2.5 percent, creates a clear need for development of different sources and new technologies. ERDA has called for a substantial increase in energy production both from existing sources such as coal and from new technologies such as oil shale, solar, geothermal and synthetic fuels. While the relative emphasis on the role of various technologies may differ as a result of different assumptions or criteria (as, for example, relaxation of a zero imports goal), it is clear that a broad range of technologies that are not now commercially employed will be required to achieve energy policy goals.

New technologies will be required for efficient use of traditional resources in the near-term, to tap new but finite resource targets in the mid-term, and to develop essentially inexhaustible sources for the longer term. The central issues for research design implicit in alternative futures are the timing and extent of need for specific technologies.

What Are the Impediments to the Development and Timely Introduction of New Technologies?

Technical, economic, environmental, and institutional barriers may impede introduction of new technologies.

Technical Impediments

For many potential technologies, major technical uncertainties remain. For example, it is not certain that a controlled fusion reaction can be sustained and confined. Once sustained and confined reactions have been demonstrated, significant technical problems relating to materials, fuel handling, and safety remain to be resolved.

Similarly, while solar electric technologies, both thermal and photo-voltaic, do work, substantial R,D,&D efforts will be required to overcome technical impediments to sizing, efficiency and the life of units. Similar technical problems confront other potential technologies.

Economic

Many potential energy technologies are subject to substantial economic impediments, which can relate to cost, profitability, risk, and size of investment.

A chief impediment, for example, to the introduction of technology to produce crude oil from coal is the expectation that such oil would cost more than $20 per barrel. At that cost, synthetic crude oil could not compete with imported oil available at $13 per barrel.

Technologies such as solar heating and cooling of buildings, conservation technologies, enhanced recovery of oil and gas, and solar electric production are impeded by similar concerns.

Environmental Concerns

Using energy often causes adverse secondary effects, particularly relating to health and safety and environmental impacts. Smog from gasoline consumption, sulfur oxides from coal and oil use, and the effects of unreclaimed strip mining are all evident environmental impediments associated with some existing energy technologies.

The introduction of new technologies or the accelerated use of older ones can raise concern about such environmental issues as storage of nuclear wastes, the toxicity of synthetic fuel processes, and the effect on the land of oil shale development. Such environmental impacts may present strong impediments to the introduction and use of new technologies.

Institutional Barriers

Some difficulties in introducing new energy technologies result from existing institutional barriers rather than technical impediments. For example, the building industry has difficulty incorporating new solar cooling and heating techniques because local building codes often lack provisions for such innovations and jurisdiction over such codes is splintered among numerous autonomous government bodies. Development of standards in these areas is critical to the introduction of such innovations.

Other institutional barriers arise from the nature of the relevant industries. For example, the concentrated nature of the electric utility industry, with its limited number of members and highly centralized facilities, might be expected to present fewer barriers to the introduction of centralized solar electric technology than the highly diversified and decentralized local contractor/construction industry would present to the widespread introduction of localized solar heating and cooling systems.

Public acceptance of a new technology or of expanded use of an older one may also be in part an institutional barrier affecting regulatory action and consumer use. This factor can be closely related to perceived environmental and economic impediments and can influence the potential success of technological introduction.

Implications for Design of a Research Strategy

Some of these impediments are due to uncertainty about the issue: Is the technology feasible? What are the environmental impacts? What would the price be? An R,D,&D program can be designed to gather information which may reduce such uncertainties. Other impediments are not due to uncertainty; the price may be known to be too high; existing standards would not be met. The decision then must be made whether to try to overcome the barrier or to defer pursuit of the technology. In some cases, an R,D,&D program may generate information to reduce the barrier, but in others entirely different mechanisms--such as an incentive program for commercialization--are appropriate. In any event, an R,D,&D program can be effective in providing a basis for decisions about new or expanded technologies.

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CHAPTER III
DESIGNING A RESEARCH STRATEGY

Given these perceptions of the range of likely and desirable roles for new technologies and the impediments to realization of those roles, two further questions pertain: (1) What should be the role of the federal government in attempting to remove these impediments? And (2) What should be the criteria for a research strategy?

The Federal Role

As indicated earlier, limits on the federal role are, to some extent, spelled out in legislation. The Atomic Energy Act of 1954, as amended, sets forth a policy of research, development, and demonstration for nuclear technologies. The Nonnuclear R&D Act states that the federal government should conduct a comprehensive, aggressive and vigorous investigation of all potentially beneficial energy sources and technologies.* The program

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*P.L. 93-577, Section 5(b)(2), Nonnuclear Energy Research and Development Act of 1974. "In determining the appropriateness of Federal involvement in any particular research and development undertaking, the Administrator [of ERDA] 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 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.
CO The extent of the problems treated and the objectives sought by the undertaking are national or widespread in their significance.
CD) 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.

is to be designed to facilitate the commercialization and use of these new and alternate technologies and sources, especially energy conservation and renewable or essentially inexhaustible sources. While the nation's energy future could take almost any of the forms described either in ERDA's six scenarios or in numerous other projections, the more widely acceptable possibilities seem to share three characteristics: (1) a reasonable balance between total demand and domestic supply, resulting in reduced dependence on imports; (2) minimal adverse environmental impacts; and (3) a phased transition from the dominance of petroleum oils and natural gas to a much greater role for a broad variety of new technologies dependent on more abundant domestic resources.

Achieving a future with these characteristics will necessitate: (1) a heavy reliance on conservation or demand management, supported by research into methods that would make energy usage more efficient; (2) important contributions--necessitating near-term R,D,&D--from all the major near-term technologies, such as nuclear fission, coal and coal-based synthetic fuels, and oil and gas from traditional sources; and (3) in the long run (perhaps well after the turn of the century) a dependence on some sort of "ultimate" technology, thus requiring a long-term R,D,&D program to explore such ultimate technologies.

Congressional criteria suggest federal involvement if: (1) private sector research is unlikely because of large costs or risks or long lead-times, (2) the public need for results is urgent, and (3) the public benefits are anticipated to be extensive.

(E) The degree of risk of loss of investment inherent in the research is high, and the availability of 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."

In a strategy for energy research, development and demonstration, a stronger case can be made for federal support in the earlier, more risky research phases than in the later phases. Where private research does exist, the federal role would be supportive and complementary.

Finally, it is sometimes argued that the social benefit--whether it be increased safety, low environmental impact, or reduced oil imports--of advancing new technologies justifies further federal expenditures beyond those required simply to prove that a process will work. In particular, the Nonnuclear Energy R&D Act directs ERDA to formulate its plan not merely to prove processes will work but also to achieve solutions to energy supply and environmental problems. Thus, if in some cases--notably conservation and solar heating and cooling--economic and institutional, rather than technical, barriers are controlling, then research with that focus would also be appropriate.

Criteria for a Research Strategy

Properly conceived, a research strategy should be designed to collect knowledge that will allow informed choices to be made among technologies and stages of research, development, and demonstration. Criteria for design may be divided into three groups: A research strategy should (1) support the attainment of desirable futures, (2) provide insurance against technical failure, and (3) do so at minimum cost. These criteria are not always compatible; therefore judgments on relative emphasis and balance within a research strategy will vary.

Support of Desirable Futures

Consistency with Futures. Clearly, any research strategy should be directed toward achieving a future that is considered desirable. (The obverse is also true; the strategy should not be directed toward gathering information about technologies that broad consensus indicates are undesirable.) The Nonnuclear Energy R&D Act, in calling for emphasis on conservation, renewable resources, and mitigation of adverse environmental effects, establishes three characteristics of the nation's desired energy future.

Scope and Diversity of Source Types. An energy R,D,&D strategy should investigate several kinds of energy sources to provide maximum flexibility among options. In addition, it should explore technologies suitable for different organizing principles. For example, attention should be given to decentralized as well as to centralized energy systems, to avoid fostering dependence on a single kind of delivery system. Local solar heat and cooling units, for instance, could provide an alternative to large centralized electric generators and their extensive transmission systems to serve heating and cooling demands.

Timing and Scale of Benefits. An energy research strategy should be keyed to the scale of benefits to be derived from a proposed undertaking. Thus, other things being equal, a new supply source with potential widespread application could be a better candidate for federal support than one which might produce only local or marginal advantages.

The urgency of a particular need, such as supply in the short run, also bears on a research strategy. A technology to increase supply or reduce demand which could have a quick payoff may deserve support even if its long-term benefits would not be great.

To provide adequate options for the future, a strategy should cover three major timeframes: near-term (until 1985), mid-term (1985-2000), and long-term (beyond 2000). According to ERDA, each of these has technological possibilities that are considerably different, although they overlap somewhat. For the near-term, the major potential sources requiring research are conservation, direct use of coal, enhanced oil and gas recovery, nuclear fission reactors, and use of waste materials. For the mid-term, they are conservation, synthetic fuels from coal, shale oil, nuclear reactors, geothermal, and direct solar heating and cooling of buildings. For the long-term, the potential sources are centralized solar electric" generation, fusion, and the breeder reactor.

Insurance against Failure

There is no *a priori* certainty that any particular technology or approach will ultimately be successful. Indeed, a research strategy that resulted in no failures at all might well be criticized as too conservative. But a properly designed research strategy can help insure against the simultaneous failure of all lines of investigation.

Basic vs. Applied Research. Basic research tends to be applicable to more than one long-range technological problem and hence has a wider set of potential benefits as compared with applied research, which generally has an earlier payoff. Because basic research is more risky and more remote from payoff, private enterprise is generally less likely to support it, so federal support is far more important. Basic energy research also has the advantage of generally not requiring facilities and costs as large as are frequently necessary for applied and developmental work. Thus, a federal strategy should contain substantial support for basic research, particularly in areas not well supported by private enterprise.

Diversity of Technical Approach. As indicated above, a research effort should investigate the broadest range of energy sources. Each source can be tapped through several technological approaches. For example, within the nuclear program, both the standard light water and high-temperature gas-cooled reactors have potential for increasing energy supplies. Research efforts in both would help provide insurance against the failure of one.

Balance Among R,D,&D Stages. Balance is particularly important in allocating manpower and funding among research stages, from pilot processes to the more costly demonstration stages. Although ultimate indications of technical, economic, and environmental viability of a process are obtained only at a large scale, most of the essential information about the process is obtained earlier. Budget constraints limit the number of options that can be pursued at the larger scales. In addition, the large costs of demonstration plants may threaten to squeeze out new and promising research areas. Thus, high-cost demonstrations and earlier stages of research should be balanced on the basis of a clear set of criteria for progressing to the costlier stages. This does not mean that program design should not be selective at the smaller scale as well;

indeed, careful attention to selectivity is an essential component of research management.

Pace of Development. A desire to explore all options fully can conflict with a need to move quickly to commercialize one or several possibilities. To maintain options, a strategy could be designed to investigate as many of the technical paths as seemed promising, putting off as long as possible the choice between options. However, a need for rapid commercialization could require an early commitment to a particular technical approach.

Because research is directed toward gathering information, it is critical that commitment to development not be premature. The key information that one stage of the R,D,&D process is designed to elicit should be available before the next stage is begun. While this does not mean that foreshortened sequencing is not possible, prudence would suggest that such sequencing allow for the assimilation of previous research results.

This element is clearly related to the time interval in which the source would hopefully provide energy. Obviously, long-term options do not require choices to be made as early among options as do near- and mid-term options.

Cost of Research

As indicated, federal support is necessary if a research effort is too costly for the private sector, as is the case, for example, with fusion technology. In addition, although the costs might not be too great, federal support could be essential if the potential private sector involvement were small, diverse, and fragmented.

In the face of limited resources, research efforts must be selective. Avoiding premature commitment to a particular technical approach and carefully assessing research costs relative to expected benefits can maximize effectiveness of available resources.

CHAPTER IV
ALTERNATIVE LONG-TERM RESEARCH STRATEGIES AND BUDGETS

This chapter briefly summarizes the President's energy budget request for fiscal 1977, describes some alternatives for long-term research strategies, and analyzes these alternatives with regard to 10-year budget projections and the criteria presented in Chapter III.

The President's Budget for Fiscal 1977

The President's 1977 budget authority request of approximately $3.1 billion for energy R,D,&D represents an increase of 32.9 percent over fiscal 1976; outlays of approximately $2.7 billion would be an increase of 30.6 percent over fiscal 1976 estimates. (See Tables II and III.) Approximately 90 percent of those funds are allocated to ERDA.

All but one of the major ERDA direct energy research programs would receive increases of 30 percent of more in budget authority. The exception is the relatively mature fossil energy program which would receive an increase of 19.8 percent. Direct and supporting research on nuclear technologies continues to receive the majority of funds. The largest dollar increase over fiscal 1976 ($188 million in new budget authority) is in the largest program--fission reactor research--primarily for further work on the breeder reactor. Smaller dollar increases are provided for other portions of the nuclear program and for nonnuclear programs.

Increases for other agencies and for supporting technologies are lower; budgets for EPA's energy research and ERDA's nuclear science research program would actually decline.

Funding of major demonstration programs and non-nuclear (especially fossil) programs contributes importantly to budget increases requested for fiscal 1977. Major projects include continued increases for the liquid metal fast breeder reactor (LMFBR), three demonstration plants for coal conversion technologies, the Tokamak fusion test facility, and major increases in nuclear fuel cycle research.

TABLE II

COMPARISON OF THE PRESIDENT'S FISCAL 1977 REQUEST FOR FEDERAL ENERGY R,D,&D WITH FISCAL 1976: BUDGET AUTHORITY[a]

(millions of dollars)

Programs	Fiscal 1976 Estimate	TQ Estimate	Fiscal 1977 Request	Fiscal 1977 as % Of Total	Fiscal 1977 Increase Over 1976
I. Direct Energy Technologies:					
A. Fossil Energy	$398	$105	$477	15.5%	+19.8%
B. Solar Energy	115	34	160	5.2%	+39.1%
C. Geothermal Energy	31	12	50	1.6%	+61.3%
D. Conservation	75	17	120	3.9%	+60.0%
Subtotal	(619)	(168)	(807)	(26.2%)	(+30.4%)
E. Fusion Power	250	80	392	12.7%	+56.8%
F. Fission Reactor	602	137	790	25.6%	+31.2%
G. Other Nuclear	173	50	347	11.3%	+100.6%
Subtotal	(1,026)	(267)	(1,529)	(49.6%)	(+49.2%)
H. Other Agencies[c]	250	(b)	257	8.3%	+ 2.8%
TOTAL DIRECT	$1,894	(b)	$2,593	84.2%	+36.9%
II. ERDA Supporting Technologies:					
A. Environmental	213	55	260	8.4%	+22.1%
B. Basic Energy Sciences	211	54	227	7.4%	+ 7.6%
TOTAL SUPPORT	424	109	487	15.8%	+14.9%
III. Grand Total, Energy R,D,&D:	$2,319	(b)	$3,080	100%	+32.9%

a. Operating expenses plus plant and capital equipment.

b. Not estimated.

c. Contains direct energy-related R,D,&D programs of the Nuclear Regulatory Commission, the Department of the Interior, the National Aeronautics and Space Administration, and EPA.

SOURCE: CBO, Federal Energy Research.

TABLE III
COMPARISON OF THE PRESIDENT'S FISCAL 1977 REQUEST FOR FEDERAL ENERGY R,D,&D WITH FISCAL 1976: OUTLAYS[a]

(millions of dollars)

Programs	Fiscal 1976 Estimate	TQ Estimate	Fiscal 1977 Request	Fiscal 1977 as % Of Total	Fiscal 1977 Increase Over 1976
I. Direct Energy Technologies:					
A, Fossil Energy	$333	$ 64	$442	16.5%	+32.7%
B. Solar Energy	86	26	116	4.3%	+34.9%
C. Geothermal Energy	32	9	46	1.7%	+43.8%
D. Conservation	56	14	91	3.4%	+62.5%
Subtotal	(507)	(113)	(695)	(25.9%)	(+37.1%)
E. Fusion Power	224	65	304	11.3%	+35.7%
F. Fission Reactor	522	158	684	25.5%	+31.0%
G. Other Nuclear	163	44	282	10.5%	+73.0%
Subtotal	(909)	(267)	(1,270)	(47.3%)	(+39.7%)
H. Other Agencies[c]	248	(b)	272	10.1%	+ 9.7%
TOTAL DIRECT	$1,664	(b)	$2,237	83.3%	+34.4%
II. ERDA Supporting Technologies:					
A. Environmental	204	54	244	9.1%	+19.6%
B. Basic Energy Sciences	188	52	204	7.6%	+ 8.5%
TOTAL SUPPORT	392	106	448	16.7%	+14.3%
III. Grand Total, Energy R,D,&D:	$2,056	(b)	$2,685	100%	+30.6%

a. Operating expenses plus plant and capital equipment.

b. Not estimated.

c. Contains direct energy-related R,D,&D programs of the Nuclear Regulatory Commission, the Department of the Interior, the National Aeronautics and Space Administration, and EPA.

SOURCE: CBO, Federal Energy Research.

Continued emphasis is placed on developing new supply technologies and sources, although there is substantial growth--60 percent increase in budget authority--for the conservation program. CEven so, conservation accounts for only 3.9 percent of energy R,D,&D budget authority.) Details of the 10 individual programs are provided in Appendix A.

The President's request is a final stage in administrative budget design, leading from division to agency to OMB to Congress. Each year, ERDA informs Congress of (1) levels of funding initially requested within the agency by each of its program divisions, (2) the levels that ERDA subsequently requested within the Administration, and (3) the levels finally requested in the President's budget.

The fiscal and policy assumptions--and even the technical judgments--that underlie initial division and agency requests may differ markedly among different levels of the executive branch. Similarly, optimism about program capability and fiscal realities may differ among divisions within a single agency. Without a complete knowledge of such assumptions--and the extent to which initial division requests may therefore represent "straw men"--it is unwise to rely uncritically on any such numbers to indicate the real needs and potential of programs. Nevertheless the requests can serve as a basis for discussion of alternatives.

The initial budget authority requests made by all divisions of ERDA totalled $4.4 billion; ERDA's request to OMB was $3.9 billion, about 90 percent of the divisional totals. The President's budget requested budget authority of $2.8 billion, about 72 percent of the agency's request.* Table IV summarizes these requests.

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*These figures include ERDA's portion of direct energy R,D,&D plus ERDA's research on supporting technologies. Comparable figures for other agencies are not available.

TABLE IV
COMPARISON OF DIVISIONAL, ERDA, AND PRESIDENTIAL REQUESTS
FOR FISCAL 1977 BUDGET AUTHORITY

(millions of dollars)

Program	Division Request	ERDA Request To OMB	President's Request
A. Fossil	$816	$721	$477
B. Solar	300	255	160
C. Geothermal	102	90	50
D. Conservation	255	235	120
E. Fusion	588	513	392
F. Fission Reactor	1,022	901	790
G. Other Nuclear	549	537	347
Subtotal	$3,633	$3,252	$2,336
Supporting Technologies	752	668	487
Total ERDA R,D,&D	$4,384	$3,920	$2,823

SOURCE: See Appendix A.

Relative differences in priorities can be noted by comparing ERDA's request to OMB with the President's budget authority requests submitted to Congress, For example, the President's requested budget places greater relative emphasis on nuclear energy research than does ERDA, as indicated by the fact that the President granted proportionately more of ERDA's funding request for fission research than for other programs. The fission reactor program received almost 88 percent of the agency's request, while at the other end the conservation research program received only half of the agency's request.

Alternative Long-Term Research Strategies

Several sources have been used to estimate budget paths for alternative research strategies. The President's fiscal 1977 budget request and ERDA's 1977 budget estimates include five-year budget commitment projections, which formed the basis for CBO's subsequent calculations.* These calculations include updated figures for several major projects for which total costs were not reflected in either the fiscal 1977 budget request or its accompanying five-year budget projection. Such project costs total nearly $1.4 billion. Finally, the costs of the possible future projects itemized and tentatively scheduled in ERDA's national plan were estimated. The federal share of the total estimated cost for future major projects (those costing over $50 million) is estimated at $19 billion. (See Appendix C for a list of such projects.)

Using these sources, CBO has calculated total 10-year funding levels for five alternative energy R,D,&D strategies. Numerous additional alternatives are possible; these were selected to illustrate a range of possibilities and varying degrees of consistency with the research strategy criteria described in Chapter III (support of desirable futures, insurance against failure, and costs).

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*For a more complete discussion of the methodology, see CBO, Federal Energy Research.

The alternatives include strategies that would:

- Continue present programs, completing ongoing projects and allowing modest real growth (the "base program completion" strategy).

- Build from the first strategy and carry out all the additional major R,D,&D projects identified by ERDA in its national plan (the "full funding" strategy).

- Emphasize the fission and breeder programs as long-term technologies and downplay all others (the "long-term fission" strategy).

- Emphasize all other long-term technologies and downplay the fission program (the "long-term nonfission" strategy).

- Emphasize near- and mid-term technologies, deferring all major long-term R,D,&D projects not already underway (the "near- and mid-term" strategy).

Each of these strategies is more expensive than the present R,D,&D program. Reductions below present funding levels would require on average at least a 30 percent reduction in the Base Program Completion strategy (which itself is tied to pre-embargo priorities). This would suggest major reduction in existing demonstrations or whole programs (e.g., no fusion R,D,&D), or abandonment of new priorities. Because it would require a major shift from the priorities that Congress has recently established in response to growing energy supply problems, this alternative was not developed.

Completion of the Base Program

The baseline for this alternative is the five-year projection in the President's fiscal 1977 budget request. It reflects present commitments and therefore a budget level that is close to "no new starts." (In order to complete the data base at this level for a full decade, CBO has extended these five-year projection levels from 1981 through 1986.)

This alternative includes, increases to allow for more modest growth (beyond inflation) in each program area. An annual growth rate of 3 percent has been assumed for mature programs, such as fission and fossil energy, and 6 percent for less developed programs such as fusion, solar, geothermal and other nuclear programs. Because it is new and has very few large projects planned at present, the conservation program has been treated separately: It has been assumed to grow 40 percent per year for four years. By then the annual program level would reach nearly $600 million; the program has then been held at that level in subsequent years.

Finally, this alternative includes funds to cover the full costs of large demonstration projects that have been started in fiscal 1977 or previously but for which certain out-year costs were not fully included in the President's budget. For example, while architect and engineering (A&E) costs for a new demonstration plant might be included in the President's fiscal 1977 budget projection, the full construction costs might not be included, pending completion of the A&E estimates.

This strategy would result in gradual annual increases in budget authority during the next decade. Budget authority would reach a maximum annual peak of $4.7 billion in fiscal 1986, and the cumulative 10-year total would be $40.5 billion. CSee Table V and Chart 2.) Program trends are assumed to continue their present pattern, with nuclear R,D,&D dominating. Because there would be no funding for any major demonstration projects not initiated in 1977 or earlier, few major processes would be developed at demonstration scale. For example, the Clinch River Breeder Reactor would be completed, as would three demonstration plants to make synthetic fuels from coal; however, a larger scale breeder would not proceed, nor would a number of other fossil energy demonstrations planned for fiscal 1978 and subsequent years.

This strategy would not be consistent with several criteria described in Chapter III. Perhaps the most important shortcoming would be its reliance upon old projects and its perpetuation of current program priorities. For example, it would not respond to recent Congressional mandates to expand research into solar energy and conservation. It would limit the diversity of sources and neglect many near- and mid-term technologies.

The strategy would provide some measure of insurance against failure. Its pace would not be excessive because no new projects would be started; the scale would be directed toward earlier and smaller levels of research than would be the case with other alternatives. Within each source, it is unlikely that a diversity of technical approaches would be encouraged without additional initiatives. The balance between basic and applied research cannot be determined without more information.

Full Funding

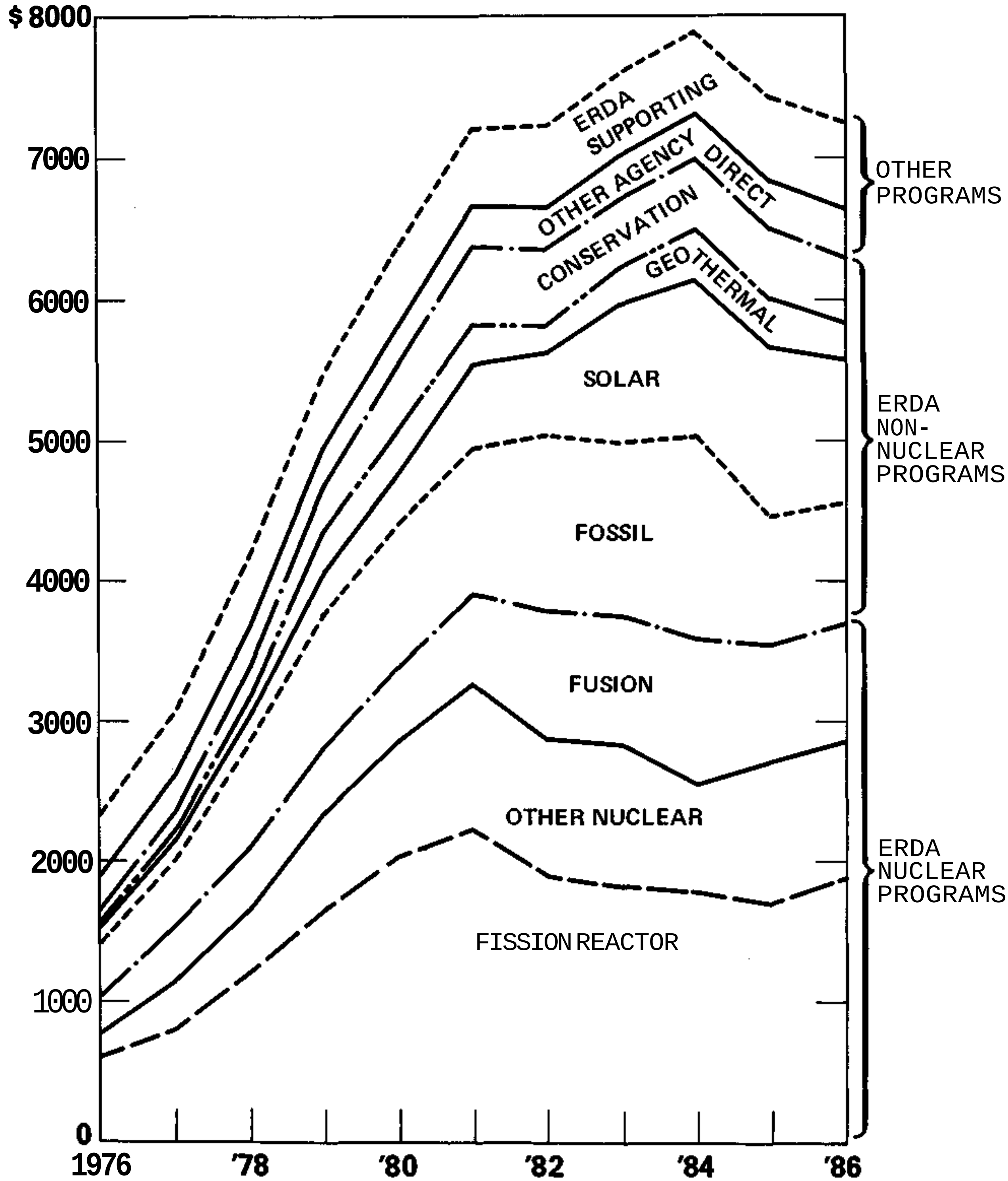
This second strategy would include all of the costs and projects of the first one, as well as all of the large future energy R,D,&D projects that ERDA describes in its national plan as reasonable future projects. (Only those projects estimated to have a total federal cost greater than $50 million each are included in the calculation.)

This strategy assumes that minimal fiscal constraints would be placed on energy R,D,&D. Required budget authority would reach an annual maximum of $7.9 billion in fiscal 1984. Cumulative 10-year budget authority would be about $63.7 billion. (See Table V and Chart 2.) All programs would receive increases; nuclear (fission and fusion) programs would continue to receive the largest percentage of the budget totals, reflecting partially the costs of the demonstration projects planned for these programs. Chart 1 shows what this budget authority pattern would be annually for the next decade.

One of the characteristics of this strategy is the increasing share of the budget that would be devoted to demonstration projects of all types. By 1981 such projects would constitute nearly half of all energy R,D,&D budget authority. (Today demonstration projects account for about 17 percent of energy R,D,&D funding.) This 45 percent, however, would fund only those projects already contained in ERDA's plan, leaving--after basic R&D expenses--relatively little to expend on projects not yet planned. Under this strategy, the nuclear program (including fission and fusion) would account for nearly one-half of the total effort, and nonnuclear technologies would account for a little over one-third, with the rest allocated to supporting research and other agencies.

chart 1 Full Funding Strategy: Budget **Authority, 1976-1986**

(In Millions of 1977 Dollars)



In relation to the energy R,D,&D criteria, the strongest point of this strategy is its clear support for the future deemed desirable by ERDA.* The strategy reflects scope and diversity in its research programs (e.g., it increases emphasis on solar and conservation research in order to increase diversity) and consistency with energy futures that require a broad range of technologies. It would explicitly increase emphasis on conservation, renewable resources, and the environment, and it would extend projects across all time ranges. It would also encourage a diversity of technological approaches.

The weaknesses of this strategy stem from its emphasis on demonstration projects, which would leave little funding for pursuit of other new initiatives or earlier stages of research. The pace of development might be too quick to allow information gained from earlier stages in the research process to be analyzed and assimilated before later stages are undertaken.

Emphasis on Long-Term Fission Technology

This strategy assumes that full funding may be too costly and that key long-term technologies must be investigated and developed as soon as possible. In this case fission breeder technology has been selected for emphasis because of its proven technical feasibility, its near-commercial status, and the unproven feasibility or unfavorable economic outlook for other long-term alternatives. Such a strategy would fund all of the large demonstrations planned for the fission reactor and "other nuclear" programs (except fusion) in order to resolve issues relating to the economics, safety and efficiency of the breeder cycle. However, other programs (near-, mid-, and long-term) would be funded at the level described above for the base program completion strategy, thus allowing some growth while deferring until after 1986 all large projects not already underway. The growth in conservation funding, however, would be reduced by one-half to cut back conservation demonstration projects.

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*If the choice of futures were to be changed by Congress or the Administration, this strategy could then be less consistent.

This strategy would explicitly emphasize nuclear demonstration projects that carry somewhat higher risks and more distant payoffs than would a short-term strategy.

It would result in cumulative budget authority of $51.3 billion over 10 years, of which nuclear fission research would receive 49 percent. Annual budget requests would rise to $6.1 billion in 1981 and decrease by several hundred million in following years. (See Table V and Chart 2.)

Such a strategy would not generally support ERDA's desired future because it would neglect such important alternative sources as synthetic fuels and solar energy. Its technological scope and diversity would be limited because only nuclear fission would be substantially supported. Conservation, renewable resources, and environmental programs would not be emphasized. This strategy would meet the test of timing and scale of benefits within the fission program, because research efforts at all time horizons and all sizes from pilots through demonstration would be funded.

However, supporting the demonstration phase of only a single technology would provide no insurance against failure. Appropriate pacing of development and the balance of R,D,&D programs among all energy sources are likely to be jeopardized as a result of speeding a single technology to success as quickly as possible.

Emphasis on Long-Term Nonfission Technologies

Like the fission alternative described above, this strategy assumes that a full funding budget is too costly and that a choice of long-term technologies must be made quickly. It is, however, based on a judgment that the unresolved issues of safety, plutonium toxicity, economics, and proliferation of nuclear weapons materials make the breeder less attractive than other potential long-term technologies. This strategy would therefore provide full funding for research into emerging technologies--including solar, coal, geothermal, and fusion sources. Nuclear fission research would be supported only at the level described in the base completion strategy, allowing projects now underway to be completed but deferring all new large demonstrations until after 1986.

This strategy would explicitly carry somewhat higher technical risks and more distant payoffs than the short-term strategies. It would require budget authority significantly below that for the full funding strategy. The cumulative 10-year total would be $51.6 billion, of which nuclear fission research would receive only 25 percent. The annual budget authority requests under this strategy would reach a maximum of $6.7 billion in 1984 and decline thereafter. (See Table V and Chart 2).

Like the strategy emphasizing fission technology, this alternative would not be consistent with the future preferred by ERDA in its national plan, because the strategy does not assign to fission and the breeder the central role which ERDA deems necessary. The strategy would provide insurance against failure because it would explore diverse sources and diverse technical approaches to each source. It would explicitly emphasize conservation, renewable resources, and the environmental programs; all considerations of timing and scale of benefits can be satisfied. However, the strategy could allow too much emphasis on the demonstration stage, which could squeeze out earlier levels of investigation.

Emphasis on Near- and Mid-Term Technologies

This strategy is based on the judgment that, because long-term technologies are not expected to become major energy sources until the next century, a selection among those potential technologies need not be made now. Thus demonstration projects for long-term technologies--although not research and development up to and through the pilot plant stage--would be delayed, giving preference in terms of budget dollars to projects with potential payoffs that are particularly needed for the near- and mid-term. For example, this strategy would fully fund such technologies as conservation, solar heating and cooling, synthetic fuels, shale oil, and advanced recovery of oil and gas, but it would eliminate or defer past the end of the decade funding for longer-term projects such as magnetohydrodynamic demonstrations, an ocean thermal gradient demonstration, a volcanic hydrothermal demonstration, a fusion demonstration, a prototype breeder demonstration (beyond the Clinch River Breeder, which would be funded), and a gas-cooled fast reactor demonstration.

This strategy would emphasize the earlier priority benefits, basic research, and those technologies with less technical sophistication and risk in comparison to the long-term technologies. It would result in cumulative 10-year budget authority of $48 billion; its maximum annual peak would be $5.4 billion in 1983. (See Table V and Chart 2.)

This strategy would be somewhat inconsistent in its support of ERDA's desired future because major new fission and long-term nonfission demonstrations would be deferred. However, it would provide diversity among sources, particularly at the early research and development stages, and it would emphasize conservation and renewable resources. Ultimately, this strategy's consistency with a desirable energy future would depend on decisions about long-term technologies; demonstrations of such technologies would be scheduled when a more complete data base is gathered from R&D results.

Insurance against failure is also mixed: The pace would not be too fast because demonstrations of long-term technologies would be delayed, and thus earlier research would not be squeezed out. However, if some long-term technological approaches were not explored, the diversity within each approach could then be inadequate.

Summary

The alternative strategies result in very different budget paths. Chart 2 illustrates the differences that might occur if the alternatives were to be funded in accordance with the assumptions discussed.

Table V summarizes the cumulative 10-year budget authority and the peak years for each alternative discussed in the preceding pages.

chart 2 Budget Authority for Alternative Research **Strategies,** 1976-1986

(In Millions of 1977 Dollars)

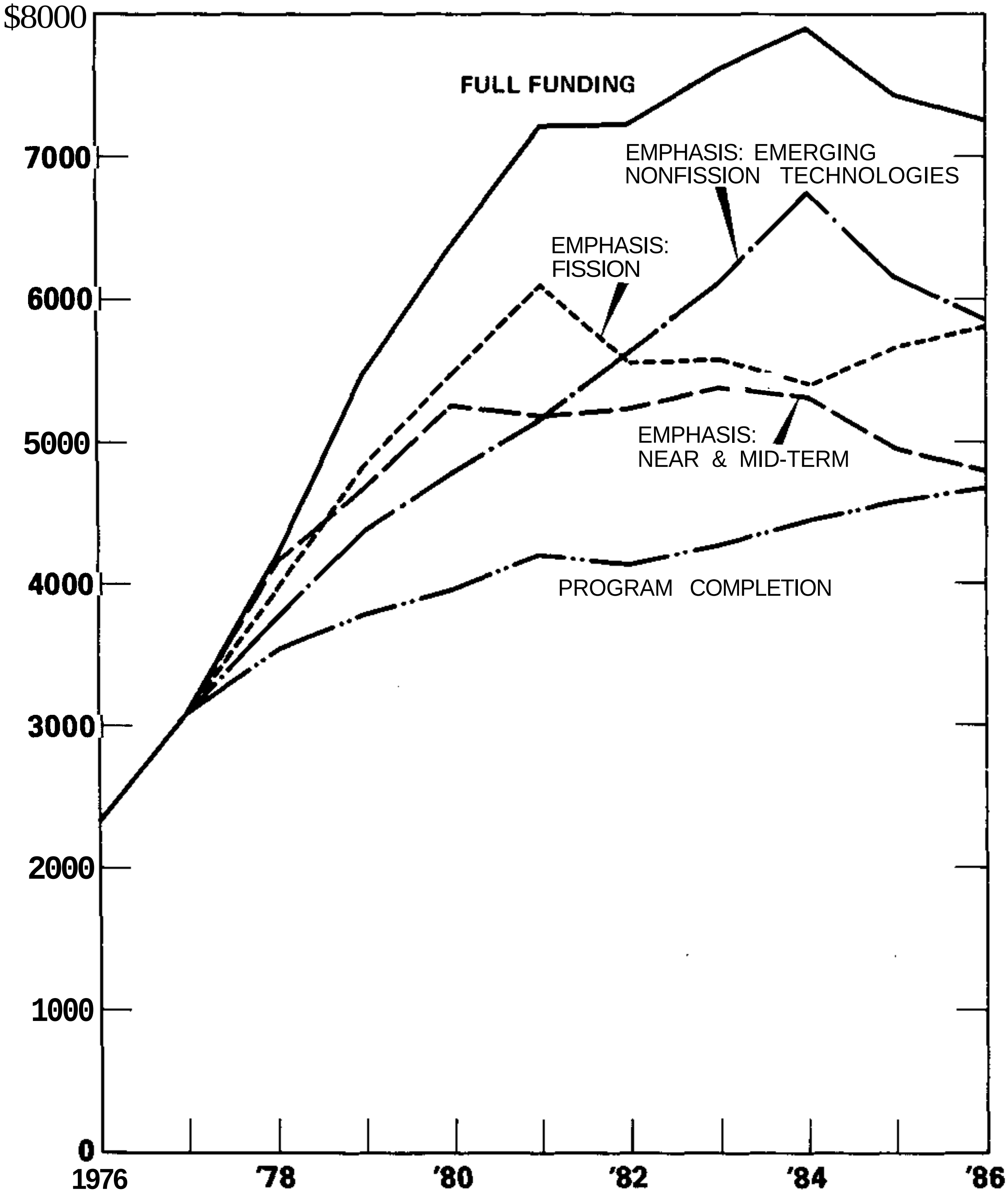

TABLE V
FIVE ENERGY R,D,&D BUDGET ALTERNATIVES
(billions of dollars)

Strategy	Cumulative Ten-Year Budget Auth.	Peak One-Year Budget Auth.	Year of Peak
Base Program Completion	$40.5	$4.7	1986
Full Funding	63.7	7.9	1984
Fission Emphasis	51.3	6.1	1981
Nonfission Emphasis	51.6	6.7	1984
Near- and Mid-term Ennphasis	48.0	5.4	1983

Implications for the Fiscal 1977 Budget

Each of the alternative strategies assumes that some growth in funding for federal energy R,D,&D will occur and that the majority of projects underway will be completed. Because there are additional decision points for current projects, no final path is locked in for any R,D,&D program (i.e., solar, fossil, or nuclear). Pending selection of a long-term research strategy, Congress could provide fiscal 1977 budget authority at or near the level proposed in the President's budget; this would allow any one of the long-range alternative strategies to be pursued. However, as more large demonstrations are mounted in the next few years and as demonstration costs increase as a percentage of the R,D,&D budget, then potential future budget paths would become more clearly defined.

Implications of each of the five alternative strategies for the fiscal 1977 budget would be as follows:

- Completing the base program would imply no changes in the fiscal 1977 budget.

- The full funding strategy implies an intensive effort in all technologies; additions could be made to the President's 1977 budget request. Such additional funding could simply be allocated proportionately to each technology or it could be used to bring the levels of effort directed at each one into a different balance. In any event, ERDA has indicated that, for all programs, a total of over $1.1 billion in budget authority above the President's request could be used in the research program in fiscal 1977.

- The strategy emphasizing fission technology could imply an accelerated breeder reactor program. However, additional fiscal 1977 budget authority might not be required, because two of the major demonstrations for the program are about to start: The Fast Flux Test Facility is about to begin operation, and construction of the Clinch River Breeder Reactor is about to begin. By increasing funding for other nuclear research in a manner similar to that described for the fission program, over $100 million in additional budget authority could be added in fiscal 1977.

- The strategy emphasizing long-term nonfission technologies could imply increased funding for such technologies, including fossil, solar, geothermal, fusion, and conservation. ERDA's original request to OMB indicated that the agency believed it could use an additional $700 million for these programs. Increasing budget authority at a level somewhat reduced from this request could give these programs an additional $400 million in fiscal 1977.

- The strategy emphasizing near-, and mid-term technologies would imply increased funding for programs such as direct burning of coal, solar heating and cooling, geothermal energy, and conservation. If these programs were increased in proportion with the President's request for increases in the nuclear fission program (see Table IV), up to $200 million in additional budget authority could be added to the President's 1977 budget request.

Final detailed decisions on a research strategy do not have to be made now. The budget paths described above would result from a series of decisions to be made over the next decade. Research is dynamic, and new information becomes available almost daily. That information is useful in itself; it can also be used to help shape those decisions to be made in the future.

Each such decision, however, represents a step along a strategic path. The pattern of those decisions over the next few years, especially with respect to funding major demonstrations, will--whether by conscious design or by piecemeal actions--result in the definition of a U.S. energy R,D,&D strategy. That pattern of decisions will have significant impacts on the federal budget over the next 10 years.

APPENDIX A

THE PRESIDENT'S FISCAL YEAR 1977 BUDGET BY MAJOR PROGRAM AREA

The federal energy R,D,&D budget can be separated into 10 major program areas. These are Fossil Energy (including coal, oil and gas, and oil shale), Solar Energy (encompassing wind, solar heating and cooling, electric conversion, and ocean gradient), Geothermal, Conservation (including electric energy systems, energy storage, end-use conservation, and technologies to improve efficiency), Fusion Power (both magnetic and laser-induced), Fission Reactors, Other Nuclear (containing ERDA's nuclear fuel cycle, nuclear materials security and safeguards, uranium enrichment process development, and advanced isotope separation programs), Direct R&D by other agencies, Environmental, and Basic Energy Sciences.

This appendix consists of summaries of each of these 10 major program areas. The format of each is identical, consisting of (1) charts of alternative budget authority and outlay projections, (2) tables showing budget authority and outlays for the components in fiscal 1975, 1976, and the transition quarter, and fiscal 1977 budget requests from the program division to ERDA, from ERDA to OMB, and from the President to the Congress,* (3) narrative descriptions of program content and recent trends, (4) initiatives and issues for fiscal 1977, and (5) future program implications and decisions.

The 10-year budget projection charts were developed using the methodology described in Chapter IV. Four levels are shown, in increasing order: (1) the OMB projections of commitments resulting from fiscal 1977 requests and extrapolated through fiscal 1986; (2) an increment to provide probable real growth; (3) in addition, an increment to provide for recently revised cost estimates of existing construction items and to fund fully those projects for which seed money is contained in the President's budget, (referred to in Chapter IV as the Base Program Completion); and, finally, (4) a budget that would do all of the above and fully fund all those initiatives suggested for subsequent years in the program implementation portion of ERDA's national plan, (referred to in Chapter IV as Full Funding). No commitments to the full funding level have been made or are being suggested for fiscal 1977; they represent potential decisions for fiscal 1978 and later budgets.

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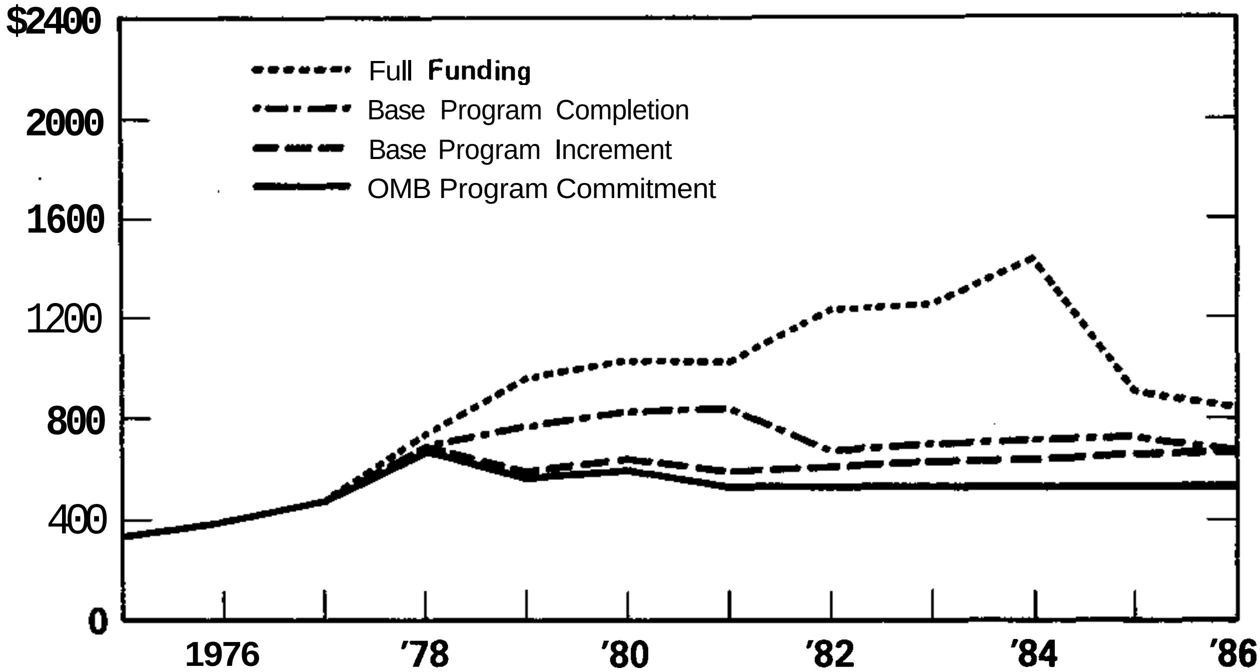
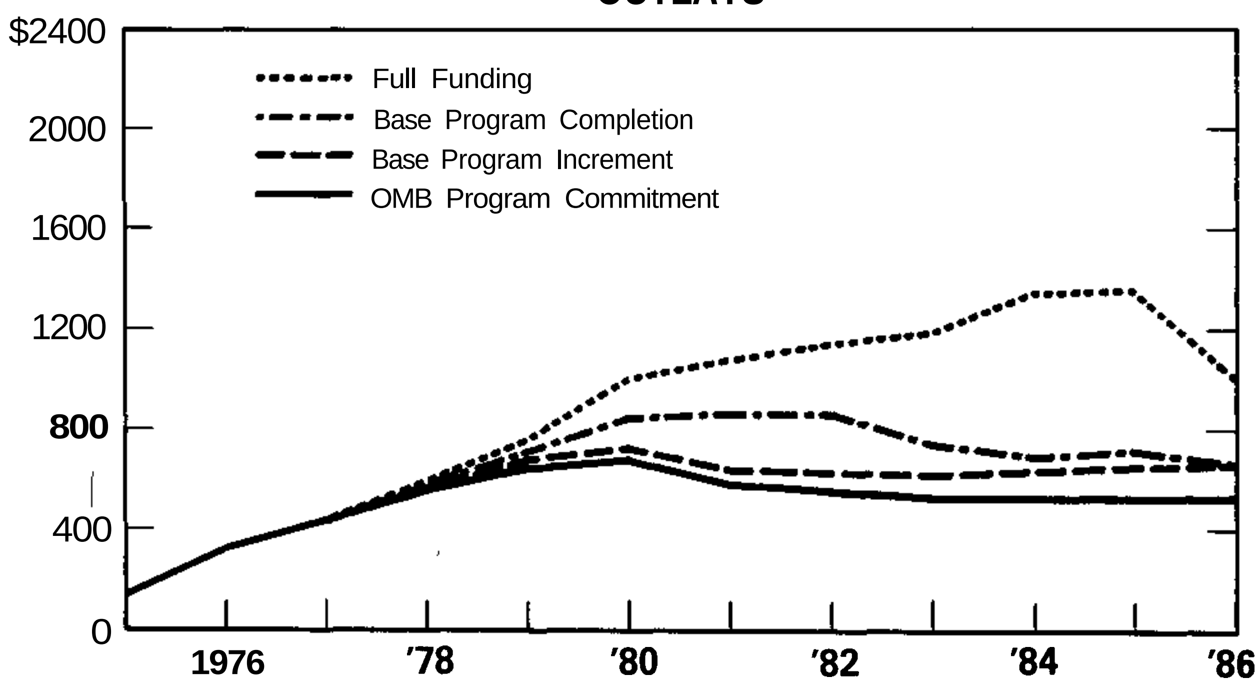
*Division and ERDA requests are contained in U.S. Energy Research and Development Administration, FY 1977 Budget History Tables, Comparing Division Requests with Requests Submitted to the Office of Management and Budget and to the Congress, undated.

Fossil Energy **Development Program,** 1975-1986
(In Millions of 1977 Dollars)

Appendix Chart 1.
BUDGET AUTHORITY



Appendix Chart 2.
OUTLAYS



	1975 Actual	1976 Estimate	TQ Estimate	FY 1977 Request Div. Request	ERDA Request	Pres. Request
Budget Authority	335	398	105	816	721	477
Outlays	128	333	64	614	570	442

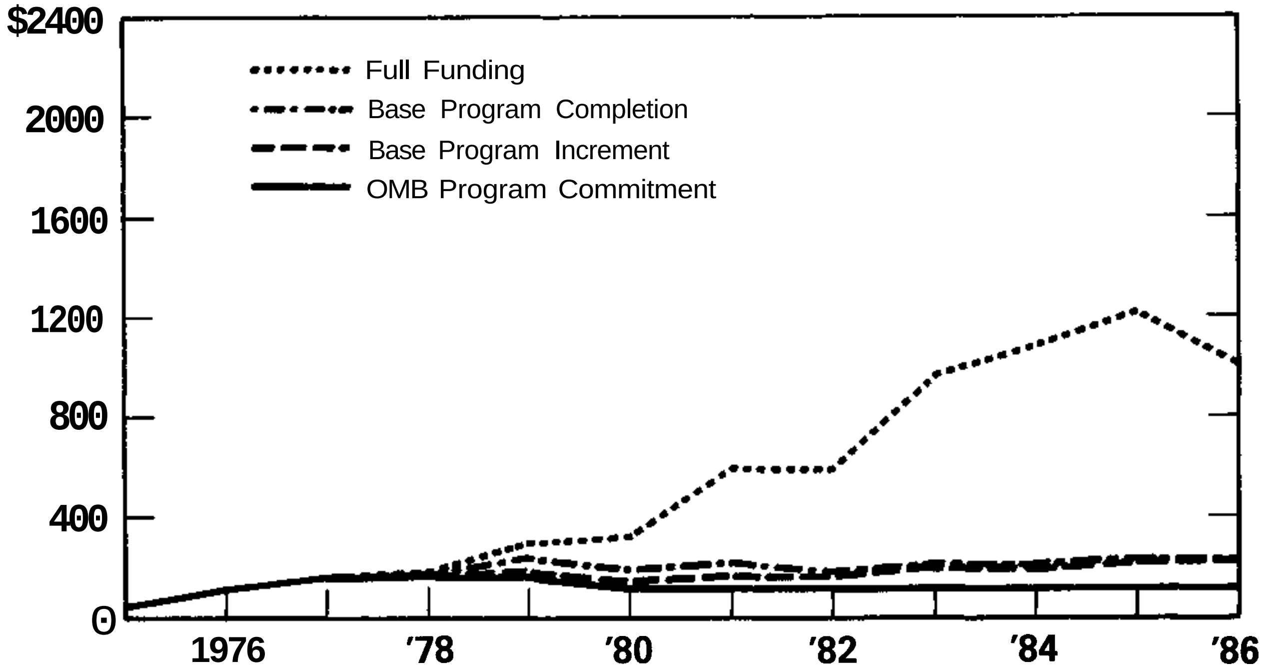
(1) Program Content and Recent Trends. Most of the funding for fossil energy (some 85 percent) is for a coal program whose objectives are: to develop an environmentally acceptable technology for converting coal to liquid and gaseous fuels, to improve methods for the direct combustion of coal, and, for the longer term, to advance more efficient power conversion systems. Other significant fossil energy programs include enhanced recovery of petroleum and natural gas, and *in situ* technology (in-place retorting and production of oil and gas without earthmoving operations) for oil shale and coal. Funding has been provided in recent years for construction and operation of a number of pilot plants, each costing tens of millions, to investigate a variety of technologies. Overall, the fossil energy program is the second largest energy research program. Growth in the fossil energy budget has been steady, and the President's budget requests an increase for fiscal 1977 of 19.8 percent in budget authority and 32.7 percent in outlays over 1976 levels.

(2) Initiatives and Issues for Fiscal 1977. The major new thrust in the fiscal 1977 fossil energy budget is funding for three demonstration plants: one designed to convert high-sulfur coal to a clean boiler fuel, one to convert coal to a "high-BTU" gas of quality sufficient to ship by pipeline, and one to convert coal to a "low-BTU" fuel gas for electric utilities and larger industrial users.

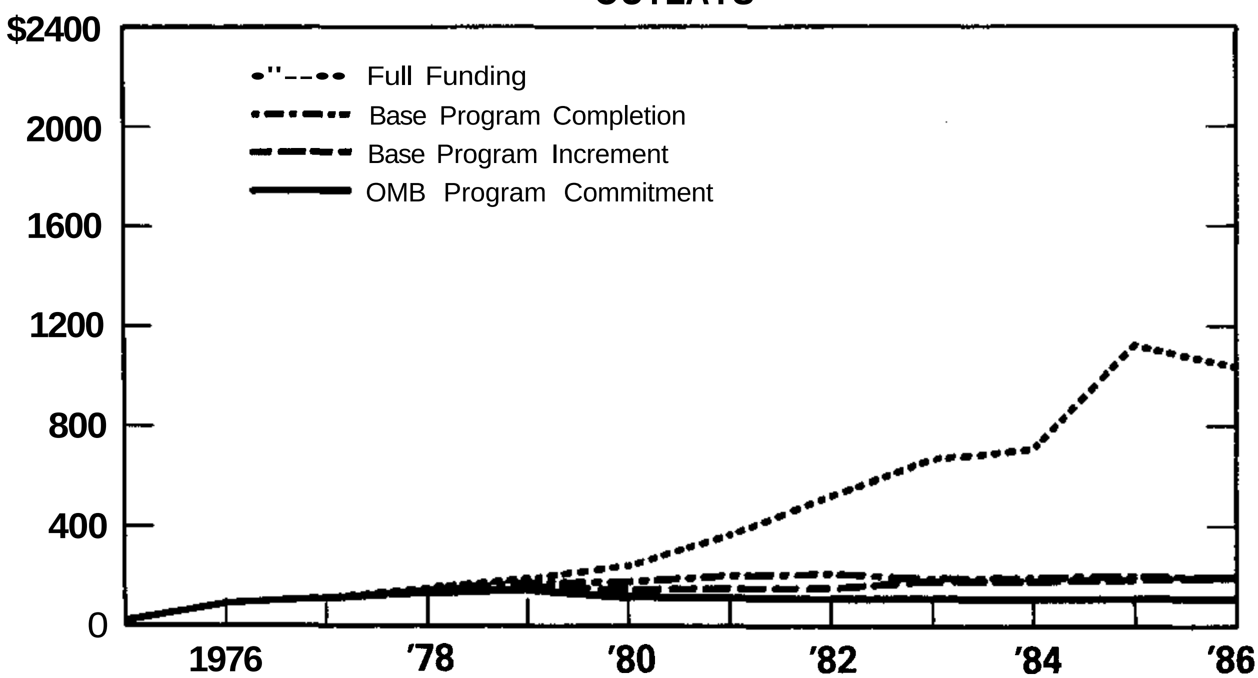
(3) Future Program Implications and Decisions. ERDA's national plan envisions an ambitious construction program, beginning with future large scale pilots for synthetic oil and pressurized fluid-bed gasifiers in the late 1970s, and peaking with the near-commercial magnet-hydrodynamic demonstration plant scheduled for the mid-1980s. Total program budget authority could peak around fiscal 1984 and outlays shortly thereafter. At its peak, 54.9 percent of fossil energy program budget authority would be earmarked for construction and operation of large test facilities, pilots, and demonstration plants.

Solar Energy Development **Program,** 1975-1986
(In Millions of 1977 Dollars)

Appendix Chart 3.
BUDGET AUTHORITY



Appendix Chart 4.
OUTLAYS



	1975 Actual	1976 Estimate	TQ Estimate	FY 1977 Request: Div. Request	ERDA Request	Pres. Request
Budget Authority	42	115	34	300	255	160
Outlays	15	86	26	230	202	116

(1) Program Content and Recent Trends. The solar energy development program includes diverse projects to determine the viability of proposed solar technologies and to tap the essentially unlimited energy of the sun. These projects include (1) using solar thermal energy directly for heating and cooling buildings, (2) converting solar energy into electricity through photovoltaic and solar thermal electric systems, (3) developing wind power systems, (4) using the thermal gradients in the ocean, and (5) converting organic matter such as garbage and plant matter into useful clean fuels. The solar energy program is relatively new, accounting for only 5.2 percent of all energy research budget authority and 4.3 percent of outlays in fiscal 1977. Overall, this program ranks eighth as a percentage of total energy R,D,&D funding. However, program growth is beginning to accelerate, having increased by 29.1 percent in budget authority and 34.9 percent in outlays over fiscal 1976 levels.

(2) Initiatives and Issues for Fiscal 1977. There are, as yet, few big-ticket items in the solar program. Accordingly, debate on the appropriate funding level must center on assessments of the availability of appropriate research opportunities and on ERDA's ability to manage a rapidly expanding program. Differences in perception of these issues apparently exist even within ERDA as reflected by the fact that the divisional request for solar energy was cut more sharply by the ERDA Administrator than any other budget request for a major energy research program. Nevertheless, even the President's budget request represents almost a fourfold increase in the solar program in two years.

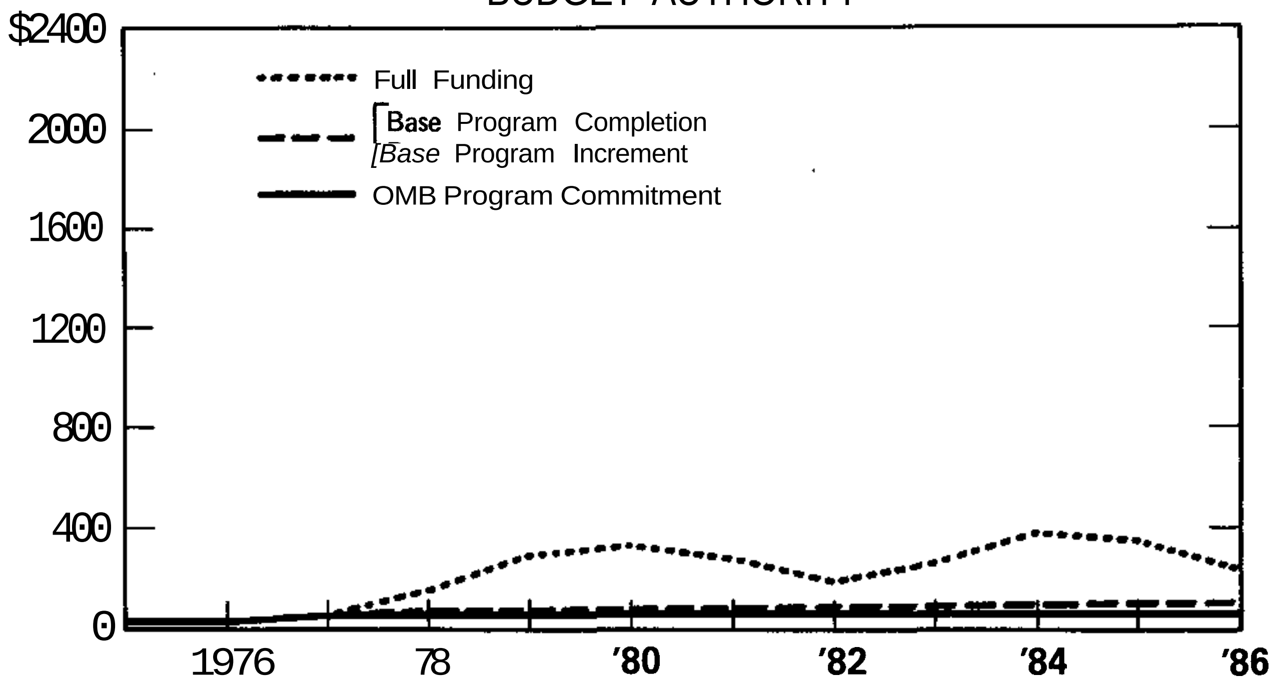
(3) Future Program Implications and Decisions. Full funding for solar energy development would move the program up to fifth largest (as a percentage of total budget authority for energy R,D,&D) in 1981 and second by 1985. It is during this period that construction is scheduled to begin for large-scale pilot and demonstration plants testing such technologies as multiunit complexes, off-shore ocean temperature power generation barges, silicon arrays and large area silicon sheets for conversion to electricity, central receivers, distributed collectors, and terrestrial and marine biomass conversion units. Since these pilot and demonstration units will be costly, a major decision may have to be made prior to 1981 as to which of these programs holds the greatest promise of commercial and economic success.

Geothermal Energy Development **Program,** 1975-1986

(In Millions of 1977 Dollars)

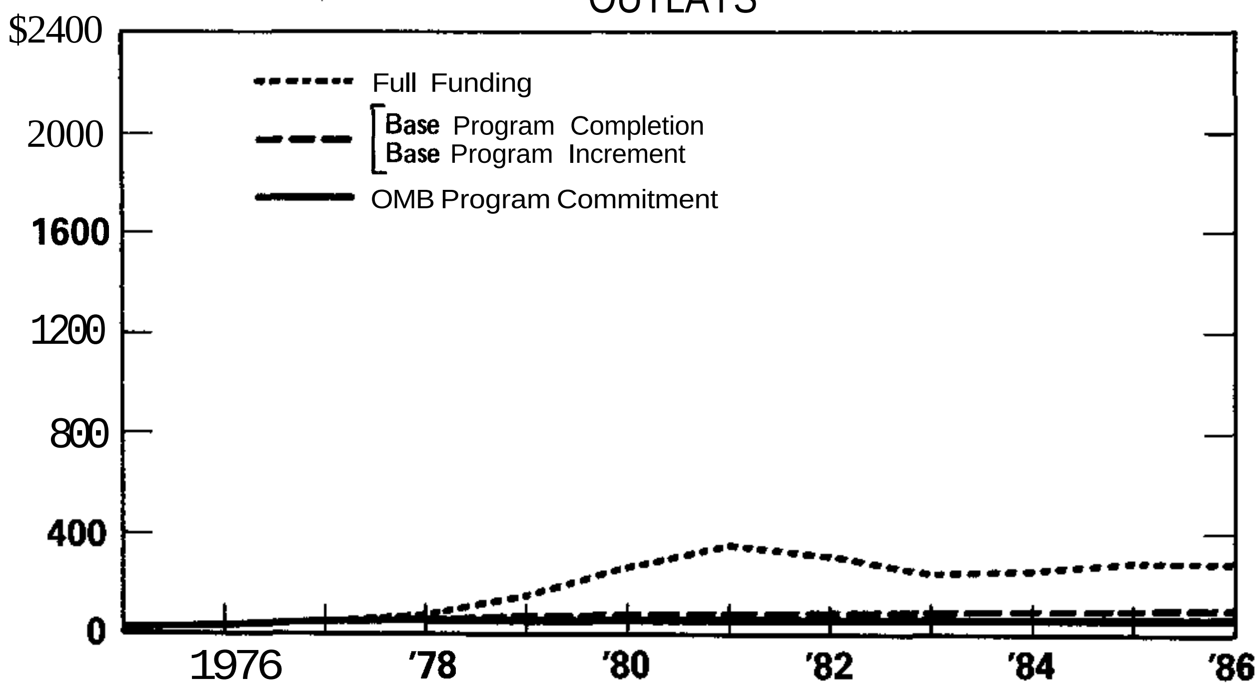
Appendix Chart 5.

BUDGET AUTHORITY



Appendix Chart 6.

OUTLAYS



	1975 Actual	1976 Estimate	TQ Estimate	FY 1977 Request: Div. Request	ERDA Request	Pres. Request
Budget Authority	28	31	12	102	90	50
Outlays	21	32	9	79	71	46

(1) Program Content and Recent Trends. The geothermal energy program is designed to permit exploiting the energy potential of high and low temperature liquids, dry steam, hot dry rock, and geopressured resources deep beneath the surface of the earth. Major components, which presume improvement in understanding and assessment of geothermal resources, include research to overcome problems caused by temperature and corrosiveness of the resource fluids. As a percentage of total energy R,D,&D funding for fiscal 1977, this program area ranks last in both budget authority and outlays. However, the geothermal energy program is augmented by a proposed loan guarantee program presented elsewhere in the fiscal 1977 budget. This incentive program is designed to make funds more readily available from financial institutions for projects with a direct potential for producing income--as opposed to encouraging greater research and development efforts on the part of the private sector.

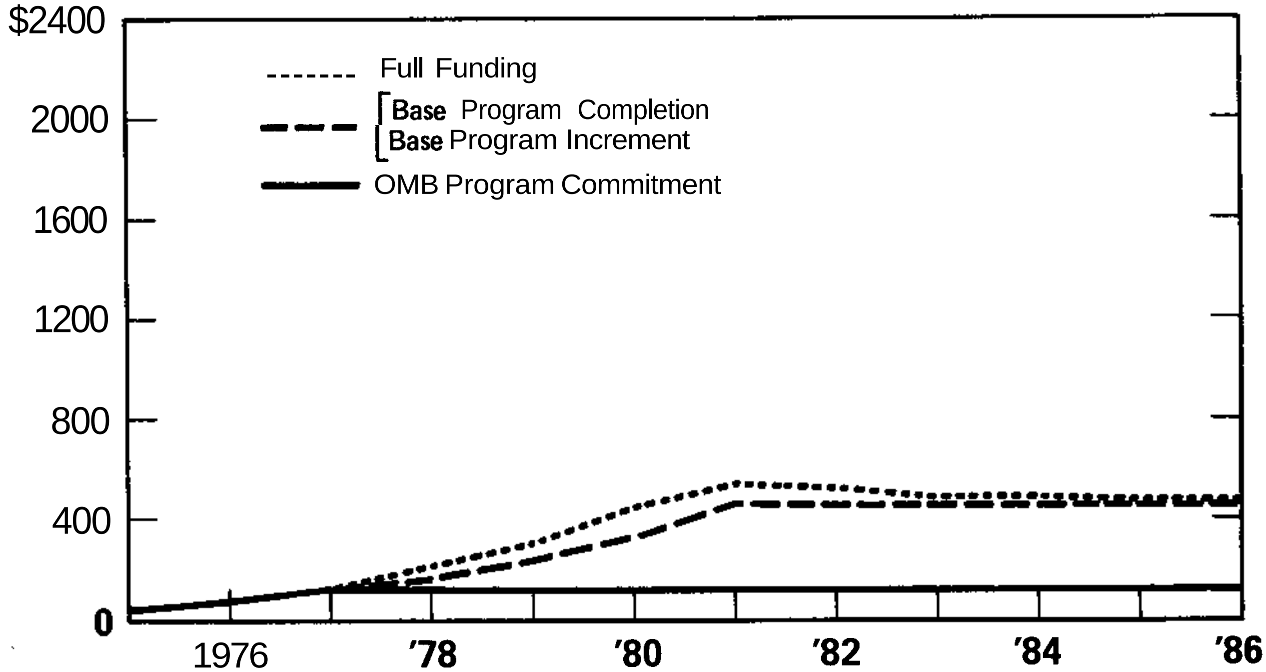
(2) Initiatives and Issues for Fiscal 1977. As in the case of solar energy, the basic issue is the level of funding for a fairly new program, which depends, in turn, on the assessment of the availability of suitable research opportunities and the ability to effectively spend large increases in funding.

(3) Future Program Implications and Decisions. A fully funded geothermal program would have a near-term peak around 1980-1981, followed in the mid- to late 1980s by a second and possibly larger program peak. This second peak will depend upon interim progress made in the more advanced geopressure and hot dry rock technology areas. However, overall budget authority for the geothermal research program is never expected to exceed 5.4 percent of the total R,D,&D program annually over the next 10 years. Indeed, for many of these years the program will rank last in importance among major programs as a percent of total energy R,D,&D--primarily because of the relatively small scale and low numbers of pilot plants envisaged.

Conservation Research and Development **Program, 1975-1986** (In Millions of 1977 Dollars)

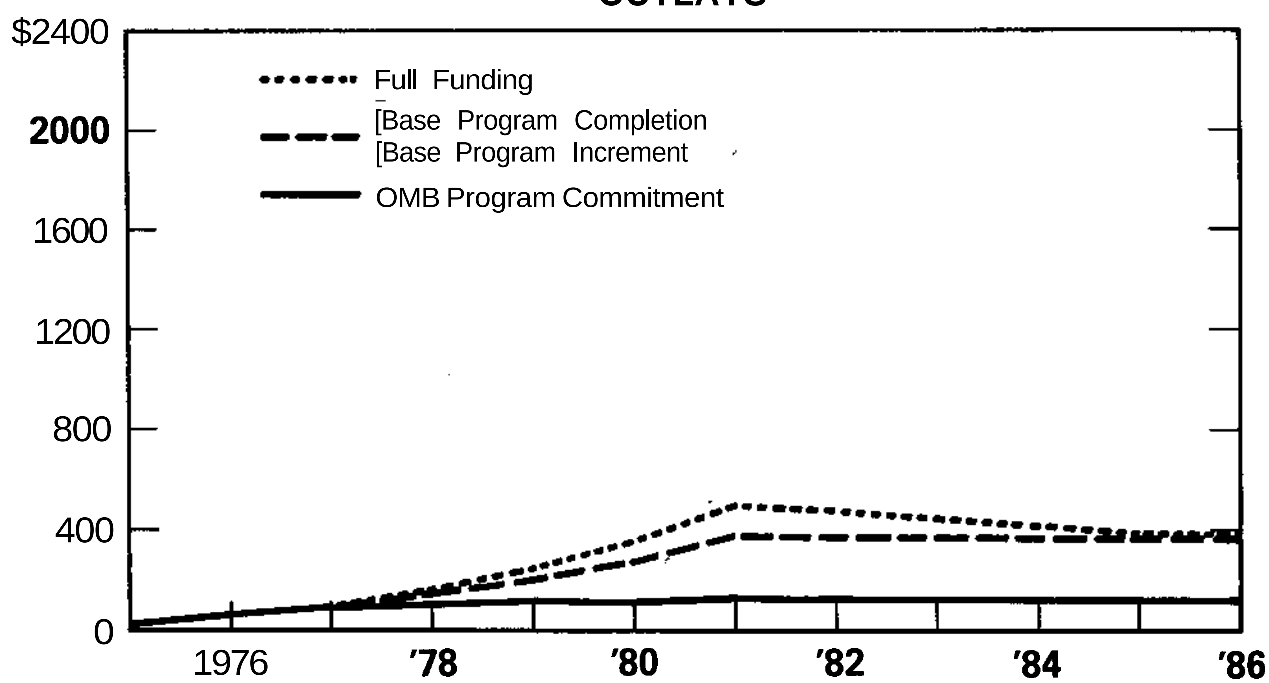
Appendix Chart 7.

BUDGET AUTHORITY



Appendix Chart 8.

OUTLAYS



	1975 Actual	1976 Estimate	TQ Estimate	FY 1977 Request: Div. Request	ERDA Request	Pres. Request
Budget Authority	36	75	17	255	235	120
Outlays	21	56	14	185	166	91

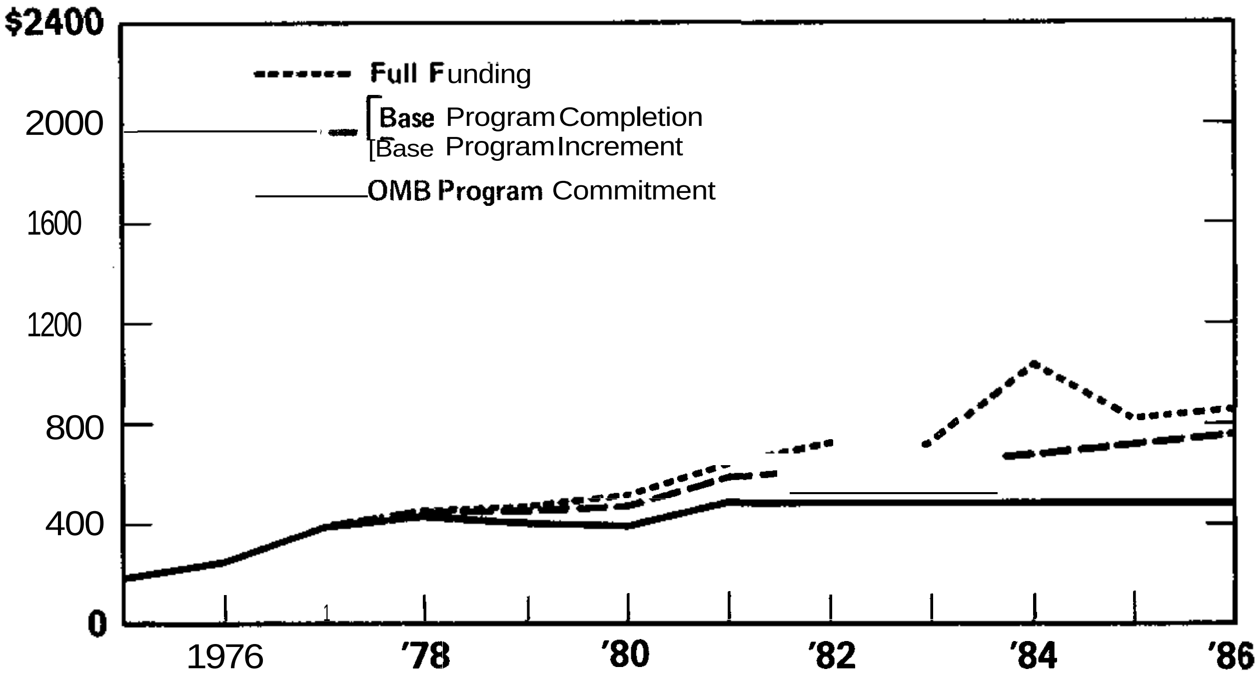
CD Program Content and Recent Trends. The conservation R,D,&D program has two major subprograms. The first encompasses efforts designed to improve electric energy systems and develop feasible energy storage systems, while the second and larger deals primarily with end-use conservation and technologies to improve conversion efficiency. Within these areas, conservation in industry and in heating and cooling buildings has received the greatest emphasis over the fiscal 1976 request. On the other hand, improved conversion efficiency funding is down over last year. Overall, conservation R,D,&D ranks ninth in the fiscal 1977 energy R,D,&D budget. However, this program has expanded robustly over its 1976 level. Budget authority is up 60.0 percent, and outlays are up 62.5 percent.

(2) Initiatives and Issues for Fiscal 1977. Recent studies in Long Island reveal that conservation and end-use demand management measures are at least twice as cost-effective as construction of additional electric generating capacity. The major issue in the conservation program is the level to which the base program of experiments and field demonstrations should be expanded. Administrators familiar with the conservation R&D community feel that $600 million per year by 1981 is not unreasonable for R&D communities to absorb; at issue is how fast--and whether--such a level should be attained. Differences in perception of these issues are dramatically reflected in the relative ranking of funding ratios at various stages in the development of the conservation program budget for fiscal 1977. For budget authority, the ratio of the level recommended by the ERDA administrator to that originally requested by the responsible division was the second highest overall. However, the President's budget requested a lower percentage of ERDA's request than was the case for any other program, which would be consistent with administration view (as set forth in ERDA 76-1) that the private sector should play the dominant role in conservation efforts.

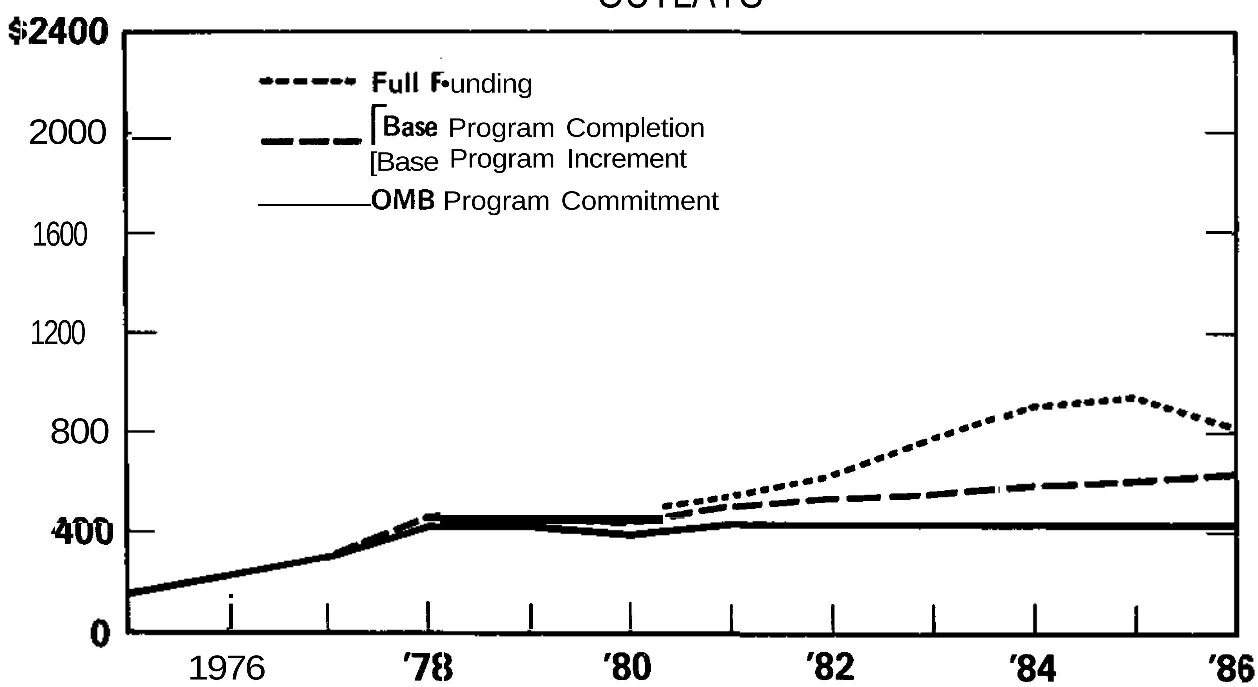
(3) Future Program Implications and Decisions. The conservation R&D program has the potential for sizeable future increases in level of program effort. In general, conservation projects are not particularly capital-intensive in that traditional sense of moving forward from experiments to pilots to near-commercial demonstration plants. Thus, the rapid program growth anticipated for the 1980s (should *a* full program funding path be followed) will take the form of many diverse, small-scale experiments that separately will be small budget items but in total will be significant.

Fusion Power Research and Development Program, 1975-1986 (In Millions of 1977 Dollars)

Appendix Chart 9.
BUDGET AUTHORITY



Appendix Chart 10.
OUTLAYS



	1975 Actual	1976 Estimate	TQ Estimate	FY 1977 Request Div. Request	ERDA Request	Pres. Request
Budget Authority	183	250	80	588	513	392
Outlays	151	224	65	426	386	304

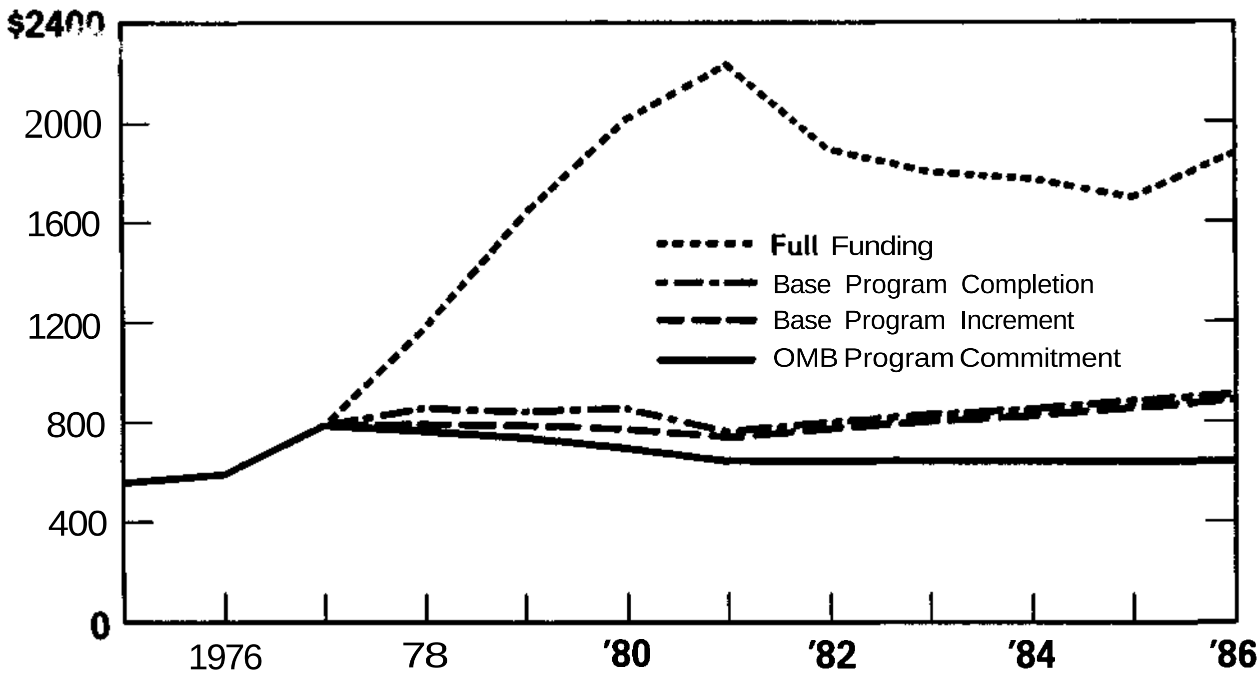
(1) Program Content and Recent Trends. While it has a long history, the fusion power R&D program is still very far from achieving technical maturity because of difficult problems in physics and advanced engineering. If successful, the program could lead to demonstration of the scientific feasibility of fusion power and to development of a reliable, economic, environmentally safe, and essentially inexhaustible source of electric power for the longer term. Subprogram emphasis is developing along two paths. The first relies upon the magnetic fusion process. Major procurement obligations are planned for fiscal 1977 in support of the Tokamak fusion test reactor. Actual heavy construction for this facility will begin early in fiscal 1978. The second path encompasses continued work on the emerging laser fusion process (which was formerly shown in the budget for defense-related activities). Experimental facilities, particularly for the magnetic techniques, are extremely expensive. Overall, the fusion power program currently ranks third in total program funding, and the President has requested a 56.8 percent increase rate in budget authority and 35.7 percent increase in outlays for fiscal 1977.

(2) Initiatives and Issues for Fiscal 1977. No major new initiatives or questions are raised in the fiscal 1977 fusion power R&D program. This budget is essentially an extension of previous program intentions, including the accelerated support now being given to the Tokamak facility.

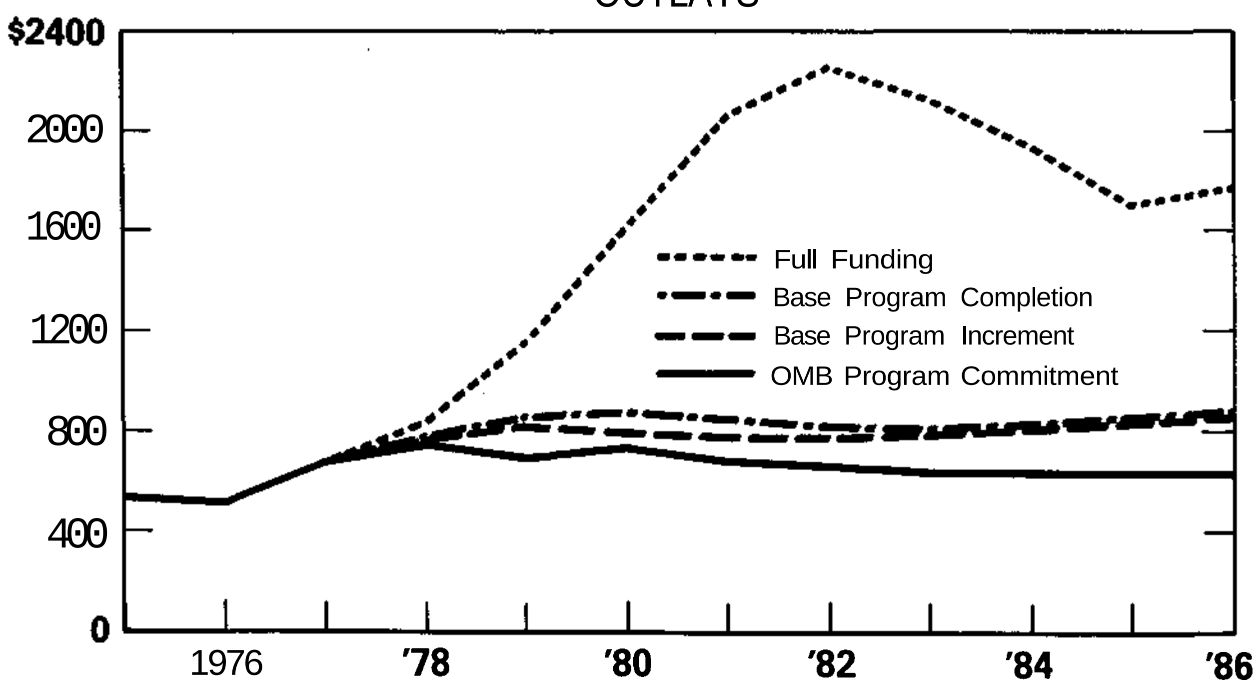
(3) Future Program Implications and Decisions. Of all the major energy R,D,&D programs, the future shape of this program is the most difficult to predict, in large part because of the very basic nature of the technical problems. If the pattern of development conjectured in ERDA's national plan occurs, construction of an experimental power reactor could begin as early as 1982, with a major increase in funding at that time.

Fission Power Reactor Development **Program,**
1975-1986 (In Millions of 1977 Dollars)

Appendix Chart **11.**
BUDGET AUTHORITY



Appendix Chart 12.
OUTLAYS



	1975 Actual	1976 Estimate	TQ Estimate	FY 1977 Request: Div, Request	ERDA Request	Pres. Request
Budget Authority	567	602	137	1,022	901	790
Outlays	538	522	158	833	777	684

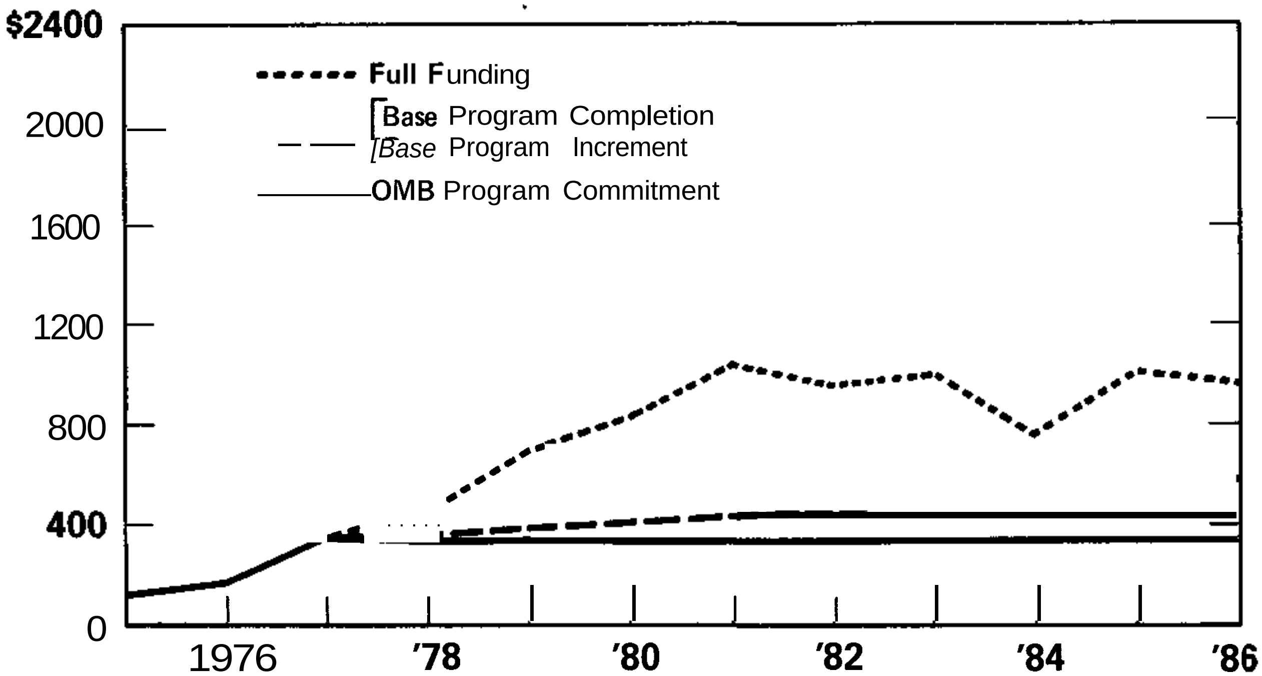
(1) Program Content and Recent Trends. The major fission power reactor development effort supports development of the liquid metal fast breeder reactor (LMFBR). This program is unique by ERDA budgeting standards in that the largest single item (the $1.5 billion Clinch River demonstration plant) in the ERDA budget is not reflected as a separate construction line item but rather is being funded entirely under operating expenses. Other fission subprograms, which are funded at significantly lower levels, include the water cooled breeder reactor, gas cooled reactors, and light water converter reactors. As both a percent of total President's request for fiscal 1977 energy R,D,&D (25.6 percent of total budget authority and 25.5 percent of total outlays) and dollar change over fiscal 1976 funding levels (budget authority up $188 million and outlays up $162 million), the fission power reactor program is the largest program in the federal energy research budget.

(2) Initiatives and Issues for Fiscal 1977. With elimination of the molten salt breeder reactor from the President's 1977 budget, three breeder reactor technologies remain. These are the LMFBR, which is heavily funded; the light water breeder reactor, which was allocated less funds this year than last; and the gas cooled fast breeder reactor, which received a modest increase over fiscal 1976 funding levels. Considerable controversy has attended the decision to go forward with the LMFBR, focusing on environmental and safety questions. Evaluation of current generation light water converter reactors continues in an attempt to amass a broader technology base and to assist industry in achieving better on-line availability and productivity.

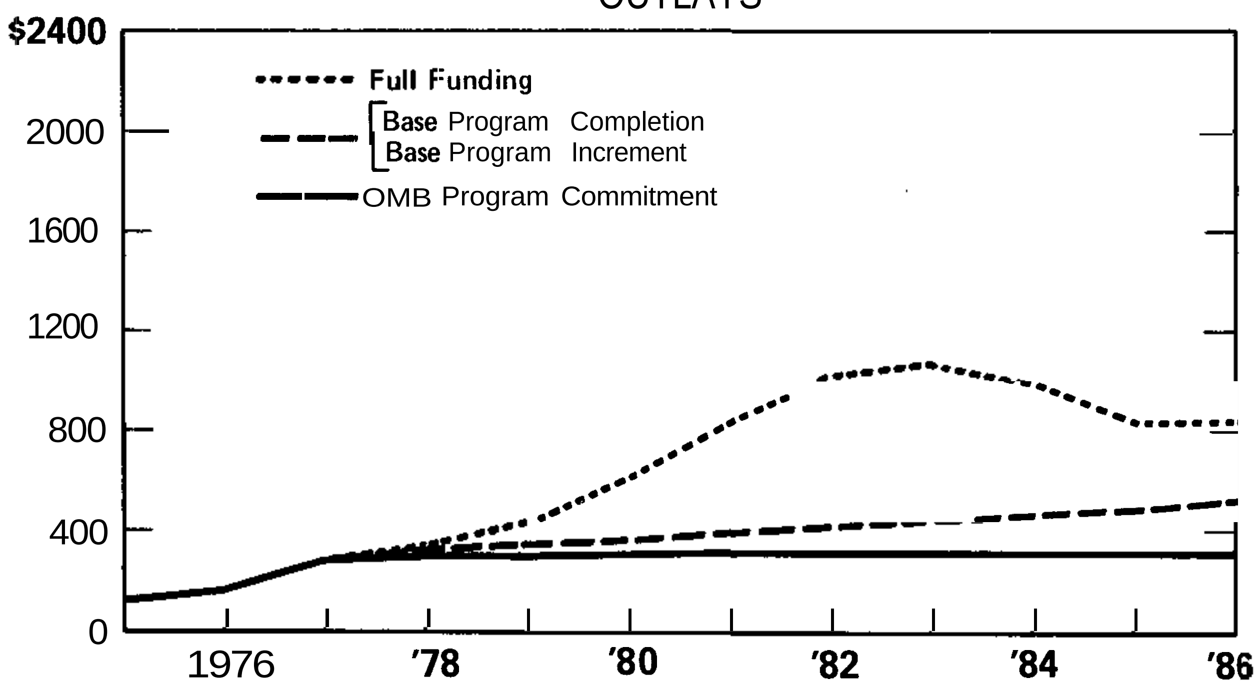
(3) Future Program Implications and Decisions. Most of the impact of a well-funded Fast Flux Test Facility and Clinch River Breeder Reactor has already been incorporated into the OMB commitment projection. However, full funding of the entire fission program will dramatically increase the size of future energy R,D,&D budgets as this program continues its dominance throughout the projection period. By the time such a program funding level reaches its projected peak in 1981, the fission power reactor program will exceed $2 billion in annual budget authority and consume about 31 percent of the entire fully funded energy research budget. Much of the early increase will come about as a result of broad-based support for the LMFBR program. Several additional major projects will be candidates for construction beginning in fiscal 1978. At issue for the longer term--but also for fiscal 1977--is the number of alternative fission breeder and converter technologies that can be investigated at increasing scales and the relative emphasis among fission and nonnuclear programs in designing an overall energy research strategy.

Other Nuclear Programs, 1975-1986
(In Millions of 1977 Dollars)

Appendix Chart 13.
BUDGET AUTHORITY



Appendix Chart 14.
OUTLAYS



	1975 Actual	1976 Estimate	TQ Estimate	FY 1977 Request: Div. Request	FY 1977 Request: ERDA Request	FY 1977 Request: Pres. Request
Budget Authority	117	173	50	549	537	347
Outlays	120	163	44	376	369	282

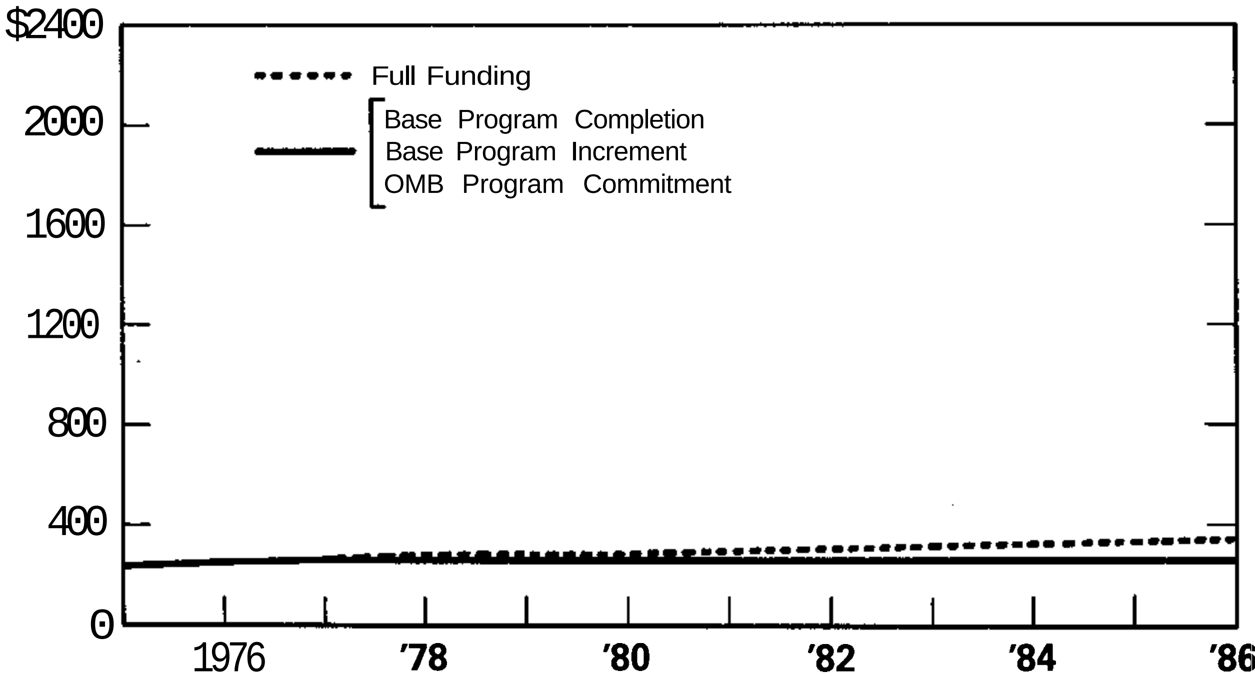
(1) Program Content and Recent Trends. The "other" nuclear programs area is an amalgam of ERDA programs that essentially provide backup for the fission reactor program. The largest portion of the budget allocated to this area supports fuel cycle R&D including uranium resource assessment, development of commercially viable technologies for reprocessing spent reactor fuel and recycling recovered uranium and plutonium, and design of terminal storage concepts for radioactive wastes. Smaller percentages have been earmarked for materials security and safeguards (to prevent possible diversion of special nuclear materials from ERDA facilities by developing and evaluating cost-effective safeguards systems), process development (to demonstrate emerging centrifuge technologies for the enrichment of natural uranium), and advanced isotope separation (primarily the evaluation of alternative laser-induced U-235 separation techniques). Combined, this area amounts to 11.3 percent of budget authority and 10.5 percent of outlays for total federal energy research--a ranking of fourth in overall program funding. Moreover, this is the fastest growing program area in the President's fiscal 1977 energy research budget.

(2) Initiatives and Issues for Fiscal 1977. The size of the increases requested for this program area reflects increasing awareness of the problems associated with the total nuclear fuel cycle. A key issue is relative emphasis and support for redundant nuclear fission technologies. In addition to reprocessing R&D tailored to both the liquid metal fast breeder reactor (LMFBR) and current light water (converter) reactors, this program area contains support for reprocessing wastes from the high-temperature gas-cooled reactor (HTGR)--whose development receives little support from the fission program, and whose sole U.S. manufacturer has indicated a desire to withdraw from the market. Regarding program initiatives, the major new thrust for fiscal 1977 is funding for a gas centrifuge plant demonstration facility.

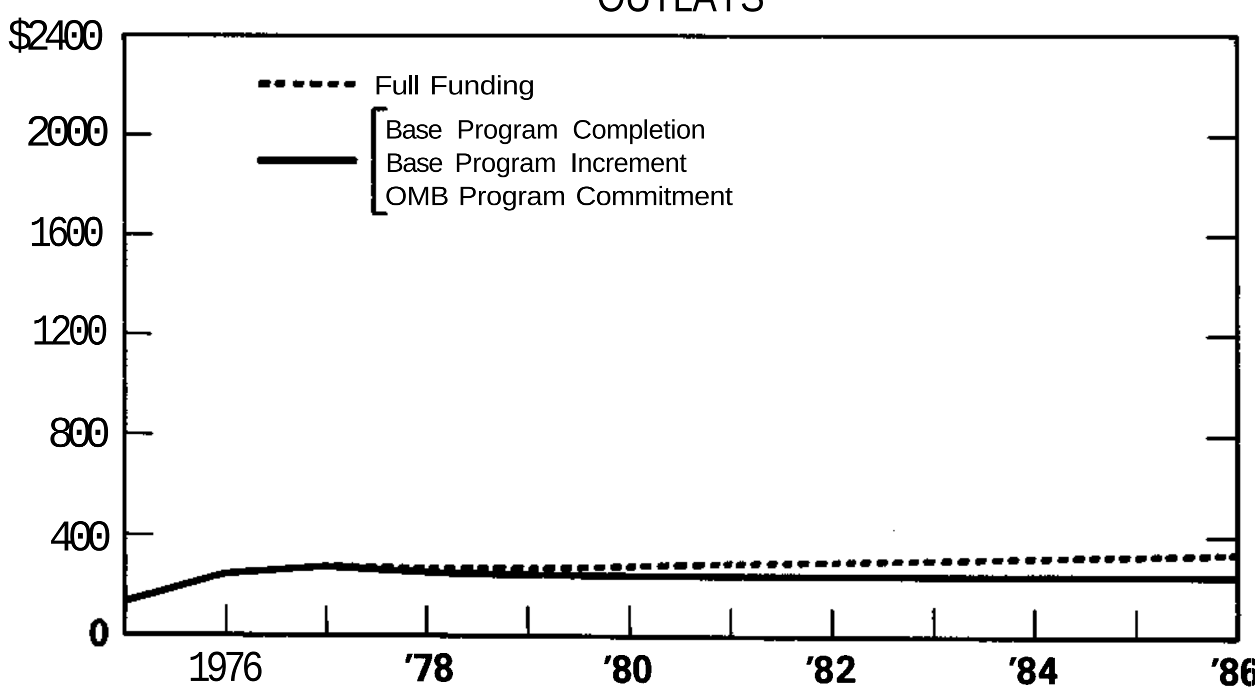
(3) Future Program Implications and Decisions. If full program funding is carried out in accordance with the time schedule set forth in ERDA's national plan, the area will triple by 1981, moving from fourth to second in budget authority as a percent of total energy R,D,&D. This substantial increase in an already sizable program effort is attributable to large construction projects in the three reactor/fuel cycle technology areas. In particular, liquid metal fast breeder reactor fuel cycle construction projects alone could require total federal investment of at least $1.35 million between 1978 and 1986. At issue for the longer term is how many fission reactor technologies--and thus how many supporting fuel cycle research programs--can be supported at large scale.

Other Agency Direct Energy **Programs,** 1975-1986
(In **Millions** of 1977 Dollars)

Appendix Chart 15.
BUDGET AUTHORITY



Appendix Chart 16.
OUTLAYS



	1975 Actual	1976 Estimate	TQ Estimate	FY 1977 Request
Budget Authority	231	250	—	257
Outlays	125	248	—	272

— Not estimated.

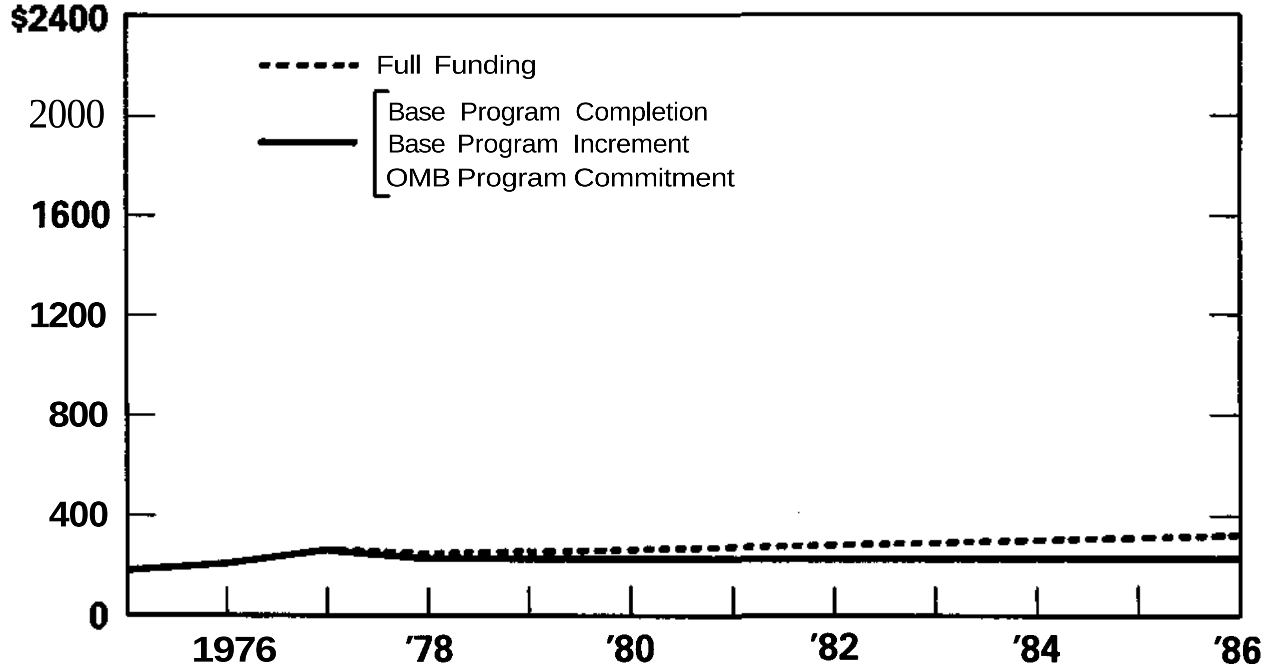
(1) Program Content and Recent Trends. The area of other federal agency direct energy research involves diverse efforts designed to augment many of the nine major program areas administered by ERDA. The Nuclear Regulatory Commission conducts reactor safety studies in direct support of ERDA nuclear fuel cycle R&D and the fission power reactor development program. Similarly, the Bureau of Mines of the Department of Interior directly supports the fossil energy program through extensive research on the mining of coal and oil shale. Other portions of Interior play a minor role in nuclear fuel cycle R&D, the conservation program, geothermal energy development, and environmental control technology. Likewise, EPA investigates environmental impacts and develops technologies to control such impacts so as to supplement ERDA efforts in environmental control technology. Lastly, the National Aeronautics and Space Administration is completing its contribution to the solar energy program. These other agency efforts for fiscal 1977 will constitute 8.3 percent of requested budget authority and 10.1 percent of outlays for total federal energy research if fully appropriated. However, new budget authority has grown at the slowest rate of any major program area. Indeed, with the exception of the Nuclear Regulatory Commission, funding requests for these agencies are lower than their respective 1976 levels.

(2) Initiatives and Issues for Fiscal 1977. No new budget authority has been requested for the National Aeronautics and Space Administration this year in an effort to phase out direct energy research by this agency.

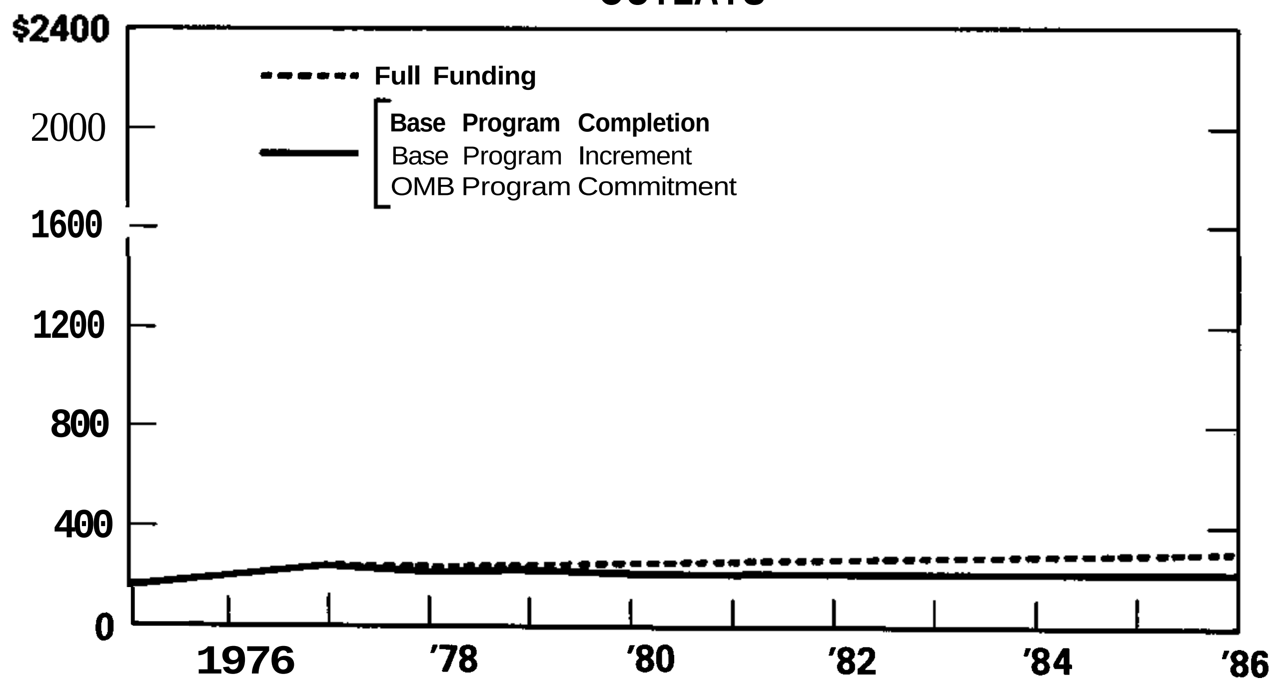
C3) Future Program Implications and Decisions. No items planned for these programs approach the magnitude of the larger fossil and nuclear demonstration plants. Basic issues involve the extent of work on a large number of items at considerably smaller scales, and the relative attractiveness of these augmenting environmental, safety, and mining research programs as candidates for energy R,D,&D funds.

Environmental Research and Safety Program, 1975-1986 (In Millions of 1977 Dollars)

Appendix Chart 17.
BUDGET AUTHORITY



Appendix Chart 18.
OUTLAYS



	1975 Actual	1976 Estimate	TQ Estimate	FY 1977 Request: Div. Request	ERDA Request	Pres. Request
Budget Authority	183	213	55	430	377	260
Outlays	159	204	54	338	315	244

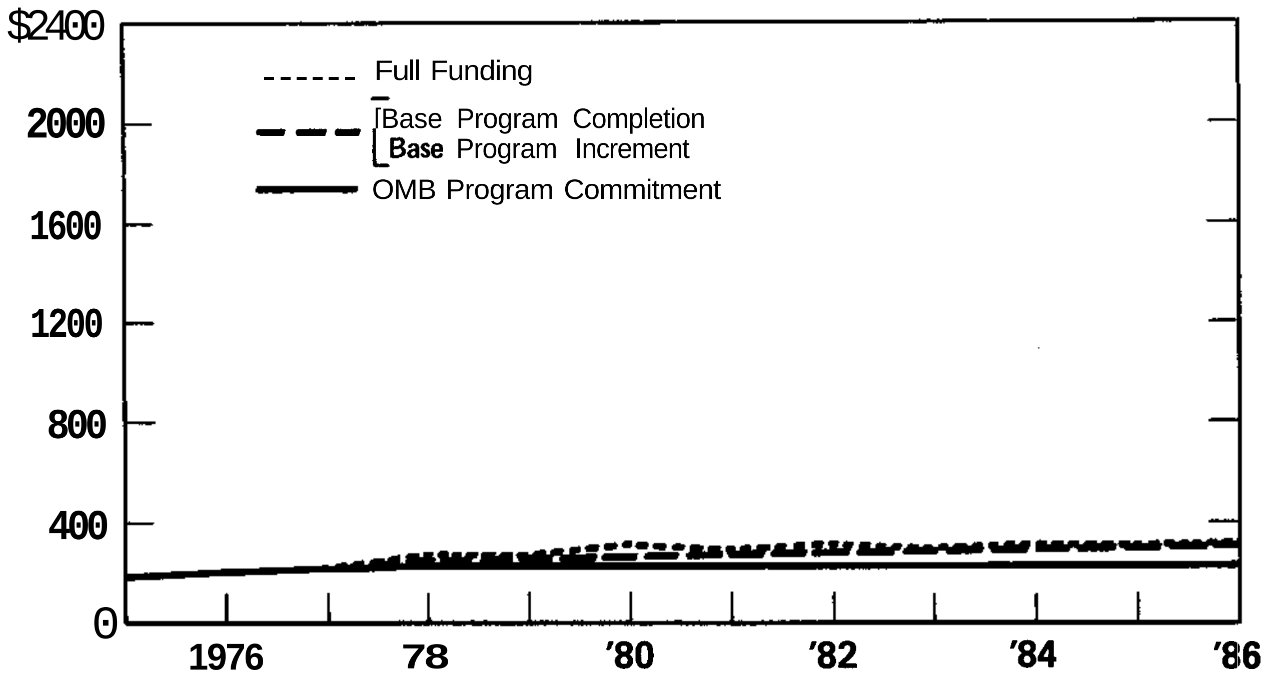
(1) Program Content and Recent Trends. The environmental research and safety program supports activities designed to determine the effects of energy technology development on man and his environment. Subprograms include (1) biomedical and environmental research to provide data on the health and environmental effects of pollutants generated by existing and emerging energy technologies, (2) operational safety which performs safety studies and provides a quick response capability for performing aerial radiological measurements, (3) environmental control technology to assess potential environmental intrusions associated with energy technology development, evaluate radioactive waste disposal techniques, and develop safety standards for the transport of nuclear shipments, and (4) reactor safety facilities to investigate techniques for neutralizing accidents in power reactors. Overall, this program ranks fifth in budget authority as a percent of total federal energy research and sixth in outlays. Program growth over the last two years has been steady but relatively moderate,

(2) Initiatives and Issues for Fiscal 1977. It appears that the fiscal 1977 budget for this area is beginning to shift in emphasis from historical concentration on nuclear energy health and environmental effects toward a somewhat more balanced research strategy encompassing broader environmental concerns, especially in the biomedical and environmental subprogram. However, the largest share is still allocated to nuclear projects. An additional initiative this year is the transfer of responsibility for the reactor safety subprogram from the Nuclear Regulatory Commission to ERDA.

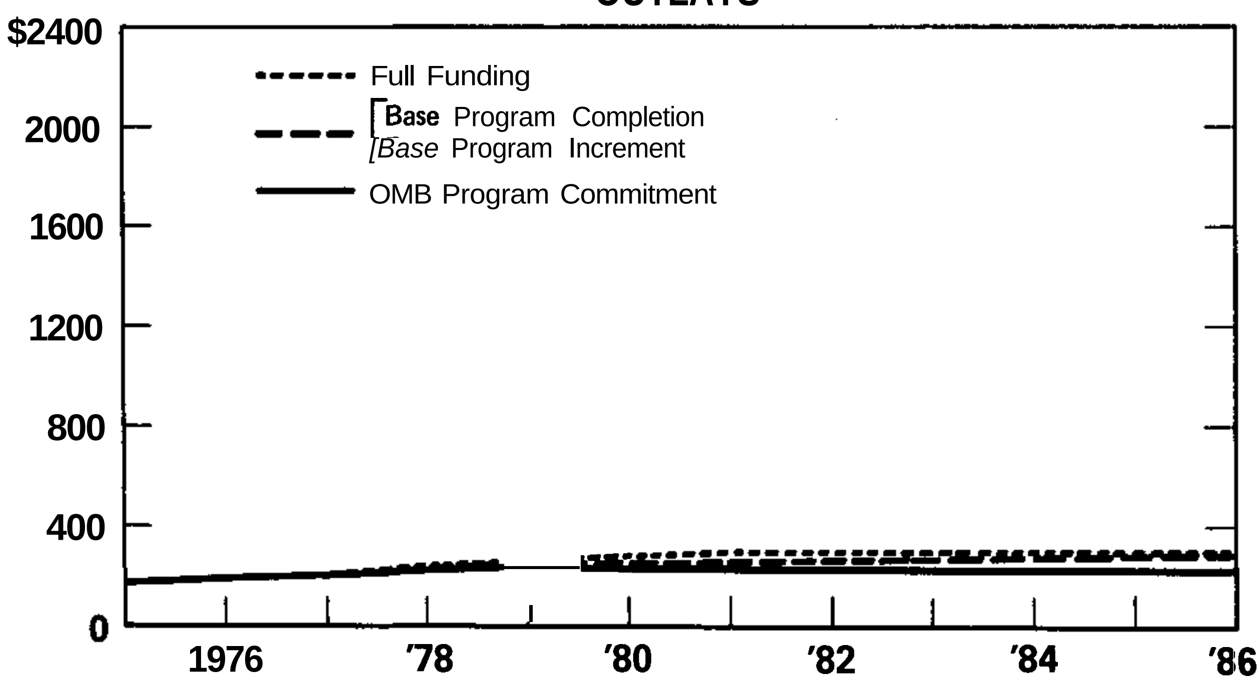
(3) Future Program Implications and Decisions. No new big-ticket construction projects are envisioned for this program over the next ten years.

Basic Energy Sciences Program, 1975-1986
(In Millions of 1977 Dollars)

Appendix Chart 19.
BUDGET AUTHORITY



Appendix Chart 20.
OUTLAYS



	1975 Actual	1976 Estimate	TQ Estimate	FY 1977 Request: Div. Request	FY 1977 Request: ERDA Request	FY 1977 Request: Pres. Request
Budget Authority	191	211	54	322	291	227
Outlays	165	188	52	274	257	204

(1) Program Content and Recent Trends. Funding for the ERDA basic energy sciences program supports theoretical and experimental research to develop scientific understanding basic to all energy technologies. Major subprograms are (1) nuclear science, which--through a broad range of basic studies employing various nuclear particles as probes--provides a new level of understanding of nuclear phenomena and processes; (2) materials sciences to expand knowledge of the properties of conventional materials required in all aspects of energy generation, conversion, transmission, and storage; (3) molecular, mathematical, and geosciences which provides basic scientific knowledge of the characteristics of potential energy sources; and (4) other capital equipment for the various ERDA national laboratories. Overall, this program area ranks seventh as a percent of total federal energy research; its growth rate over fiscal 1976 levels has been minimal.

(2) Initiatives and Issues for Fiscal 1977. Whereas basic research efforts in both materials sciences and molecular sciences have been allowed to increase slightly this year, the nuclear science subprogram was cut, especially in the area of low energy nuclear science (which encompasses experimental studies at national laboratory and university based accelerator and reactor facilities).

(3) Future Program Implications and Decisions. The only big-ticket items scheduled at full program funding are three items: an intense pulsed neutron source, an advanced synchronous radiation source, and a very high flux neutron source.

APPENDIX B

POTENTIAL DOMESTIC ENERGY RESOURCES[a]

SOURCE	ENERGY POTENTIAL (in quads)[b]	CONSUMPTION IN 1974 (in quads)
Existing Sources		
Natural Gas	1,030	22
Petroleum	1,100	33
Uranium (no breeder)	1,800	1
Hydroelectric		3
Coal	12,000	13
TOTAL		73[c]
Emerging Sources		
Oil Shale	1,200 - 5,800	--
Uranium (breeder)	130,000	--
Geothermal	As much as 400	—
Solar	Essentially Unlimited	—
Fusion	Essentially Unlimited	—

SOURCE: U.S. Department of Interior, Bureau of Mines, United States Energy Through the Year 2000 (revised), 1975, and ERDA-48, op.cit.

a. These are estimates of total remaining resource potential. Much of these resources remains to be discovered; not all could be developed economically at today's prices.

b. See Table I (Chapter II) for a definition of quad.

c. Does not add due to rounding.

APPENDIX C
LIST OF MAJOR CONSTRUCTION PROJECTS AT FULL FUNDING LEVELS FOR FISCAL YEARS 1978-1986*
(millions of 1977 dollars)

PROGRAM AREA AND PROJECT	TOTAL ESTIMATED COST OF FEDERAL SHARE	ESTIMATED PROJECT START DATE
● FOSSIL ENERGY		
1. Synthoil Pilot	100	1978
2. Pressurized Fluid Bed Pilot	100	1978
3. Closed Cycle Gas Turbine Pilot	75	1979
4. Alkali Turbine System Pilot	75	1979
5. MHD Engineering Test Facility	125	1979
6. MHD Advanced ETF	300	1982
7. MHD Demo	750	1982
8. Press. Fluid Bed/Comb. Cycle Demo	450	1982
9. In Situ Oil Shale Demo	100	1979
10. In Situ Large Gasif. Test Facility	50	1979
11. In Situ Large Gasif. Demo	150	1982
● SOLAR ENERGY		
1. Multi-Unit Wind Pilot (10MW)	100	1980
2. Multi-Unit Wind Demo (100MW)	250	1981
3. Wind Energy Factory Facilities	50	1981
4. Ocean Thermal Offshore Pilot (25MW)	400	1981
5. Ocean Thermal Demo (100MW)	850	1984
6. Solar Energy Research Inst.	50	1978
7. Low Cost Silicon Array Pilot	100	1979
8. Low Cost Silicon Array Demo	200	1983
9. Large Area Silicon Sheet Pilot	125	1983
10. Automated Array Pilot	150	1982
11. Automated Array Demo	200	1984
12. Central Receiver Demo (100MW)	400	1983
13. Distributed Collector Pilot	85	1980
14. Distributed Collector Demo	400	1983
15. Hybrid Solar Thermal Pilot	75	1981
16. Wood Plantation Pilot	100	1979
17. Wood Plantation Demo	250	1985
18. Marine Biomass Pilot	100	1982
19. Marine Biomass Demo	250	1986

*Only those projects estimated to cost more than $50 million are included.

- GEOTHERMAL

1. High Salinity Pilot	50	1978
2. Moderate Temp. Resource Pilot	50	1978
3. Magmatic Resource Test Facility	100	1979
4. Geopressure Pilot	150	1982
5. Hot Dry Rock Pilot	200	1983
6. Hot Dry Rock Demo	400	1985
7. Sedimentary Hydrothermal Demo	200	1978
8. Volcanic Hydrothermal Demo	375	1979

- CONSERVATION

1. Deno of Fuel Cells Power Plant	50	1980
2. Large Scale Recovery Pilot	50	1978
3. Large Scale Land Fill Pilot	60	1978
4. Large Scale Bioconversion Pilot	60	1978
5. Large Scale Pyrolysis Pilot	70	1979
6. Large Scale Combustion Pilot	80	1980

- FUSION POWER

1. Experimental Power Reactor I	700	1982
2. Advanced Fusion Facility	50	1979
3. Fusion Eng. Research Facility	100	1980
4. Oper. Test System Facility	150	1982

- FISSION REACTOR

1. Prototype Large Breeder Reactor	1,600	1981
2. High Performance Fuel Lab	100	1978
3. Fuel and Mat'l. Eval. Facility	100	1978
4. Plant Component Test Facility	290	1978
5. Safety Research and Eval. Facility	500	1978
6. Gas-Cooled Fast Reactor Demo	900	1980
7. Gas-Cooled Test Facilities	100	1978
8. Direct Cycle HTGR Dem	1,500	1979
9. VHTR Demo	1,400	1984

- OTHER NUCLEAR

1. LWR Training and Tech. Center	150	1978
2. LWR Commercial Assist. Program	450	1979
3. HTGR Recycle Demo Facility	750	1979
4. LMFBR Large Scale Camp. Testing	200	1978
5. LMFBR Fuel Cycle Pilot	450	1979
6. LMFBR Fuel Cycle Demo	700	1985
7. First Terminal Storage Plant	100	1981
8. Second Terminal Storage Plant	100	1983
9. Third Terminal Storage Plant	100	1985
10. Laser Uranium Enrichment Pilot	100	1981

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