BUDGET
ISSUE PAPER

Energy Research, Development, Demonstration, and Commercialization

January
1977

Congressional Budget Office
Congress of the United States
Washington, D.C.

ENERGY RESEARCH, DEVELOPMENT, DEMONSTRATION, AND COMMERCIALIZATION

The Congress of the United States
Congressional Budget Office

For sale by the Superintendent of Documents, U.S. Government Printing Office
Washington, D.C. 20402 - Price $1.15

PREFACE

As Congress makes decisions about budget targets for the First Concurrent Resolution on the Budget for fiscal year 1978, the appropriate level of funding for federal energy research, development, demonstration, and commercialization (R,D,D, and C) will be a topic of debate. That level could vary substantially, not just in fiscal year 1978 but also during the next ten years, depending on the level of federal effort devoted to implementing new energy technologies. Specifically, decisions about the federal role in commercializing such technologies and the methods selected to carry out that role will have major effects on the size of the federal energy budget. The paper discusses the R,D,D, and C process, criteria that can be used to judge potential energy R,D,D, and C strategies, and the costs associated with various elements of such strategies.

This paper is one of a continuing series of CBO background papers and budget issue papers analyzing energy issues for the Congress. It draws together previous analyses of federal energy research, development, and demonstration; uranium enrichment; synthetic fuels; and financing alternatives. In keeping with the Congressional Budget Office's mandate to provide non-partisan analysis of policy options, this paper contains no recommendations.

This paper was prepared by Richard M. Dowd, of the Natural Resources and Commerce Division under the direction of Douglas M. Costle and Nicolai Timenes, Jr. The author wishes to acknowledge the assistance of Mary Ann Massey of the Natural Resources and Commerce Division. The paper was edited by Katharine Bateman, and Angela Z. Evans typed the manuscript.

Alice M. Rivlin
Director

January 1977

TABLE OF CONTENTS

TABLES

SUMMARY

The oil embargo of 1973-1974 focused national attention on the need to develop new energy policy initiatives to resolve a broad range of energy problems. Initially, measures were developed to cope with the most pressing problems--temporary shortages and rapidly rising prices. However urgent the short-run problems, they may be considered but a manifestation of a set of longer-term problems that includes resource depletion, dependence on imports, rising prices, and environmental degradation. Thus, Congressional attention is now turning to longer-term energy issues such as pricing policy, import levels, energy conservation, and the development and implementation of new energy technologies.

This paper focuses primarily on the process by which those new energy technologies are developed to the point of being accepted in the marketplace, and specifically on the potential federal role in that process.[1]

It is useful to think of that process--the research, development, demonstration, and commercialization (R,D,D, and C) process--as a series of activities characterized by the development of information of increasing amount and changing character: first scientific, then technical, economic, and finally institutional information is needed to buttress--or encourage--an entrepreneur's decision to use a new technology in a commercial environment.

Such information can be costly. The federal government has long supported energy R and D, but in recent years federal expenditures for such R and D have climbed rapidly, until in the fiscal year 1977

---

1. Broader energy policy issues--and shorter-range concerns--are discussed in a companion CBO Budget Issue Paper, Energy Policy and the Federal Budget, January, 1977.

82-041 O - 77 - 2

budget they totaled $3.3 billion, or two-thirds of all federal money budgeted for energy. Proposals for commercialization, together with possible increases in the amount spent for R and D, could markedly increase the size of the overall federal energy budget. Furthermore, contingent liabilities associated with commercialization could equal expected total outlays for R,D,D, and C over the next ten years.[2]

In designing a national R,D,D, and C strategy, choices must be made about the technologies to be investigated, the nature and extent of federal participation, and the level of federal funding. Congressional action on such issues rarely takes the form of clear choices on overall strategies or decade-long funding patterns. Rather, the R,D,D, and C strategy is likely to be shaped by a series of decisions--many of which will come up in fiscal year 1978--on questions such as expansion of the nation's uranium enrichment capacity; commercialization of synthetic fuels; nuclear proliferation; support for the breeder reactor; and a host of technical, regulatory, and institutional decisions concerning nuclear reprocessing, solar energy, and conservation.

Because of the budgetary significance of the pattern of those decisions--and the perhaps greater significance for the future shape of the nation's markets for energy--it is important that Congress understand this R,D,D, and C process in deciding where and how the money to be allocated for it should be spent.

---

2. A contingent liability is a potential outlay. It generally takes the form of a loan guarantee or similar mechanism whereby the government pledges to pay costs incurred by private lenders if they cannot recoup their investment. Contingent liabilities may or may not be counted in the budget as budget authority, at the discretion of Congress. Outlays resulting from realization of such liabilities, e.g., from defaulted loans, are counted in the budget when they occur.

Certain generalizations are possible about the successive stages of this process. Summary Table 1 shows the nature of information, the nature and mechanisms of the federal role, and the relative cost associated with each of the stages. In deciding on specific action with respect to a specific technology, it is important to understand exactly at what point--or at which stage in the process--the given technology is.

These considerations, developed in detail in the body of the paper, lead to the definition of several criteria for the design of an R,D,D, and C strategy. Such a strategy should: (1) support the attainment of a desirable energy future,[3] (2) provide insurance against technological failure, (3) entail minimum costs, and (4) require the least federal involvement possible in implementing a chosen technology.

To illustrate the consequences for the federal budget of alternative R,D,D, and C strategies, four examples are constructed in the paper. Each strategy represents a collection of decisions on the level of funding for research and development, the nature and scope of the more extensive demonstration programs, and the federal role in commercialization. Until now, federal commercialization efforts have been limited to nuclear technologies, but numerous initiatives have been suggested for other technologies as well, and a comprehensive strategy would involve decisions on such issues.

While the strategy ultimately selected by the Congress will doubtless differ in many respects from those illustrated here, the examples can help to suggest the broad range of alternatives available. The four, in order of increasing federal outlays over the next decade, are:

---

3. An energy future implies a pattern of energy markets in future years. It includes energy prices, energy technologies, and the quantities of energy consumed, produced, and imported.

SUMMARY TABLE 1: CHARACTERISTICS OF R,D,D, AND C STAGES

	R&D	Demonstration	Commercialization
Information	Technical feasibility Process condition Basic cost Environmental effect	Economic potential Costs Environmental effect Institutional factors	Markets Risks Institutional
Federal Role	Grants Government/labs. Incentive for R&D Dissem'n of info.	Cost sharing Government ownership Contracts Dissem'n of info.	Loan guarantees Price supports Guaranteed purchases Cost sharing Regulation
Total Relative Cost	Lowest	Mid	Most (potentially)

(1) A strategy that would involve continuing the present policy by allowing only modest growth of R and D programs, completing only those demonstration projects currently underway; retaining government ownership of new uranium enrichment plants; and making no special efforts to speed improving profits.

The reliance of such a strategy on past programs and emphases implies failure to respond to recently articulated priorities in areas such as solar energy, conservation, and environmental protection. The minimum federal involvement and expenditures would provide neither assurance of technical diversity nor major stimulus to introduction of new energy technologies.

(2) A strategy that would focus on the reduction of uncertainty by supporting an R,D, and D program emphasizing a few chosen long-term technologies and by providing financial incentives for high-risk but profitable enterprises (including uranium enrichment), but would include no subsidies for projects estimated to be unprofitable.

By selecting for heavy support, at the more expensive stages, a subset of the available major technologies at the expense of others, this strategy would threaten achievement of certain desirable futures through neglect of technologies which might, in the long run, turn out to be more advantageous than those emphasized. However, the pace of development would not be excessive and federal intervention in energy markets would be less than for the more expensive strategies.

(3) A strategy emphasizing energy production by focusing the R,D, and D program on near- and mid-term technologies; by providing financial incentives for commercialization of ventures that are marginally profitable, rather than for those that are inhibited by uncertainty and risk; and by providing for government ownership of new uranium enrichment facilities.

Like the preceding strategies, this one would be inconsistent with certain desired futures because demonstrations for long-term technologies would be deferred. However, diversity would be preserved at predemonstration stages. Limited federal intervention in energy markets could lead to a rise in prices, due to the encouragement of technologies not profitable at current prices.

(4) A strategy that would strengthen federal stimulus by carrying out all new R,D, and D projects identified to date; would support a program of financial incentives for commercialization of those technologies inhibited by either risk or unprofitability; and would provide financial incentives for private commercialization of uranium enrichment.

The significant federal involvement, in terms both of intervention in markets and expenditure of federal funds, would support a variety of desired futures. The weaknesses stem from scale and pace of effort, heavy emphasis on the later stages in the R,D,D, and C process, and extent of federal involvement.

A comparison of these four alternative strategies prompts the following observations. Given present energy priorities--or even with some important changes--each alternative is expensive: the outlays over a decade would range from $44 billion to $66 billion. In addition, contingent liabilities could approach these figures. Ten-year budget impacts are summarized in Summary Table 2 and provided in detail in the text.

For fiscal year 1978, a choice of strategy could result in a variation of as much as $700 million (from $4187 million to $4887 million), as shown in Summary Table 3.

Both in fiscal year 1978 and during the ensuing ten years, there are a number of possible tradeoffs, and the way in which moneys are spent, as well as the total of funds allocated to R,D,D, and C, will be important determinants of success in assuring that new energy technologies will be available to the marketplace when they are needed.

SUMMARY TABLE 2: FEDERAL COSTS FOR ALTERNATIVE R,D,D, AND C STRATEGIES 1977-1986, BILLIONS OF DOLLARS

	R,D,&D	Uranium Enrichment	Subsidies[a]	Total	Contingent Liabilities[b]
Continuation of Present Policies	43.0	1.3	---	44.3	---
Reducing Uncertainty	53.9	(3.8)[c]	---	50.1	19
Energy Production	50.5	1.3	1.1-3.7	52.8-55.4	34
Strong Federal Stimulus	66.2	(3.8)[c]	1.1-3.7	63.4-66.0	51

a. Major outlays occur after 1986.

b. Contingent liabilities are not included in the total column, because it is not possible to estimate what outlays might ensue as a result, for example, of defaults on guaranteed loans.

c. Future uranium enrichment plants--beyond those now planned--would be built and operated by private industry. Revenues from operation of existing plants will exceed costs during the decade.

SUMMARY TABLE 3: PROJECTED BUDGETS FOR ALTERNATIVE R,D,D, AND C STRATEGIES FISCAL YEAR 1978, MILLIONS OF 1977 DOLLARS

	R,D,&D	Uranium Enrichment	Subsidies	Total
Contination of Present Policy	3766	421	--	4187
Strong Federal Stimulus	4426	399	60	4885
Reducing Uncertainty	4101	399	--	4502
Energy Production	4406	421	60	4887

CHAPTER I INTRODUCTION

During the last few years, energy has become a major national issue. In responding to that concern, Congress and the executive branch have taken a number of initiatives in the energy policy area and are considering others.

Two closely related areas have received much of the attention: (1) expansion of energy research, development, and demonstration programs; and (2) initiatives for commercialization of new technologies. Decisions on the shape and scope of these programs could lead to differences in the fiscal year 1978 budget ranging from a reduction of $0.25 billion to an increase of $1.3 billion from the current policy budget.[1] (However, such extremes are unlikely; the illustrative budgets discussed in Chapter V differ by only $0.7 billion in fiscal year 1978.) Variations over a ten-year period could total as much as $16 billion. In addition, recently considered commercialization proposals concerning uranium enrichment and synthetic fuels could add over $10 billion in federal liabilities (contingent upon project operations) in fiscal year 1978, and perhaps several billion dollars in actual outlays over the years.[2]

This paper discusses the framework of a continuous research, development, demonstration, and commercialization (R,D,D, and C) process and

---

1. Based on the methodology used in preparing CBO's estimates given in Five-Year Budget Projections: Fiscal Years 1978-1982, December 1976.

2. A contingent liability is a potential outlay. It generally takes the form of a loan guarantee or similar mechanism whereby the government pledges to pay costs incurred by private lenders if they cannot recoup their investment. Contingent liabilities may or may not be counted in the budget as budget authority, at the discretion of Congress. Outlays resulting from realization of such liabilities, e.g., from defaulted loans, are counted in the budget when they occur.

82-041 O - 77 - 3

the potential costs of four illustrative alternative energy R,D,D, and C strategies. It describes some initiatives likely to be considered by the 95th Congress. While this paper is limited to discussion of issues as they relate to the R,D,D, and C process, such issues should, as well, be considered in the larger context of overall energy policy. Such a discussion can be found in a companion CBO budget issue paper entitled, Energy Policy and the Federal Budget.

RESEARCH, DEVELOPMENT, AND DEMONSTRATION

The federal government has long supported basic research and development on a modest scale; those efforts were intensified in the aftermath of the oil embargo of 1973-1974. The Congress appropriated $3.3 billion in budget authority for energy R,D, and D in fiscal year 1977, more than four times the $790 million for energy activities in fiscal year 1974. Depending on future choices, federal expenditures for energy research, development, and demonstration could total as much as $65 billion over the next decade.

COMMERCIALIZATION

New technologies developed in the R,D, and D program promise to permit the exploitation of resources hitherto untapped or underutilized. Because economic and institutional, as well as technological, barriers inhibit the introduction of such technologies into the marketplace, a number of initiatives have been proposed to make at least some of these technologies commercially viable. Some of the commercialization initiatives considered by the 94th Congress indicate the potential federal expenditures that could occur now and in the years ahead: For example, Congress has already enacted a $50 million geothermal loan program. It has also considered: a program for synthetic fuels, with (in one version) $2 billion in loan guarantees and $600 million in price supports; a program for uranium enrichment with up to $8 billion in contingent government liabilities; the proposed Energy Independence Authority, with $100 billion in budget authority; and an incentive program to promote conservation. A variety of specific mechanisms--loan guarantees, price supports, technology guarantees, and so forth--have been suggested as part of such initiatives.[3]

Other technologies--the breeder reactor, for example--are also approaching the stage at which requirements for commercialization become relevant.

In total, such commercialization programs could cost as much as or more than the R,D, and D programs that now consume most of the federal energy budget.

THE ISSUES

The ensuing chapters of this paper take up the following issues: Chapter II discusses the nature of the R,D,D, and C process and its relationship to other energy policy initiatives. Chapter III describes some criteria for design of an R,D,D, and C strategy. Chapter IV discusses the federal role and instruments available in the context of proposals that have been before Congress. Finally, Chapter V formulates several alternative R,D,D, and C strategies and estimates their budget costs.

---

3. For discussion of these and other mechanisms, see Congressional Budget Office Background Paper No. 12, Financing Energy Development, July 26, 1976.

CHAPTER II THE ENERGY RESEARCH, DEVELOPMENT, DEMONSTRATION, AND COMMERCIALIZATION PROCESS

The R,D,D,and C process, which involves the creation, accumulation, dissemination, and use of knowledge, combines two disciplines: science and engineering. When commercialization is involved, economics and finance also become important.

Scientists and engineers, by the nature of their disciplines, are likely to focus on individual segments of the process, such as the scientific basis and feasibility of fusion or the design of less expensive or more reliable synthetic fuel plants. Economists and financiers are concerned more with profitability and risk in the marketplace.

Policymakers must take a broader view of the many factors that make possible the completion of the process, including the desirability of a technology itself, budgets for support (and the competing claims on those budgets), and the extent and timing of participation by the private sector.

As a technology (solar, nuclear, etc.) moves from research through development to demonstration and commercialization, it will at each step make varying demands upon scientific and engineering personnel, funding, and market incentives. The characteristics of success will also vary at each of the four stages. Progress will depend on what has already been learned, what can be achieved in any particular stage, and any major uncertainties that might surround the project at a given stage. It is this information component that ought to determine how quickly decisions can be made about ultimate disposition of the technology.

The distinctions between successive stages in the R,D,D, and C process are rarely clear. Indeed, the process can be viewed as a continuous one, in which the nature and volume of information available is constantly--if often almost imperceptibly--changing. As the information changes, so do the questions which must be asked next. The first questions tend to be scientific, but as the technology matures, engineering, economic, and institutional questions become increasingly important.

It is not surprising that problems arise even with definition of the terms research, development, demonstration, and commercialization. Yet there are important distinctions which have to do with the nature of information to be gained, the appropriate policy instruments to be used, and the timing of major decisions. The following discussion of each of the stages may help to clarify their relation to each other and to the entire process.

RESEARCH AND DEVELOPMENT

Research and development is generally designed to gather information about theoretical and technical uncertainties and to carry the investigation to a point where it is possible to determine the technical feasibility of a technology or process.

The distinction between research and development is difficult to make and, with the exception of certain "basic research" programs, is rarely made in practice. (It is also unnecessary for the purposes of this paper, because of the relative funding levels involved. However, this is not to say that basic research can be ignored in comparison to later stages that generally cost more.) Research is now being carried out in the fusion program, for example, to show whether it is possible to extract more energy from the process than it consumes. This break-even point will determine, at a very basic level, whether fusion can possibly become a source of energy. In the solar area, for another example, photovoltaic (light to electricity) materials can convert sunlight to energy. However, to become an economic energy source, the photovoltaic process requires the production of huge quantities of material that have uniform, reliable characteristics. Techniques for manufacturing this material in quantity and at competitive costs need to be established. Likewise, production of oil or gas from shale requires the development of in situ techniques to extract these materials from the shale while it remains in the ground.

The information gained in the research and development stage about basic feasibility, about subsidiary problems like materials performance, and about necessary design features will determine whether and how a demonstration is to be carried out.

DEMONSTRATION

It is appropriate to begin the demonstration stage when basic uncertainties have been resolved and the new information gained indicates that the demonstration will generate information about other remaining uncertainties associated with a much larger scale effort. For energy technologies, such uncertainties are likely to be economic, environmental, or institutional in nature. The point of constructing a demonstration project at near-commercial scale is not simply to increase its size, but to find answers to still unresolved questions that can only be found with a model constructed on this larger scale. For example, environmental impacts will be more extensive and measurable, the institutional impediments may be more apparent, and the costs are likely to be far greater than those incurred in earlier stages.

All of these uncertainties--economic, environmental, institutional--need not exist in order to justify a demonstration project. Each demonstration will have a specific combination of factors, some of which are well known and some of which pose substantial uncertainties. In general, technical feasibility is, or should be, better known than other factors, because feasibility relates more closely to technological principles (e.g., the laws of physics) that generally are not altered by enlargement; and because feasibility can be tested at a smaller scale more quickly and less expensively.

The demonstration project can be designed to address these problems as well as the viability of the technology at a scale close to commercial operation. Indeed, if a new energy technology were known to be feasible and reliable; if the cost of its operation at a commercial scale were well understood; if its environmental effects were well catalogued and techniques for mitigating such effects were well in hand; if its price were competitive with alternative sources; and if this knowledge were perceived by users and suppliers, there would be no reason to undertake a demonstration. The technology could be put into commercial production immediately.

In a recent study by the Rand Corporation,[1] a large number of federal demonstration projects in many areas were evaluated with regard to success in demonstrating the technology, diffusing the knowledge gained, and accelerating commercial implementation.[2]

The study concluded that the elements of a sucessful demonstration tended to include: (1) a technology well in hand; (2) cost and risk-sharing with nonfederal participants; (3) project initiatives from nonfederal sources; (4) the existence of a strong industrial system for commercialization; (5) inclusion of all participants needed for commercialization; (6) absence of tight time constraints.

Those conclusions are relevant to the present discussion in several ways. First, it is clear that an important factor in the success of a demonstration is that the technology be ready to leave the R and D stage (i.e., uncertainties about technical feasibility are resolved). A demonstration designed to uncover a large amount of new information about technical feasibility or environmental effects is less likely to provide a system ready for commercialization and could more appropriately be carried out as an R and D project. Second, demonstration projects should include major private sharing in the initiation, planning, and funding to create the conditions--particularly the existence of direct experience--which enhance the likelihood of ultimate commercialization.

These findings would indicate that complete funding by the federal government, with a dominant federal planning and management presence, makes ultimate commercial success less likely. Rand cited,

---

1. Rand Corporation, Analysis of Federally Funded Demonstration Projects, April, 1976.

2. In the context of this paper, commercialization is not meant to include the implementation of already existing and unchanged technologies such as strip-mining of coal or light water nuclear power plants, but rather the implementation of new or emerging energy technologies.

as an example of a demonstration project that was successful in encouraging commercialization, the Yankee Atomic nuclear power plant, built and managed by a utility consortium with less than 20 percent of costs borne by the federal government.

COMMERCIALIZATION

The final stage in the progression of a new technology is its commercialization, i.e., its implementation in a commercial or production framework.[3]

Most technological innovation, of course, needs no government intervention to encourage commercial adoption if an appropriate market exists. The market rewards successful innovation with profits and punishes failures with losses. Government action to commercialize a technology becomes necessary only when two conditions exist simultaneously: (a) a promise of substantial benefit to the nation or society from that technology, and (b) a market environment that does not encourage its adoption.

The kind of marketplace obstacle to commercialization varies with the technology to be introduced; therefore the type of government action necessary to remove the obstacle will vary. If, for example, the obstacle is not technical feasibility or costs, but the inability of the private sector to raise large amounts of investment capital, then a government commercialization program including direct grants, loans, or loan guarantees might be appropriate. If, on the other hand, the obstacle were the availability of competing lower-priced energy sources, some form of price supports might be helpful. However, government intervention to reduce one type of obstacle will generally not be appropriate for the other and may even be counterproductive. These varying roles and instruments are discussed in Chapter IV.

---

3. It is often said that federal energy R and D programs are designed to "push technology" which is developed independent of demand, while commercialization programs represent "demand pull" in which technologies which are ready to produce energy at competitive prices are implemented.

82-041 O - 77 - 4

There are precedents for government provision of commercialization incentives. The nuclear power industry, for example, was helped to the commercialization stage with insurance incentives (the Price-Anderson Act).

Costs are likely to be the largest at the commercialization stage because the scale of effort is largest. This does not necessarily mean that the cost to the government will be proportionately high, because private industry may be more willing to accept an important share of costs at this stage when profits may soon be realized.

Table 1 summarizes the characteristics of each stage of the R,D,D, and C process: the type of information to be gained, the different roles and mechanisms that the federal government could adopt, and the relative costs.

TABLE 1: CHARACTERISTICS OF R,D,D, AND C STAGES

	R&D	Demonstration	Commercialization
Information	Technical feasibility Process condition Basic cost Environmental effect	Economic potential Costs Environmental effect Institutional factors	Markets Risks Institutional
Federal Role	Grants Government/labs. Incentive for R&D Dissem'n of info.	Cost sharing Government ownership Contracts Dissem'n of info.	Loan guarantees Price supports Guaranteed purchases Cost sharing Regulation
Total Relative Cost	Lowest	Mid	Most (potentially)

CHAPTER III DESIGNING A RESEARCH, DEVELOPMENT, DEMONSTRATION, AND COMMERCIALIZATION STRATEGY

A successful R,D,D, and C strategy will ultimately result in the implementation of some of the new energy technologies, thereby increasing supplies or decreasing consumption. This chapter discusses the design of such strategies.[1]

Various standards or criteria must be applied at various stages in the design of energy strategies. For purposes of this paper, these criteria can be divided into four groups: the first and third apply to all stages, the second relates primarily to the earlier R,D, and D stages, the fourth primarily to commercialization. An R,D,D, and C strategy should: (1) support the attainment of desirable futures;[2] (2) provide insurance against failure; (3) do so at the lowest possible cost; and (4) provide the least federal intervention consistent with implementation of new energy technologies.

SUPPORT OF DESIRABLE FUTURES

Clearly, any R,D,D, and C strategy should be directed toward achieving a future that is considered desirable.

In a companion budget issue paper on energy policy, four possible broad goals are articulated: (1) economically efficient use of energy resources, (2) availability of energy to consumers at low cost, (3)

---

1. Some of the criteria for designing a R,D, and D strategy are discussed more fully in Energy Research: Alternative Strategies for Development of New Energy Technologies and Their Implications for the Federal Budget, CBO Background Paper No. 10, July 15, 1976.

2. In this context an energy future implies a pattern of energy markets in future years. It thus includes energy prices, energy technologies, and quantities of energy consumed, produced, and imported.

protection from supply interruption, and (4) protection of the environment. There are certain inherent conflicts among these goals and among methods to achieve them, so that a balancing is required to achieve an agreed upon future.[3]

The federal Nonnuclear Energy R and D Act of 1974, in calling for emphasis on conservation, renewable resources, and mitigation of adverse environmental effects, established three characteristics of a desirable energy future, and thus suggests priorities among both goals and means to achieve them.

An energy R,D,D, and C 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 (e.g., highly centralized or locally diffused).

An R,D,D, and C 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 selection of technologies to be supported. A technology which could have a quick payoff in increased supply or reduced demand 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 time frames: 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.

---

3. Energy Policy and the Federal Budget, CBO Budget Issue Paper, January 1977.

INSURANCE AGAINST FAILURE

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

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 a quicker payoff. For example, research dealing with the nature of nuclear reactions is generally considered basic, while research into specific technical problems, such as the effect of a high neutron flux on structural materials, is generally termed applied research. A federal strategy should contain substantial support for basic research, particularly in areas not well supported by private enterprise, which tends to favor applied research because of potentially earlier payoffs.

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 fusion program, both the laser-induced and magnetic confinement systems have potential for increasing energy supplies. Research efforts in both would help provide insurance against failure of one.

Balance is particularly important in allocating manpower and funding among R,D,D, and C 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--and the even higher costs of certain mechanisms, such as subsidies, for commercialization--could threaten to squeeze out support for 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.)

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.

It is critical that commitment to development not be premature. The key information that one stage of the R,D,D, and C process is designed to elicit should be available before the next stage is begun. While a shortened sequence is possible, prudence would suggest that such a sequence allow for the assimilation of previous research results. As the Rand study suggests, tight time constraints also increase the chance of failure for demonstrations.

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

COST

As indicated, federal support may be 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 excessive, federal support could be essential if the potential private sector involvement were small, diverse, and fragmented.

Because of limited resources, R,D,D, and C efforts must be selective. Avoiding premature commitment to a particular technical approach and carefully assessing program costs relative to expected benefits can maximize the effectiveness of available resources.

MINIMUM FEDERAL INTERVENTION

One argument for minimizing federal intervention is basically philosophical: the government should not pre-empt the private sector in a sphere normally reserved to it. Economic arguments would indicate that government intervention could retard the operation of market forces; less intervention would therefore be preferable. Exceptions can be made in cases where an important public goal is receiving insufficient private sector attention. In the Nonnuclear Energy Research and Development Act of 1974 (P.L. 93-577), Congress has specified that federal involvement should occur only when nonfederal action is inhibited and the anticipated public benefit is large.

Furthermore, as stated in Chapter II, too much federal involvement at the demonstration and commercialization stages makes success less likely. The Rand study[4] indicates that the larger the private sector role in demonstrating and commercializing a technological process, the more likely the success in implementing the process. This private sector role should, according to the study, include planning and funding the project. This standard of maximum private sector participation becomes even more important at the commercialization stage, because the proof of success is private sector operation. The study provides some evidence that extending the nonfederal role to the direct management of a demonstration also increases the possibility of success. In addition, a comparison by Paul Joskow[5] of R and D policies in Britain, France, and West Germany indicates that very concentrated government control and planning through nearly the entire process will likely result in failure of commercialization efforts. The results of these studies strongly suggest the need for as little federal involvement as possible.[6]

---

4. Rand Corp., Analysis of Federally Funded Projects, pp. 6-8.

5. Paul Joskow, Research and Development Strategies for Nuclear Power in the United Kingdom, France, and Germany, unpublished monograph, July 15, 1976.

6. This is not to say that the government should relinquish all control and not demand accountability from program managers. The clear tension between the need for accountability and the proven effectiveness of unified program management is a continuing dilemma in the design of federal programs.

Implicit in these criteria is the need to apply them selectively to a technology as it proceeds through the various stages. Different technologies will require more or less time for each stage and more or fewer decision points. It is critical, however, that within any program for developing a single technology (solar, fusion, etc.) allowance be made for the possibility of failure of a particular approach at a particular stage. Neglect of this possibility may doom an entire program to commercial failure.

Applying these criteria in specific instances is not an easy task. Many layers of agreement and disagreement must be penetrated. There will be scientific as well as political disagreement on some issues such as costs or pace of development. However, those managing a project should in each case have a clear idea of what is to be learned or accomplished by each project and what knowledge has already been gained. Then a policy decision must be made as to whether and how the next step should be accomplished.

CHAPTER IV POTENTIAL RESEARCH, DEVELOPMENT, DEMONSTRATION, AND COMMERCIALIZATION PROGRAMS BEFORE CONGRESS

This chapter discusses energy proposals likely to come before the 95th Congress with regard to the R,D,D, and C process described in Chapter II and the evaluation criteria outlined in Chapter III. Enactment of any of these proposals will reinforce the recent policy of substantially altering the federal role in energy R,D,D, and C. In the past, the federal government has generally played an active role only in basic energy R and D; even then, the private sector provided more support than did the public sector. In the past decade, much greater federal support has been directed, not only to R and D, but also to the development and demonstration levels formerly left largely to the private sector. The federal government exceeded the private sector in energy R,D, and D support around 1975.[1] Currently, federal support has been growing even faster, more than doubling from fiscal year 1975 and reaching $3.3 billion in appropriations for fiscal year 1977.

POTENTIAL FISCAL YEAR 1978 R,D, and D Issues

CBO's current policy estimate[2] of ERDA's R,D, and D budget in fiscal year 1978 is approximately $3.7 billion.[3] This represents a continuation of present policies with no change in level of effort. Issues of potential changes in that level and in the types of energy sources emphasized are likely to be the focus

---

1. For a fuller discussion of this issue see John E. Tilton, U.S. Energy R&D Policy, Resources for the Future, Inc. Washington, D.C., September 1974, p. 19.

2. Congressional Budget Office, Five Year Budget Projections: Fiscal Years 1978-1982, December 1976.

3. This calculation derives the ERDA budget from the larger aggregate figures in the Five-Year Budget Projections and applies the same formulas for years after 1977.

of Congressional discussion during the next budget cycle. These issues include: real growth in base program; additional new starts in large demonstration programs; the government's continued support of the nuclear fuel cycle; and work on the breeder reactor.

- Real growth. Allowing real growth (of around 3 percent for mature programs such as fossil energy, 6 percent growth in less mature programs such as solar energy, and 40 percent growth in the relatively new conservation program) would increase budget authority by $159 million and outlays by $139 million in fiscal year 1978.

- New demonstration starts. Starting new demonstration projects could require up to $740 million in new budget authority and $130 million in outlays, depending on which projects were approved and whether the emphasis on nuclear power were continued.

- Uranium enrichment. Continuing additional expansion of the existing government-owned enrichment facility at Portsmouth, Ohio, could require additional budget authority and outlays of as much as $280 million.

- Reprocessing. If the government were to initiate a demonstration program in conjunction with the privately-owned nuclear fuel reprocessing plant now under construction at Barnwell, South Carolina, the total federal cost might exceed $500 million. For fiscal year 1978 this might require budget authority of $150 million and outlays of $25 million.

- The breeder reactor. Construction of the Clinch River breeder reactor demonstration has already been partially funded. Substantial additional funding of about $1 billion is still needed. Stretching out the completion of this project could reduce fiscal year 1978 budget authority by as much as $280 million; outlays could decrease by a lesser but still significant amount.

POTENTIAL FISCAL YEAR 1978 COMMERCIALIZATION ISSUES

Although the federal government has had an indirect role in the commercialization of energy technologies through regulation and patent policy, it has played a direct role only in the case of nuclear power. The Atomic Energy Commission (AEC), from which ERDA was created, in an extensive effort, provided the basic research to develop the light water reactor (LWR) and then encouraged implementation by removing the prime impediment to commercialization: through the Price-Anderson Act, the government limited to $560 million (in combined federal and private funds) the potential financial liability that would be incurred by electric utilities in the event of a nuclear disaster at an LWR site.

During the 94th Congress, there were several proposals to increase substantially the federal role in the commercial implementation of technologies other than the LWR. In the aggregate, these initiatives could have amounted to a major intervention in the normal market place and could have substantially increased the size of the federal budget for years to come. Many of the same commercialization issues can be expected to arise in the 95th Congress, although proposed solutions could differ. The issues include:

Uranium Enrichment

The proposed Nuclear Fuel Assurance Act (NFAA) provided a mechanism for transferring to the private sector the government-owned commercial technology for enriching the uranium used in LWRs. Congress did not enact this bill, but it did authorize funds for expanding enrichment capacity at the government's Portsmouth plant.[4] Congress has yet to decide

---

4. For more detailed discussion of these issues, see CBO Background Paper No. 7, Uranium Enrichment: Alternatives for Meeting the Nation's Needs and Their Implications for the Federal Budget, May 18, 1976.

whether further expansion of domestic enrichment capacity will be needed. If additional capacity is needed, questions remain as to whether the government or private industry should own this additional capacity and how it should be financed. The federal role could be one of a producer of services sold to utilities (enrichment services) or of a guarantor (to whatever extent) of processes made available to the private sector.

The NFAA was designed to mitigate three perceived impediments to private ownership and financing. These impediments are:

a) the classified nature of the technology;

b) the large size of the initial investment; and

c) the potential risks of financial losses if national policy regarding LWRs were to be changed or if new unproven enrichment technology did not work.

The instruments proposed in the NFAA took the form of guarantees which would reduce the financial and technological risks of the project and make private financing possible. The government would have guaranteed to take over the project--and its liabilities if necessary--thus in effect guaranteeing private loans, even though direct loan guarantees were not provided. This would have reduced the risk of technological failure, but it would not have guaranteed profitability.

As was pointed out in the report prepared by the Energy Task Force of the Senate Budget Committee[5], instruments such as these for guaranteeing loans or reducing financing risks are useful when risks and unknown factors or the scale of effort are the impediments to commercializing a technology, but these instruments are not as appropriate if unprofitability is at issue.

---

5. United States Senate, Financing Energy Development: Financial and Budgetary Implications of Government Guarantees, Staff Report of the Task Force on Energy of the Committee on the Budget, August 30, 1976.

Synthetic Fuels

During the 94th Congress, the President proposed to encourage the immediate commercialization of existing technology to produce synthetic fuels from coal. While Congress did not enact such legislation, it is likely that the issue will again arise, and many elements of a new synfuels proposal could be similar to previous ones.

The federal role in commercializing synthetic fuels could be restricted to general support for the development and demonstration of technology (e.g., through development of hardware) or the government could directly intervene in financial and consumer markets. If it were to intervene, the choices of mechanism could be from the range--loans, loan guarantees, price supports, etc.-- considered during the 94th Congress.[6]

The impediments to commercialization of synthetic fuels were seen as:

a) potentially unprofitable operation,

b) unknown environmental and institutional impacts, and

c) the large scale of effort (and hence financing) required.

The instruments suggested took the form primarily of loan guarantees, which would act to reduce the financial risk and thus encourage private investment; under various conditions, the federal government could have assumed potentially large liabilities. In addition, subsidies were considered in the form of

---

6. For a more detailed discussion, see CBO Background Paper No. 3, Commercialization of Synthetic Fuels: Alternative Loan Guarantee and Price Support Programs, January 16, 1976.

guaranteed prices or buy-back contracts to eliminate unprofitable operations if prices of energy from alternative sources were too low to make synthetic fuels competitive. Thus both risks (those of operation and scale and those of unprofitability) were addressed.[7]

NUCLEAR ISSUES BEYOND 1978

Several specific nuclear R and D issues will require attention beyond 1978. The major ones are likely to concern the breeder reactor, reprocessing, and proliferation.

Although it has already been decided to build the Clinch River breeder demonstration plant, ground has not been broken and at least an additional $1 billion will have to be appropriated.

ERDA may request funding for the High Performance Fuel Laboratory in fiscal year 1978. A decision on this request will influence a host of related issues on the many components of the breeder cycle, the nascent breeder industry commercialization question, and the widespread use of plutonium.

The issue of reprocessing spent nuclear fuel for reuse could be raised primarily as it affects light water reactor technology, particularly in the context of the private nuclear fuel reprocessing plant now under construction in Barnwell, South Carolina. If the federal government were to construct the plutonium conversion and radioactive waste solidification facilities at this plant, costs could be close to $500 million. While the present generation of light water reactors can operate without reprocessed fuel, breeders cannot, thus tying some of the reprocessing issues to the breeder.

---

7. The use of such instruments for mitigation of risk and unprofitability are discussed in more detail with reference to synthetic fuels, uranium enrichment and the Energy Independence Authority in the CBO paper, Financing Energy Development, cited on page 3.

Finally, proliferation raises significant issues of national and world security: while not primarily budgetary in nature, decisions affecting proliferation could affect many of the issues that do have large budget implications.

CHAPTER V FOUR ALTERNATIVE RESEARCH, DEVELOPMENT, DEMONSTRATION, AND COMMERCIALIZATION STRATEGIES AND BUDGETS

The future federal energy R,D,D, and C strategy will be determined by Congressional decisions regarding technologies, expenditures, and the level of federal support for private sector efforts. This chapter discusses some alternative strategies.

Included in each alternative strategy is a description of its R,D, and D components and their budget costs. In addition, various individual commercialization issues--such as direct subsidies (e.g., price supports) for new technologies, indirect assistance (e.g., contingent liabilities incurred by providing loan guarantees), and alternative roles for the federal government in the uranium enrichment program--are considered within each alternative strategy. Costs associated with such commercialization programs are estimated when possible.

For purposes of this paper, four alternative strategies, each containing a mix of the components outlined above, have been formulated. These strategies differ in the amount of federal funding as well as in the scale of government intervention in energy markets. The strategies vary from a continuation of the present free market approach for implementing new technologies to a strategy that would significantly increase the level of federally funded energy R,D, and D and would include substantial subsidies and large-scale federal intervention to promote commercialization. The remaining two strategies contain a mix of components that fall between the first two. It should be noted, however, that including any particular technology in a strategy does not imply a judgment about its suitability as a candidate for commercialization.

The strategy ultimately selected is likely to contain components gleaned from all of the alternative strategies put forth here, depending on the kinds of technologies favored, the amount of the federal budget allocated, and the individual commercialization mechanisms used.

Each of the alternative strategies differs in terms of its likely costs.[1] Particularly at the commercialization stages, such estimates can only be regarded as ballpark figures. As new technologies proceed through the R,D, and D stages into commercialization, individual project changes will occur, and cost estimates will be refined.

Any budget estimate for commercialization also depends strongly on the time interval concerned (which here is restricted to the 1977-1986 period) and on several other key assumptions. Some potential commercialization programs would have a major effect on the budget only after 1986. For example, a program to commercialize the liquid fast metal breeder reactor, beyond the Clinch River demonstration, would not require a final go-ahead decision until 1986. Estimating the costs of commercialization programs is also complicated because some instruments--particularly those, such as loan guarantees, designed to mitigate the risk and scale of commercial application--could result in large contingent liabilities. Outlays, however, would be large only if defaults occurred in excess of any payments required as a condition of obtaining such guarantees. For commercialization programs, estimates of contingent liabilities--but not of outlays that might result from them--are included together with estimates of direct outlays from subsidies, etc.

The research components outlined in the four alternative strategies draw heavily upon the R,D, and D strategies developed in CBO's energy research background paper.[2]

---

1. The cost estimates are largely drawn from earlier CBO background papers: Uranium Enrichment: Alternatives for Meeting the Nation's Needs and Their Implications for the Federal Budget, Background Paper No. 7, May 18, 1976; Energy Research: Alternative Strategies for Development of New Energy Technologies and Their Implications for the Federal Budget, Background Paper No. 10, July 15, 1976; and Financing Energy Development, Background Paper No. 12, July 26, 1976.

2. Energy Research, cited above.

The first alternative is a continuation-of-present-policy strategy. It assumes that, over the next ten years, only presently planned R and D programs will be continued. This strategy allows for modest real growth in those programs and assumes that no special efforts will be made either to reduce financial risks or to improve profits in order to encourage demonstration and commercialization of new energy technologies. It assumes that, without commercialization incentives, no private firms will build and own uranium enrichment facilities; thus all new uranium enrichment facilities would be constructed and owned by the federal government. There would be no commercialization programs for synthetic fuels, solar energy or Arctic pipelines; therefore new energy production would depend on private initiative in commercializing technologies. This alternative could require expenditures of $43 billion over the next decade for energy R,D, and D. Under this strategy, the government would make additional federal expenditures for uranium enrichment (net of receipts) of about $1.3 billion,[3] resulting in a total of $44.3 billion for this strategy. Because this strategy would not provide for any new commercialization initiatives, no contingent liabilities or outlays for subsidies are anticipated.

In terms of the criteria suggested in Chapter III, this strategy would not be consistent with desirable futures because it relies upon past projects and priorities. Thus it would not respond to recently articulated research priorities in solar energy, conservation, and environmental protection, nor would it permit pursuit of diverse technical approaches within any one source of energy. Although its pace of development would not be excessive, its lack of diversity would not provide much insurance against the likelihood of future failures. This strategy would, however, provide for minimum federal intervention in energy markets.

---

3. These outlays for uranium enrichment would be recouped with profit, however, in subsequent years.

The second alternative would strengthen federal stimulus in part through a "full funding" R,D, and D strategy; it would carry out all identified demonstration projects in all technologies. In addition, it would support a broad commercialization program characterized by federal intervention to encourage projects inhibited by lack of private investment, whether due to estimates of unprofitable operation, market risks, or the scale of investment. This alternative would include efforts to encourage the private sector to build and own new uranium enrichment facilities, to stimulate synthetic fuels production at a large scale (1 million barrels per day by 1985), to support large-scale projects such as the Alaska pipeline, and to encourage the commercialization of solar and geothermal energy sources both for centralized electricity production and for decentralized heating and cooling. This alternative reflects an attempt to pursue all technologies as intensively as possible. While it is unlikely that every potential project would be carried out, the range represents, at least as a proxy, the magnitude of effort necessary. Thus this strategy would include direct grants, loan guarantees with liabilities contingent upon future conditions, and direct subsidies for operation; in short, a massive federal presence.

The basic R,D, and D components of this strategy would cost approximately $66.2 billion over the next decade; contingent liabilities for commercialization could add up to $51 billion.[4] The commercialization component designed to address risk and scale could increase total investment in new technologies by about $23 billion, resulting in federal contingent liabilities of about $19 billion. (The latter amount would include about $8 billion in contingent liabilities for loan guarantees for uranium enrichment, and about $11 billion--75 percent of the total $15 billion investment sought--for other federal contingent liabilities.) Net revenues accruing to the government from sale of uranium enrichment services would be $3.8 billion.

---

4. No attempt has been made to estimate potential outlays associated with contingent liabilities because of the difficulties involved in formulating reasonable assumptions about default rates.

Encouraging investment by increasing profitability could be done in several ways, including direct subsidies as well as contingent liabilities. In this strategy, it is assumed that domestic energy prices are too low to make energy from these new technologies competitive; thus price guarantees will be necessary. In order to illustrate the outlays that might be required, the calculation assumes a synthetic fuels program producing 1 million barrels per day by 1985; support could entail federal outlays in the form of direct subsidies that might total as much as $3.7 billion by 1986. In addition to this direct federal subsidy, the private investment for this synthetic fuels program could total about $18 billion. Solar heating and cooling would be encouraged to attract investment of as much as $25 billion. Contingent liabilities for these programs, with a total private investment of as much as $43 billion, could be as much as $32 billion (i.e., 75 percent of total investment).

This strategy would be consistent with support of desired futures because it would pursue all program areas. Its weakness stems from the scale of effort and the pace, which may be too fast and too oriented toward large demonstration projects. It would clearly provide for massive federal intervention in the demonstration and commercialization process, which could imperil its success. In addition, it would probably result in increased energy prices.

The third alternative focuses on reduction of uncertainty by gaining information about new technologies and sharing risks of implementation. This alternative assumes R,D, and D emphasis on a long-term technology chosen by Congress and the President (in this example, either fission or non-fission). This strategy would encourage the commercial development of processes that could be expected ultimately to be profitable, but that could initially be inhibited by technological risks or scales too large to attract sufficient private investment. It would not attempt to encourage ventures expected to be commercially unprofitable, as would the second alternative. It would encourage the commercialization of uranium enrichment by the private sector, the development of Alaskan pipelines for oil and gas, a small synthetic fuels program,[5] and solar and geothermal sources for electricity generation.

This strategy would require expenditures of about $53.9 billion for R,D, and D. It would encourage private investment of about $23 billion for uranium enrichment, pipelines, synthetic fuels, and solar technologies, which could create contingent federal liabilities of about $19 billion. Outlays during this period would be low unless defaults were large. Again, net revenues from uranium enrichment would be $3.8 billion.

This strategy would not be completely consistent with ERDA's desired future[6] because it would neglect research on either fission or nonfission technologies. (However, it could be consistent with a national energy future if Congress and the President were to choose either technology.) Pace might not be excessive, and all timeframes would be represented. The strategy would provide less direct intervention in the market than would the intensive federal activity associated with the second strategy, and it could provide for private management in demonstration stages.

The fourth alternative would emphasize energy production. This would focus the R,D, and D program on near- and mid-term technologies and would support the commercialization of those technologies whose immediate implementation is inhibited because the energy produced through their use would not be competitively priced with energy produced by existing

---

5. This strategy assumes that loan guarantees alone would suffice to commercialize a small amount of synfuels production; whether such production could in fact take place without further subsidies (such as price supports) is open to question.

6. ERDA formulated six alternative U.S. energy futures (called "scenarios") and selected one as most consistent with ERDA's criteria for a desirable future. For a brief description of the major elements of each scenario, see Energy Research, CBO Background Paper No. 10, July 15, 1976, p. 21.

sources. This alternative would not attempt to mitigate impediments due to risk or scale. It would encourage large-scale synthetic fuels production, which would probably involve both substantial contingent liabilities and large direct subsidies. It would include large-scale solar space heating and cooling (which might also entail large liabilities, although the outlays are difficult to estimate). Under this strategy, the federal government would build and own new uranium enrichment facilities.

This strategy would encourage investment in projects that could be unprofitable at present prices. It would not include provisions to reduce risks, such as are addressed in the second and third alternatives. For R,D, and D alone, the strategy would require expenditures of $50.5 billion between 1978 and 1986. In addition, commercialization measures to improve profitability could require total new investment as large as $45 billion--$20 billion for synthetic fuels and $25 billion for solar heating and cooling--resulting in federal contingent liabilities of as much as $34 billion. Cumulative outlays for otherwise unprofitable synthetic fuels could reach between $1.1 billion and $3.7 billion. The government would construct any new uranium enrichment facilities at a net outlay of about $1.3 billion, which would be recovered in later years.

This strategy would also not be completely consistent with desired futures because demonstration for long-term technologies would be deferred. However, diversity would be preserved at pre-demonstration stages. Federal intervention in financial markets would be very limited, but energy prices would probably be higher.

Table 2 presents estimates of the year-by-year budgetary impact of each of the alternatives, along with a five-year current policy budget estimate. The current policy estimate presented here is a subset of the estimates for subfunction 305 presented

TABLE 2. PROJECTED BUDGET IMPACTS OF ALTERNATIVE R,D,D, AND C STRATEGIES 1977-1986, MILLIONS OF 1977 DOLLARS, FISCAL YEARS

	1977	1978	1979	1980	1981	1982
Continuation of Present Policy						
Research & Development b/	3329	3766	4014	4199	4445	4364
Uranium Enrichment c/	826	421	5	(101)	(512)	(190)
Subsidies	--	--	--	--	--	--
TOTAL	4155	4187	4019	4098	3933	4174
Strong Federal Stimulus						
Research & Development b/	3329	4426	5720	6611	7452	7468
Uranium Enrichment c/	826	399	(78)	(163)	(629)	(513)
Other Energy Subsidies d/	--	60	60	109	147	111-357
TOTAL	4155	4885	5702	6557	6970	7066-7312
Reduced Uncertainty e/						
Research & Development b/	3329	4101	4850	5371	5854	5824
Uranium Enrichment c/	826	399	(78)	(163)	(629)	(513)
Other Energy Subsidies	--	--	--	--	--	--
TOTAL	4155	4502	4772	5208	5225	5311
Energy Production						
Research & Development b/	3329	4406	4929	5491	5430	5468
Uranium Enrichment c/	826	421	5	(101)	(512)	(190)
Other Energy Subsidies d/	--	60	60	109	147	111-357
TOTAL	4155	4887	5094	5499	5065	5389-5635
Current Policy f/						
Research & Development	3329	3329	3352	3375	3399	3447
Uranium Enrichment	826	826	832	838	843	855
Subsidies	--	--	--	--	--	--
TOTAL	4155	4155	4184	4213	4242	4302

TABLE 2 (continued)

	1983	1984	1985	1986	TOTAL a/	Contingent Liabilities
Continuation of Present Policy						
Research & Development b/	4510	4664	4824	4904	43,019	--
Uranium Enrichment c/	(223)	254	158	614	1,252	--
Subsidies	--	--	--	--	--	--
TOTAL	4287	4918	4982	5518	44,271	--
Strong Federal Stimulus						
Research & Development b/	7845	8147	7665	7493	66,156	--
Uranium Enrichment c/	(774)	(785)	(1109)	(982)	(3808)	8,000
Other Energy Subsidies d/	157-443	144-430	112-736	184-1321	1099-3678	43,000
TOTAL	7228-7514	7506-7792	6668-7292	6695-7832	63,447-66,026	51,000
Reduced Uncertainty e/						
Research & Development b/	6078	6306	6140	6081	53,934	--
Uranium Enrichment c/	(774)	(785)	(1109)	(982)	(3808)	8,000
Other Energy Subsidies	--	--	--	--	--	11,000
TOTAL	5304	5521	5031	5099	50,136	19,000
Energy Production						
Research & Development b/	5625	5557	5190	5046	50,471	--
Uranium Enrichment c/	(223)	254	158	614	1,252	--
Other Energy Subsidies d/	157-443	144-430	112-736	184-1321	1099-3678	34,000
TOTAL	5559-5845	5955-6241	5460-6084	5844-6981	52,822-55,401	34,000

Footnotes for Table 2 can be found on page 36

Notes for Table 2

a/ The numbers in this column are total estimates; they do not include the contingent liabilities listed in the next column, nor do they include any outlays associated with these liabilities.

b/ The estimates for Research and Development are based on the strategies in Energy Research, to which additional 1977 appropriations have been added.

c/ These estimates are based on the budget authority provided for fiscal year 1977. For future years estimates are the sum of (1) estimates of costs and revenues from existing plants and from the proposed expansion of the Portsmouth plant, as provided by ERDA (see appendix) and (2) the costs, if borne by the government, of further additions to capacity. The options, including government ownership of future centrifuge plants, are those detailed in Uranium Enrichment. It is assumed that individual future facilities start up in 1987, 1989, 1992, and 1998.

d/ These estimates are drawn from Financing Energy Development, corrected to 1977 dollars.

e/ The yearly amounts for this strategy are an average of the costs of fission and nonfission strategies; the total and the pattern of annual outlays would change if a policy choice were made to pursue one or another of these long-term technologies.

f/ These estimates are based on the Five Year Projection Report, disaggregated to Research and Development and Uranium Enrichment.

in CBO's budget projections.[7] The same data base and projection rules were used, making these estimates consistent. (The Appendix provides a breakdown of costs for uranium enrichment.)

Over the decade, expenditure levels change considerably for the individual components of R,D, and D programs, as well as for uranium enrichment and subsidy programs. Contingent liabilities also vary widely. Total outlays for energy R,D,D, and C could vary by 50 percent, from a low of $44 billion to a high of $66 billion over the next decade.

Table 3 summarizes direct federal outlays for R,D,D, and C and related contingent liabilities for each of the four commercialization strategies described above.

FURTHER CONSIDERATIONS

In making decisions on these issues, Congress and the Administration will be resolving questions that go considerably beyond the scope of an R,D,D, and C strategy. Some of these important questions are:

- What degree of dependence on foreign sources of energy will be deemed acceptable?
- What should be the federal role in energy markets?
- What should be the role of recycling in the nuclear fuel cycle?
- What should be the policy toward proliferation of nuclear weapons through spread of nuclear technology?

---

7. CBO, Five-Year Budget Projections: Fiscal Years 1978-1982, December, 1976.

TABLE 3: FEDERAL COSTS FOR ALTERNATIVE R,D,D, AND C STRATEGIES 1977-1986, BILLIONS OF DOLLARS [a]

	R,D,&D	Uranium Enrichment	Subsidies	Total	Contingent Liabilities [b]
Continuation of Present Policies	43.0	1.3	---	44.3	---
Strong Federal Stimulus	66.2	(3.8)	1.1-3.7	63.4-66.0	51
Reducing Uncertainty	53.9	(3.8)	---	50.1	19
Energy Production	50.5	1.3	1.1-3.7	52.8-55.4	34

a. See Table 2 for details.

b. Contingent liabilities are not included in the total column, because it is not possible to estimate what outlays might ensue as a result, for example, of defaults on guaranteed loans.

- Is the breeder reactor to become the nuclear technology of choice if it is successful?

- How should the U.S. energy technology program relate to foreign programs?

- What will be the impacts of new and emerging technologies on the environment, and how will those impacts shape the choices of technologies to be commercialized?

The answers to these questions and the specific choices suggested earlier will define an R,D,D,&C strategy. That strategy, whether conscious or accidental, will help determine energy production for the foreseeable future.

APPENDIX COSTS AND REVENUES OF URANIUM ENRICHMENT OPERATIONS FOR EXISTING FACILITIES

ERDA owns three uranium enrichment plants that sell services to commercial power plants. The agency is also preparing to expand enrichment capacity at its Portsmouth, Ohio, facility. ERDA has provided estimates for the costs and revenues for all these facilities through 1986. These estimates assume: a schedule of sales based on existing contracts; future reduced requirements for raw uranium due to increased derivation of processed uranium from feedstocks; an increase in the maximum cost for services to $104 per unit; and the number of generating facilities serviced to be a maximum equivalent to 323 one-thousand megawatt power plants. The estimates shown in the accompanying table are used in the development of table 2.

APPENDIX TABLE 1. COSTS AND REVENUES OF URANIUM ENRICHMENT OPERATIONS, MILLIONS OF 1977 DOLLARS, FISCAL YEARS

	1978	1979	1980	1981	1982	1983	1984	1985	1986
Costs	1539	1545	1507	1520	1684	1727	1698	1692	1678
Less Enrichment R&D Costs	(102)	(97)	(85)	(75)	(75)	(75)	(75)	(75)	(75)
Total	1437	1448	1422	1445	1609	1652	1623	1617	1603
Revenues	(1038)	(1526)	(1585)	2074	(2122)	(2426)	(2408)	(2726)	(2585)
Net Costs	399	(78)	(163)	(629)	(513)	(774)	(785)	(1109)	(982)

SOURCE: Letter to author from M.C. Greer, Controller, Energy Research and Development Administration, January 5, 1977.