URANIUM ENRICHMENT:

ALTERNATIVES FOR MEETING THE NATION'S NEEDS AND THEIR IMPLICATIONS FOR THE FEDERAL BUDGET

Background Paper No. 7
May 18, 1976

CONGRESS OF THE UNITED STATES
Congressional Budget Office
Washington, D.C.

For sale by the Superintendent of Documents, U.S. Government Printing Office
Washington, D.C. 20402 - Price $1.35

PREFACE

Uranium Enrichment is one of a series of papers prepared to assist the House and Senate Budget Committees in their deliberations on the First Concurrent Resolution on the Fiscal Year 1977 budget. The paper responds to requests from the Senate Budget Committee for an analysis of the uranium enrichment issue, with specific reference to the proposed Nuclear Fuel Assurance Act, and from the House Budget Committee for analyses of problems of financing energy development, with specific reference to uranium enrichment questions.

In keeping with the mandate of the Congressional Budget Office (CBO) to provide nonpartisan analysis, this paper contains no recommendations. It was prepared by Richard M. Dowd of CBO's Natural Resources Division, with substantial contributions from David Montgomery, Mary Ann Massey, and Charles Davenport, and editorial assistance by Melinda Upp, under the direction of Douglas M. Costle and Nicolai Timenes, Jr.

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

CONTENTS

TABLES

FIGURES

SUMMARY

Most projections indicate that the nation's use of electricity generated by nuclear (fission) power will continue to increase. Today's nuclear power plants are fueled by a fissionable isotope of uranium, U^{235}. Uranium in its natural state does not contain enough of this fissionable component to power a nuclear reactor. Therefore, it must be "enriched" before it can be used.

The country's three uranium enrichment facilities are owned by the federal government and managed by the Energy Research and Development Administration (ERDA). These facilities, with some expansions already planned, will be adequate only until the mid-1980s. A bill before Congress, the Nuclear Fuel Assurance Act (NFAA) (S. 2035, H.R. 8401) would authorize private ownership of uranium enrichment facilities.

This proposal has focused debate on whether the government should continue to own all such facilities or whether some or all facilities should be owned by the private sector. Several ownership options exist:

- All new capacity could be owned by the private sector, which would pay royalties for the use of technology and facility designs developed by the government. (This is essentially the NFAA plan.)

- The federal government, through ERDA, could continue to own and manage the facilities, existing and new. (A government ownership suboption would be the creation of a new government corporation to own and manage the facilities.)

- One additional facility, expected to use a mature proven process, could be owned by the government, while other new facilities, which are likely to use a newer process as yet unproven commercially, could be owned by the private sector.

70-844 O - 76 - 2

The Ownership Options

The case for private ownership rests generally on the presumption that broad efficiencies characterize private undertakings, and on the shift of the burden of financing further additions to enrichment capacity from the public to the private sector.

The case for government ownership rests, to a considerable extent, on the belief that the degree of competition required to realize the potential benefits of private ownership is unlikely to develop and that, despite the large initial outlays, additional federal enrichment activities would ultimately return large revenues to the government. The case for creating a government-owned corporation rests on the desirability of retaining government ownership of a government-developed technology and revenues from it, while avoiding large direct federal budget impacts and realizing some of the efficiencies associated with corporate (versus government) business practices.

The case for a mixture of private and government ownership rests on the belief that the need for the first new increment of capacity in the mid-1980s is such that planning and construction should begin in the very near future and that government, with its experience in building and managing three existing facilities using a proven technology, is in the best position to own this next facility, which is likely to be the last one using this older technology. Private industry would then assume responsibility for providing other future additions to capacity using new technologies.

Budget Impacts

The budgetary effects of the various options depend partially on assumptions about the amount of additional capacity that will be needed and on the timing of that need. According to how conservatively or optimistically the future of nuclear power is assessed, by the year 2000 existing and planned enrichment capacity will need to be increased by from 80 percent to 330 percent above planned 1985 levels. Such estimates will be affected by a number of factors, among them the extent of energy conservation (which would lessen demand), the growth of nuclear power as an energy source, the amount of enriched uranium that could be stockpiled and made available to future domestic customers and the amount of enriched uranium supplied to foreign customers. Current estimates of the number of new U.S. facilities that will be needed range from two to eleven. The Congressional Budget Office (CBO) has used a mid-point of six plants in analyzing the potential budgetary effects of the different options.

The federal costs and revenues from these six plants could vary considerably within the private option, depending upon the level and mix of incentives that might be offered to the private sector to encourage investment in enrichment facilities. CBO's analysis is based on the assumption that the investment tax credit will be extended at its present 10 percent rate and that interest and other construction expenses could be deducted from taxable income as ordinary business expenses. The Congress may wish to provide other incentives, however. For example, the NFAA would authorize ERDA to seek up to $8 billion in contract authority to cover contingencies that could occur if private-sector enrichment ventures were unsuccessful. In such a case, for example, ERDA could assume the domestic assets and liabilities of a private venture that defaulted. CBO's budget calculations do not include the potential effects of such contingencies, although these could be substantial.

If private industry were to own all new capacity, no federal outlays beyond those currently planned would be required--assuming contingencies would not occur--and no revenues from new sales would be received. However, the government would receive royalties for the use of government owned technology. If, for example, a royalty rate were negotiated at 3 percent of gross revenues for 17 years, each large private facility could pay the government more than $400 million in cumulative royalties during those years, and annual revenues from six plants could reach $150 million by the early 1990s.

If the government were to own all new capacity, substantial annual outlays--reaching a maximum of $2.7 billion for six plants in 1984--would be required during the next decade to finance construction. Annual revenues from sales would also increase but would not exceed annual outlays until 1988. Cumulative revenues would exceed cumulative outlays, including assumed interest, in 1993. Cumulative net revenues would reach over $30 billion in the year 2000.

If ownership were mixed, with the government owning the next facility and the private sector owning further additions, the government would receive both royalties and enrichment revenues. Royalties would reach about $125 million annually by the early 1990s. Initial government outlays would reach a maximum of $0.9 billion in 1983, with the cumulative debt (including assumed interest) repaid by 1993 and cumulative net revenues reaching over $4 billion in 2000.

Summary figure 1 illustrates the pattern of net revenues and royalties for these three options. It does not include calculations of tax receipts or expenditures resulting from private enrichment facilities, although these are discussed briefly in the text (see Chapter VI).

Decisions Facing Congress

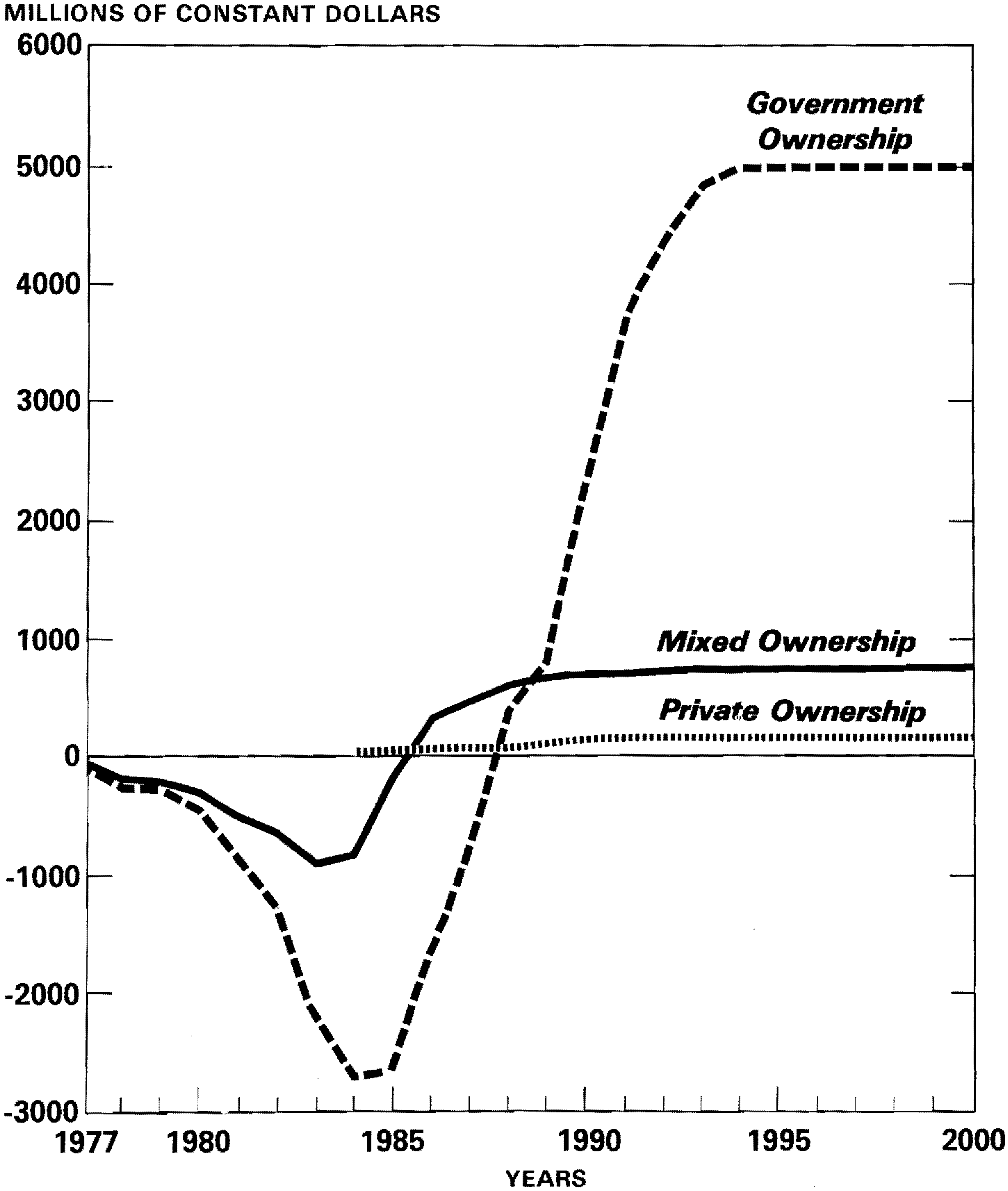
The Administration supports transfer of responsibility for providing new enrichment capacity from government to the private sector. To accomplish this transfer, it has proposed the Nuclear Fuel Assurance Act--NFAA--(S. 2035, H.R. 8401), which would provide private industry with certain guarantees and financial incentives.

The NFAA provides an immediate vehicle for Congressional decision in regard to providing enrichment capacity for potential needs beyond 1985. If Congress judges that the private sector should provide future capacity, it can enact the NFAA or other legislation to the same purpose. In this event, the Congress can determine whether diffusion as well as newer technologies would be transferred to the private sector. It can also establish the appropriate level of incentives and any consequent need for further budget authorizations.

If, however, Congress judges that the government should retain responsibility, it can reject the NFAA proposal and begin federal programs for providing further capacity. In this event, the key issues would probably be the timing of new capacity, the fraction of the foreign market to be served (which will directly affect the amount of capacity needed), and the budget impacts, particularly in regard to increased outlay levels in the early years of an expansion program.

Summary Figure 1

Comparison of Ownership Options Royalties and Government Revenues



CHAPTER I
INTRODUCTION

Most projections of the nation's future energy sources assume that electricity generated by nuclear (fission) power will be increasingly important. Today's nuclear power plants are fueled by a fissionable isotope of uranium. Uranium in its natural state does not contain enough of its fissionable component to sustain the chain reaction required to power a nuclear reactor. Therefore, it must be "enriched" to a higher fissionable concentration before it can be used in nuclear power plants.

The country's uranium enrichment facilities now are owned by the federal government and managed by the Energy Research and Development Administration (ERDA). These facilities, with expansions now on the drawing boards, will be adequate to supply enrichment needs only until the mid-1980s. A bill presently before Congress, the Nuclear Fuel Assurance Act (NFAA) (S. 2035, H.R. 8401) would permit and encourage private ownership of uranium enrichment facilities.

This proposal has spurred debate about whether the government should continue to own uranium enrichment facilities or whether all or some of this ownership should be in private hands. One issue in the debate is how much additional capacity will be needed and when; another is the level and mix of incentives that might be required to encourage private-sector ownership.

This paper discusses the major issues and options for ownership of uranium enrichment facilities. The appendices elaborate on certain of these issues and also explain the uranium fuel cycle, the enrichment process, current private proposals to construct enrichment facilities now before ERDA, the issue of competition in uranium enrichment, and some potential implications of tax expenditures associated with private ownership.

The Current Situation

Technology to enrich uranium has existed for more than 30 years; it was first developed by the U.S. Government during World War II to produce the even higher fissionable concentrations required for nuclear weapons. Since the war, the government has also used the technology to supply enriched nuclear fuel to electric utilities for commercial power generation. The government has continued to own the technology, which is classified because it is vital to the production of nuclear weapons. (See Appendices A and B for explanations of the uranium fuel cycle and the enrichment process.)

Three U.S. uranium enrichment facilities now exist, all owned and managed by ERDA but operated by private industry under contract. These facilities, at today's maximum production capacity, can annually service the equivalent of about 200 power plants with a generating capacity of 1000 megawatts (MW) each--the typical size for a nuclear power plant. The equivalent of 37 1000-MW nuclear power plants now operate in the United States. In addition, because the United States has more than 95 percent of the present noncommunist enrichment capacity, it provides enrichment services to the equivalent of 31 1000-MW foreign nuclear power plants now operating; foreign customers currently account for about 45 percent of ERDA's annual sales. ERDA estimates that the equivalent of about 185 domestic nuclear power plants will be in operation by 1985.*

---

*These figures are based on ERDA's mid-range projections of domestic and foreign nuclear generating capacity anticipated to be on line by 1985. For domestic projections, see U.S. Energy Research and Development Administration, "Total Energy, Electric Energy, and Nuclear Power Projections, United States," (February 1975), and ERDA's testimony before the Joint Committee on Atomic Energy in June, 1975. For foreign projections, see ERDA's "Draft Environmental Statement, Expansion of U.S. Uranium Enrichment Capacity" (ERDA-1543) June 1975. (See Appendix C for a more detailed discussion of growth rates for nuclear capacity.)

Currently planned expansions of existing government-owned enrichment facilities will increase U.S. capacity by 63 percent by 1985; this capacity will be able to service the equivalent of 329 1000-MW plants. ERDA indicates that this entire capacity has already been committed to customers--the equivalent of 208 domestic power plants and 121 foreign plants (with the latter accounting for 38 percent of total sales).

Because ERDA's enrichment capacity is currently greater than the demand for services, ERDA has been stockpiling enriched fuel for future sale; if existing and planned government-owned facilities were run at full capacity (which is not now the case because sufficient electricity is not always available), the resulting stockpile could, by 1985, provide between one and two years' supply of the total demand which the United States expects to meet at that time.

Two principal enrichment technologies could be used to supply potential future needs: diffusion and centrifuge. To date, the gaseous diffusion process developed during World War II has provided U.S. capacity. It is a mature, reliable process that has been used on a large scale for 30 years. The newer centrifuge process is anticipated to have several advantages over the diffusion method, including smaller commercial operating sizes (one-third the size of an economically feasible diffusion plant), lower electricity requirements (only ten percent of the amount required by the diffusion process), and--potentially--lower construction and operation costs. Because of its promise, the centrifuge process is generally considered to be the enrichment technology of the future. Nevertheless, because the centrifuge has not yet been commercially proven, the older diffusion process is expected to be used in the next U.S. enrichment facility constructed.*

*There is wide public and private sector consensus that the next new increment to U.S. enrichment capacity will use the older diffusion process and that additions after that will probably use the less mature centrifuge process. One private group, however, disagrees with this view. Uranium Enrichment Associates (UEA) is a limited partnership which has responded to ERDA's request for private sector

70-844 O - 76 - 3

The Nuclear Fuel Assurance Act

The Administration has proposed enactment of the Nuclear Fuel Assurance Act (NFAA) (S. 2035, H.R. 8401) which would permit private financing, construction, ownership, and operation of all new uranium enrichment plants. The NFAA would authorize ERDA to provide private industry with classified uranium enrichment technology, for which users would pay royalties. Private developers could purchase certain unique materials, services, and equipment from the government on a "full-cost recovery" basis (i.e., ERDA would be reimbursed for all costs except certain R&D expenses recoverable through royalties). The government would warrant that the uranium enrichment plants constructed under its oversight would perform to design specifications. To ease start-up of the new private

---

participation in providing additional capacity with a proposal to build at least one UEA-owned diffusion facility. In commenting to CBO on an earlier draft of this report, UEA stated: "...today there is insufficient evidence to support the assumption in the CBO report that the centrifuge will be successfully advanced and live up to all the claims for it by the time there is need for new enrichment capacity beyond the next... [large] diffusion plant."

UEA's pessimism about the near-term viability of the centrifuge process is at variance with the conclusions reached by two government agencies, ERDA and GAO, and by the Edison Electric Institute (EEI), a trade association of the electric utility industry. In testimony before the Joint Committee on Atomic Energy (JCAE), ERDA expressed the view that the next new enrichment facility will use diffusion technology and that all facilities beyond that will likely use centrifuge technology. GAO, in its report to the JCAE entitled "Evaluation of the Administration's Proposals for Government Assistance to Private Uranium Enrichment Groups" (RED-76-36, October 31, 1975, p. iii), stated that "The next increment of uranium enrichment capacity is likely to be the last-of-its-kind in the United States which uses gaseous diffusion technology." EEI, in its study entitled "Uranium Enrichment Facilities" (74-45A, June 1974, Appendix X, p. 16), stated that "...selection considerations tend to favor gas centrifugation even though it has not been proven on a large scale." This CBO backgound analysis assumes this latter, more widely held view.

facilities, the government could provide access to its enriched uranium stockpile, either purchasing production overruns if private customers were not ready to take delivery or providing stockpiled enriched uranium to customers if initial private production were insufficient.

To implement the warranties and to protect private lenders, ERDA would be authorized--if a particular private project faltered, and either at the request of the owners or on ERDA's initiative--to take over the plants, assume domestic assets and liabilities, and--depending on the reasons for failure--to compensate domestic investors. These warranties and conditions would be spelled out in cooperative agreements entered into by the private companies and ERDA and approved by Congress under the terms of the NFAA. The Administration estimates that if all private projects defaulted--which ERDA believes is highly unlikely--the total federal outlay could be as high as $8 billion.

CHAPTER II
EXTENT AND TIMING OF FUTURE DEMAND FOR ENRICHMENT CAPACITY

With continued growth in electricity generated by nuclear fission, the eventual need for new enrichment capacity is clear, but the timing and magnitude of that need are not. These factors could determine the size of a private enrichment industry and hence its competitiveness--one of the advantages attributed to private sector ownership. The timing and magnitude of needed new capacity will also affect the timing of decisions on who should provide that capacity and what the budgetary impacts of such decisions will be.

The timing and magnitude of additions to capacity depend strongly on the extent of the future role of nuclear power in the United States and on the share of increased foreign enrichment demand that the United States attempts to satisfy.

Determining domestic needs presents technical problems of projecting what future domestic demand _will_ be (rather than what it should be); thus this demand _is_, strictly speaking, _not_ a policy issue in the current debate. (It is, however, a policy issue in the larger context of the nation's energy future, but such questions are beyond the scope of this paper.)

Requirements arising from a desire to supply foreign markets are another matter. The United States now holds 95 percent of the free world enrichment capacity; while continued dominance at current levels is unlikely, the share that the United States should attempt to maintain in the world market is an important policy issue that will bear directly on the amount of additional U.S. capacity that must be provided within the next decade.

Estimates of future demand for nuclear power and for enrichment services are uncertain, depending on (1) the relative costs of nuclear power and alternatives, especially fossil energy; (2) the cost of energy compared with costs of other goods and services; (3) the design and effectiveness of mandatory energy conservation measures; (4) lead times for construction of nuclear power plants; (5) the extent to which the unused uranium and plutonium that is removed during a reloading is reprocessed for use in power plants; (6) the "tails assay"--the percentage of fissionable uranium allowed to remain in the depleted uranium (this analysis and ERDA assume it to be 0.3 percent); and (7) the timing and rate of introduction of alternative technologies, especially fission breeder reactors. In the past two years, as costs of all fuels escalated and historic patterns of growth in energy demand changed, there have been dramatic reductions in previous estimates of future amounts of nuclear generating capacity that will be needed. This paper uses such revised projections. (See Appendix C for a more detailed discussion.)

Timing

ERDA has projected high, moderate and low growth rates for both domestic and foreign utilities. Using its moderate growth projections and assuming that the United States will supply 35 percent of foreign demand, ERDA estimates that new enrichment facilities providing services to utilities (beyond those currently under contract) will be needed by 1984 or 1985. While not all of its present contractual customers will need services until 1987 or 1988, ERDA believes that other new customers will need enriched uranium by 1984 or 1985. Delays in construction of nuclear power plants could delay the need for added enrichment capacity (e.g., 10 percent fewer new plants in 1985 could delay the need by as much as one year).

Such a 10 percent reduction could occur. The Federal Energy Administration (FEA) has also estimated nuclear energy growth rates; FEA's estimates are as much as 10 percent below ERDA's moderate domestic projections for 1985. FEA's projections would suggest that it is possible that the next enrichment facility might not be needed until 1985 or 1986.

ERDA views its present stockpile of enriched uranium primarily as insurance for its present contractual customers against unforeseen events. However, if a policy decision were made to expand the stockpile, a fraction of it could also be used to smooth discontinuities in providing new enrichment capacity. By drawing down the stockpile during the years before new capacity is operating (after which some or all of the drawdown could be repaid), considerable flexibility could be obtained in timing the advent of new capacity. (This possibility is contemplated in some private-sector proposals made in anticipation of enactment of the Nuclear Fuel Assurance Act.)

ERDA estimates that by 1985 its stockpile will contain 30 to 40 million SWU*. Based on ERDA's projection of 20 to 25 new nuclear power plants opening each year, the fuel for initial startup of these plants could use about four million SWU (about 10 percent of the stockpile). Such use of the stockpile would allow about a year's leeway in the introduction of new enrichment facilities.

However, because of the lead time necessary to design and construct the next enrichment facility and its power supply, these factors affecting the timing of the next facility do not affect the need to make a decision in the near future to begin such a facility.

Magnitude

Using its original moderate growth projection and assuming the United States would supply 35 percent of foreign demand for enriched uranium, ERDA has estimated that 11 large new plants, each with a 9 million SWU capacity, would be required by the turn of the century.

CBO's analysis, using ERDA's revised nuclear generating demand projection (see Appendix C) and the same moderate growth projections, indicates that nine plants would be needed, or ten if 45 percent of foreign demand were served. Using the low projection for domestic

---

*The capacity of enrichment plants is expressed in a quantity known as Separative Work Units (SWU). These units represent the amount of work necessary to transform natural uranium with only 0.7 percent U^{235} into reactor-grade fuel with approximately 3 percent U^{235}. Providing a typical 1000 megawatt (MW) nuclear power plant with a year's supply of enriched uranium takes 80,000 to 100,000 SWU each year. The present capacity of the three existing U.S. plants is 17.2 million SWU per year, which currently planned expansion will increase to 27.7 million SWU by 1985.

nuclear growth and assuming only 25 percent of foreign demand is served, five to six plants would be required by the year 2000. A decision to serve only domestic needs would suggest a need for much smaller capacity additions of three to four plants using, respectively, low or moderate growth. If the growth suggested in Scenario V of ERDA's "National Plan for Energy Research, Development and Demonstration"* is used, only two additional plants would be needed. It should be emphasized, however, that the many uncertainties associated with future energy demand and the role of nuclear power, as well as the supply of natural uranium, make these estimates conjectural.

For purposes of discussion, the budget implications described later in this paper are based on the assumption that six new facilities--a mid-point of the 2-to-11 range described above--will be constructed by the year 2000.

---

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

CHAPTER III
OWNERSHIP OPTIONS

There are several options for ownership of uranium enrichment facilities. The Administration, in proposing the NFAA, recommends that all future enrichment facilities be privately owned. An alternative would be to retain the government's exclusive role in providing uranium enrichment services. A third alternative would leave provision of all capacity using newer centrifuge technology to private firms, but would retain in the public sector responsibility for existing and new diffusion facilities. If the government were to own all new facilities or only facilities using the diffusion technology, government ownership could take one of two forms: (1) continuation of the status quo, with ERDA managing all new and existing facilities, (2) creation of a new government corporation to manage all facilities.

Private ownership and government ownership can be measured against a number of criteria. These include: economic efficiency, effectiveness in advancing the development of new enrichment technology, cost to consumers, environmental impact, effects on U.S. capital markets and balance of payments, and impact on the federal budget.* The level of competition to be expected in a private enrichment industry is also a factor in determining the relative performance of private and government ownership, and it is sometimes argued that the degree of competition is itself an additional criterion.

The Case for Private Ownership

Choice of an option to permit, at some point, private ownership of all new uranium enrichment facilities could be based on a belief that, as a matter of principle, the government should not engage in activities, such as uranium

---

*Relative merits in terms of environmental impact are mixed: no clear case for either broad option can be made. Further discussion of this issue is provided in Chapter IV.

70-844 O - 76 - 4

enrichment, which are essentially commercial or industrial. A second (and supporting) argument could be that establishing a competitive private industry would result in potentially more appropriate market prices for enriched fuel, greater technological advances, increased foreign investment and trade, and lower direct federal outlays.

This second argument rests in part on the assumption that sufficient firms will participate in the private sector to ensure competition. If moderate to high predictions of enrichment demand (i.e., nine to ten new large facilities by the year 2000) are realized, then the industry could be large enough to accommodate a sufficient number of firms to foster competition.

Economic Efficiency--A competitive industry could be expected to be economically efficient, because prices would be set at levels reflecting costs and fair market values, and producers would seek the most efficient production methods. A government enterprise could lack the incentives that could lead private enterprises to avoid waste and to choose the lowest cost method of production. Moreover, a government agency could set prices of enrichment services at levels lower than those that would be established by the interaction of supply and demand in free markets, and thus might encourage use of nuclear generated electricity in an economically inefficient way.*

New Technologies--A competitive private enrichment industry could be expected to pursue aggressively a number of new approaches to enrichment technology, possibly providing a faster pace of innovation than would a more narrowly focused government research strategy.

---

*See, for example, the testimony of Paul MacAvoy of the Council of Economic Advisors to the Joint Committee on Atomic Energy on December 4, 1975.

Foreign Trade--At least one of the private ventures interested in building uranium enrichment facilities is actively soliciting foreign investment. Inflow of foreign capital could release domestic capital for other purposes. In addition, the prospect of increased profits from foreign sales might encourage private industry to sell enriched fuel abroad, thereby improving the U.S. balance of payments.

Impact on the Federal Budget--Finally, to the extent that the private sector financed capacity that would otherwise be publicly financed, federal outlays for construction could be reduced. In addition, the government would collect royalty payments in return for providing its technology to industry. However, if enrichment plants were privately owned, the government would not realize revenues in later years from sales of federally-produced enrichment services.

The Case for Government Ownership

The case for government ownership--whether through ERDA or a government corporation--is based on several arguments.

Competition and Efficiency--If the low projection for enrichment demand (two to five large new facilities by the year 2000) is realized, or if the first firms entering the industry obtain substantial advantages over later entrants, the number of firms in the industry could be too small to foster adequate competition. The Administration's proposed program anticipates bringing four private groups into the industry almost simultaneously. If no additional firms were to enter, potential for competition would be small (see Appendix E), making it unlikely that the benefits of economic efficiency and technological advance attributed to private ownership could be achieved.

The argument for government ownership is strengthened by the claim that the economic inefficiency that can result from government enterprises could be avoided. In a separate bill (S. 2053) the Administration has proposed changes in the methods by which ERDA sets the price of enrichment services, in order to make the price of enrichment services provided by the government approximate those that would be set in a competitive marketplace. Such a change could help eliminate the economically inefficient use of nuclear power that would be fostered by a subsidy.

Cost to Consumers--A noncompetitive private enrichment industry could charge its customers prices higher than needed to cover costs and return a reasonable profit. Government ownership could, in this case, result in lower prices if the government's prices approximated those that would be set in a competitive market.

Alternatively, Congress could permit a government agency to price enrichment services below cost, if it were willing to tolerate the resulting losses in efficiency. Such action would subsidize certain electric utilities and their customers.

Impacts on the Federal Budget--With government ownership, outlays would exceed revenues in the early years, but this situation would be reversed when sales revenues exceeded costs of construction and operation. In the long run (potentially by 1993), the government investment would be repaid with interest. The budget impact is discussed in detail in Chapter VI.

The Government Corporation Alternative

The discussion above regarding government ownership applies generally to an on-budget agency.* An independent government corporation could have different consequences in terms of budget impact and--possibly--efficiency. Vesting such a corporation with ownership of all government facilities could, if the corporation were entirely self-financing, remove from the budget all direct outlays for and revenues from uranium enrichment. Alternatively, the annual net earnings or losses of the corporation could be included in the budget. If existing facilities were transferred to the new corporation, about $1 billion in current annual net earnings from sales would be transferred from ERDA to the new corporation. Proponents of such government corporations

---

*An on-budget agency has its budget authority and outlays included in the annual unified Budget of the United States Government. An off-budget agency does not.

claim that this structure encourages efficiencies similar to those attributed to private industry, particularly because decisions can be made in response to business conditions and market changes rather than in an arbitrary appropriations cycle. Budgetary impacts of this option are discussed in Chapter VI.

A discussion of several potential variations in the structure of such a corporation is contained in a recent GAO report evaluating the Administration's proposal to transfer responsibility for providing future enrichment capacity from government to private industry.*

The Mixed Ownership Alternative

A third alternative would call for the government to build the next larger new addition to capacity, using the mature diffusion process, and private industry to provide all other new increments, using riskier centrifuge technology. This alternative is examined in more detail in Chapter IV.

Conclusion

In summary, the case for private ownership rests on the broad efficiencies which are presumed to characterize private undertakings, and on the fact that major outlays would not need to be made in the near future for further additions to federal enrichment capacity. The case for government ownership rests, to a considerable extent, on a conclusion that the degree of competition required to realize the potential benefits of private ownership would be unlikely to eventuate and that, despite the large initial investment, further federal enrichment activities would ultimately be profitable. The case for mixed ownership of future new capacity rests on a combination of these arguments.

---

*Comptroller General of the United States, Report to the Joint Committee on Atomic Energy: Evaluation of the Administration's Proposal for Government Assistance to Private Uranium Enrichment Groups (RED-76-36), October 31, 1975, pp. 36-40. Appendix III of the report contains ERDA's comments on and points of disagreement with GAO's analysis.

CHAPTER IV
CONSIDERATIONS AFFECTING TRANSITION OPTIONS

If Congress were to decide that private ownership of uranium enrichment facilities should be encouraged, two options would remain: the construction by the government of one more diffusion plant, with all further additions to capacity left to private industry, or an immediate transition to private ownership of all new capacity, including the next new diffusion facility.

The case for mixed ownership--some government and some private--of further additions to capacity rests on certain unique features of the next large enrichment facility, which is expected to use the mature diffusion process.

- Even under the spur of competition, it is unlikely that private enterprise would be unable to achieve significant technical or cost advances in diffusion technology. (See Appendix B.)

- Expanding the existing government-owned capacity would cost less than constructing an entirely new plant.*

- There is little risk in applying diffusion technology, and ownership of that facility can be considered separately from subsequent additions to capacity that are expected to employ the less mature centrifuge technology.

---

*However, because of higher expected operating costs for the government's plant, which would use electricity generated from coal, it is expected that the cost of enriched fuel would be about the same in either case.

However, it can be argued that the transition to private ownership of all new facilities would be preferable to transition only of later plants expected to use the centrifuge process because:

- An immediate transition would begin to create a private industry using diffusion technology.
- Investors require assurance that they will not face competition from a government facility which might undercut their prices.
- Experience with financing the diffusion plant, using a proven technology, could make investors more willing to invest later in the more risky centrifuge process.

If the government were to construct a new gaseous diffusion plant, current ERDA plans contemplate purchase of coal-generated electricity for the plant. The only private proposal to construct a diffusion plant contemplates purchase of electricity from a nuclear power plant. Consequently the environmental impact of the mixed option would differ from that of the all-private option. Neither appears clearly superior. The environmental impacts of the private nuclear-supplied diffusion plant might be less than those of the government coal-supplied plant in regard to air quality and coal mining impacts, but nuclear generation of electricity could cause greater thermal pollution and safety and waste disposal problems.

CHAPTER V

WHAT, IF ANY, INCENTIVES WOULD BE NEEDED TO INDUCE INDUSTRY TO DEVELOP ADDITIONAL CAPACITY?

Potential Obstacles to Investment

Three of the major potential obstacles to private ownership of enrichment facilities are the classified nature of enrichment technology, the large initial investment required, and investor uncertainty with regard to technological and market risks. These are briefly discussed below; other potential obstacles--such as moratoria on nuclear power plants--are enumerated in the concluding section of Chapter VII.

Classified Technology--Enrichment technology is classified because the enrichment process is a crucial step in the production of one type of nuclear weapon. Private investors would need access to that technology. There are precedents for licensing classified technologies to the private sector; the aircraft industry, for example, has long used once-classified government-developed technology to construct commercial planes.

Size of the Initial Investment--The initial investment required to build a plant of optimum size ranges from perhaps about $1 billion for a centrifuge plant to about $3.5 billion for a new diffusion facility. The threefold difference in cost is due to the difference in plant capacity: a centrifuge plant with an annual capacity of 3 million SWU is expected to have reached an optimum size, but a diffusion plant must have an annual capacity of 9 million SWU to reach that point. If a centrifuge plant were to be built with a 9 million SWU capacity, its cost would probably be similar to that of a diffusion plant of the same size. The first centrifuge project, however, could be somewhat more expensive, because unforeseen costs could arise in the first commercial application of this complex new technology.

70-844 O - 76 - 5

Potential Risks--In view of the size of the required investment and the uncertainties it would entail, private firms have expressed unwillingness to enter the new enrichment industry if, in so doing, they would place their own assets at risk. Without such assets for collateral, however, lenders would be unwilling to risk substantial commitments.

Investors may be overestimating technical risks in the case of the diffusion process, which the government has operated successfully for many years. Diffusion process costs are well established and, as long as the current generation of nuclear reactors is used to generate electricity, a market for the product will continue. However, because the rate of nuclear power growth is not known, some uncertainty exists about the ultimate size of that market. The strength of the immediate demand is quite clear, and it is likely that the future, at least until the year 2000--or such time as technological breakthroughs allow energy production from essentially limitless sources such as fusion or solar energy--will include increased demand for nuclear fission generated electricity.

Alternatives for Reducing Financial Risks

Several methods could be used to overcome these obstacles, including project financing, external guarantees, and tax incentives.

Project Financing--Corporations providing the equity investment in uranium enrichment could limit their risks by the use of "project financing," defined as the formation of an independent venture to carry out the project.

With project financing, lenders have recourse only to the assets of the separate venture in case of default. Such an arrangement protects the owners of a project, but it does not protect lenders. Therefore, it is usually difficult to arrange loans sufficient to provide a high ratio of debt to equity financing unless external guarantees are provided.

External Guarantees--Two sources of guarantees for uranium enrichment projects have been proposed: electric utilities and the government. Utilities could guarantee loans by contracting to make payments covering principal and interest even if the project were not completed or if no product were delivered. In addition, contracts containing guarantees to pay a specific rate of return on equity could reduce risks due to variations in project revenues. Such contracts pose two difficulties: the unwillingness of utilities to guarantee the credit of the uranium enrichment enterprise, and the financial difficulties of some electric utilities, which have threatened their own credit-worthiness and ability to fulfill contracts.

Alternatively, the government could--in effect--guarantee loans. For example, under the provisions of the NFAA the government could assure lenders by agreeing to take over the project--and all its liabilities--if necessary. In addition to assuming loan obligations, the NFAA would, under certain circumstances, authorize the government to provide some compensation to stockholders. If such guarantees were to be invoked, the government could also take over ownership of the project.

The ability of project financing to limit the risks faced by the owners of a project depends on the amount of money that can be borrowed by the venture. When firm contracts with customers ensure a steady stream of revenues upon project completion, the main risk to investors would be the possibility of losing their initial capital investment. A high debt-equity ratio limits this risk because the maximum that investors can lose is the relatively small equity investment. By making possible a high debt-equity ratio, external guarantees thus provide protection from risk somewhat greater than their direct provisions imply. Such guarantees may also reduce the cost of capital, a saving that may be passed on to customers in the form of lower prices.*

Investment Tax Credit--A strong financial incentive already in existence is the investment tax credit (ITC). This credit--which would apply to the uranium enrichment

---

*Since the interest rate paid to lenders is substantially lower than the rate of return on equity required to sell stock, increasing the debt-equity ratio lowers the overall cost of capital.

industry unless the tax laws were amended specifically to exclude it--reduces capital exposure by allowing investors a credit against income tax liability equal to a fraction of their eligible investment.*

The ITC serves in most cases to increase the after-tax rate of return expected from a project. Although the increase may make investors more willing to bear risks, the ITC normally has no large direct effect of reducing risk.

The investment tax credit is computed (under current law) as 10 percent of the eligible investment, independent of any financing methods. The entire credit accrues to the owners of the project. For example, an eligible $3 billion investment would create an ITC of $300 million. If the investment were financed with $1.5 billion of equity investment and $1.5 billion of debt, the ITC would amount to 20 percent of the equity investment and might increase the rate of return in a similar proportion.

Combining government guarantees with the investment tax credit would provide an extremely strong set of incentives. The guarantees would make it possible to finance a project with a relatively small contribution from the owners and a great deal of borrowing.

For example, one consortium now proposing to build an enrichment facility anticipates that domestic equity owners would contribute $128 million of the $3.3 billion cost of the facility (with remaining financing coming from domestic lenders, operating revenues, and foreign investors). While contributing this equity during construction, domestic participants in such a consortium could utilize a combination of deductions for certain construction expenses and the investment tax credit to reduce federal taxes on their income from other sources. The resulting tax savings could

---

*The investment tax credit is currently 10 percent of eligible costs, but it is scheduled to fall to 7 percent at the end of 1976. However, it is expected that the 10 percent rate will be extended. Eligible investment comprises tangible property used as an integral part of a manufacturing process.

be $97 to $328 million (see Appendix F). Consequently, by the time an enrichment facility were completed, domestic equity investors could have more than recouped their investment through use of existing provisions of the tax law. This recoupment would be tenuous for a substantial period because some part or all of the tax credit would be "recaptured" (repaid to government as a tax) if the plant were not held for seven years following commencement of operations. Thus, catastrophic failure during construction, or a take over of the plant by the government in accordance with NFAA assurances, could trigger repayment of the credit.

ERDA has received four proposals to construct uranium enrichment plants from firms anticipating utilization of the assistance that would be provided by the NFAA (see Appendix D). The existence of these proposals indicates that the incentives proposed in the NFAA would be sufficient to stimulate private investment. Congress may, however, wish to examine the possibility of achieving the same result with a lower level of assistance.

CHAPTER VI
POTENTIAL BUDGETARY EFFECTS

The choice of private, government or mixed ownership of new enrichment capacity could significantly affect federal expenditures and revenues. While outlays in fiscal year 1977 would be small under any of these options, future outlay levels and revenues could vary sizably.

Estimated Cash Flow From Existing Facilities

The expenditures and revenues expected from existing and currently planned expansion of enrichment facilities indicate the orders of magnitude that might be associated with future new capacity. Table I, which is based on data provided by ERDA, shows the expenditures and revenues expected during fiscal years 1976 through 1990, based on a charge of $76 per SWU (this charge could be increased in the future). Through fiscal year 1977, net outlays totalling $750 million are expected ($210 million in 1976, $150 million in the transition quarter, and $390 million in 1977.* By fiscal year 1978, revenues are expected to exceed costs and increase thereafter to provide net annual income of about $1 billion from 1981 through 1986, then decrease slowly to about $700 million annually. This net income could be invested in new uranium enrichment facilities, additional stockpiles, or other energy R&D, or it could be returned to the general fund of the Treasury.

Potential Cash Flow From Future New Facilities

The estimates in this analysis illustrate the patterns of revenues and expenditures expected with each of the three major options. Based on data supplied by ERDA for government-owned facilities, the net revenues would include as costs operating expenditures, capital costs, and interest at an assumed rate of 6 percent per year on the cumulative costs, net of revenues. ERDA's revenue estimates assume a

---

*All dollars are constant 1976 dollars unless otherwise indicated.

TABLE I
Revenues and Expenditures of Existing And Planned Federal Enrichment Facilities
(millions of constant dollars)

Fiscal Year	Outlays (Costs)	Revenues	Net Cash Flow*
1976	890	680	-210
TQ	240	90	-150
1977	1050	660	-390
1978	1110	1150	40
1979	1060	1570	510
1980	1060	1620	560
1981	1040	2050	1010
1982	990	1910	920
1983	920	1760	840
1984	930	1940	1010
1985	970	1990	1020
1986	970	1890	920
1987	970	1840	870
1988	970	1810	840
1989	970	1760	790
1990	970	1660	690

*Revenues less costs

SOURCE: ERDA Letter From M.C. Greer, Controller of ERDA to George Murphy, Executive Director, Joint Committee on Atomic Energy, dated July 24, 1975.

future price for enrichment services of $125 per SWU. The estimates assume that royalties will be 3 percent of gross revenues for the first 17 years of operation. Finally, the estimates for net tax receipts (which include both tax expenditures and revenue) for the private and mixed options are based on information made available to CBO by Uranium Enrichment Associates (UEA).* These estimates assume a total plant cost of about $3.5 billion (1976 dollars), with 83 percent of this eligible for a ten percent investment tax credit and approximately 14 percent eligible for a tax writeoff as deductible business expenses. When in full operation, each private facility of this size would pay annual corporate income taxes of about $100 million and annual royalties of about $25 million. (While the actual receipts would vary from these levels, the general size and pattern is expected to be similar.)

All estimates in the following paragraphs reflect the revenues, receipts, and royalties associated with constructing six enrichment facilities, although there could be as few as two and as many as eleven. The pattern for government revenues and tax receipts follow the same trends for all options; by the mid- to late 1980s, revenues would become greater than expenditures, reaching steady levels by the early 1990s.

All Private Option

If all the enrichment facilities were constructed by the private sector, there would be no direct government outlays. Federal revenues from royalties cannot be estimated with certainty, because they would depend on the terms of the cooperative agreements between industries and ERDA that the NFAA would authorize, subject to subsequent Congressional review and approval. To illustrate the potential size of royalties, UEA's assumption of a royalty of 3 per-

---

*UEA is a private consortium of companies (Bechtel, Williams and Goodyear) with experience in the energy industry. In response to a request by ERDA for proposals from private industry to participate in expanding the nation's enrichment capacity, UEA has proposed a plan to build, own and operate the next major addition to capacity, which is expected to be a 9 million SWU diffusion plant.

70-844 O - 76 - 6

cent of gross revenues has been used. As shown in Figure 1, royalties would begin in 1984 and would rise by 1994 to about $150 million a year.* By the year 2000, cumulative royalties would reach about $1.5 billion.

Estimates of tax receipts are based on a hypothetical corporate income tax return. During construction, an enrichment plant's revenues would be small or nonexistent. Deductible expenses and the investment tax credit resulting from construction could be used by the owners to reduce tax liability on other income (see Appendix F). The annual reduction in corporate income taxes paid by the owners of six plants could reach $230 million in 1983. As the enrichment plants began to realize revenues, their tax liability would increase. By 1993, taxes of about $600 million annually would result from the six plant's income. Cumulative tax receipts would reach $5 billion in the year 2000. However, investors not subject to U.S. taxation participated in financing the facilities.

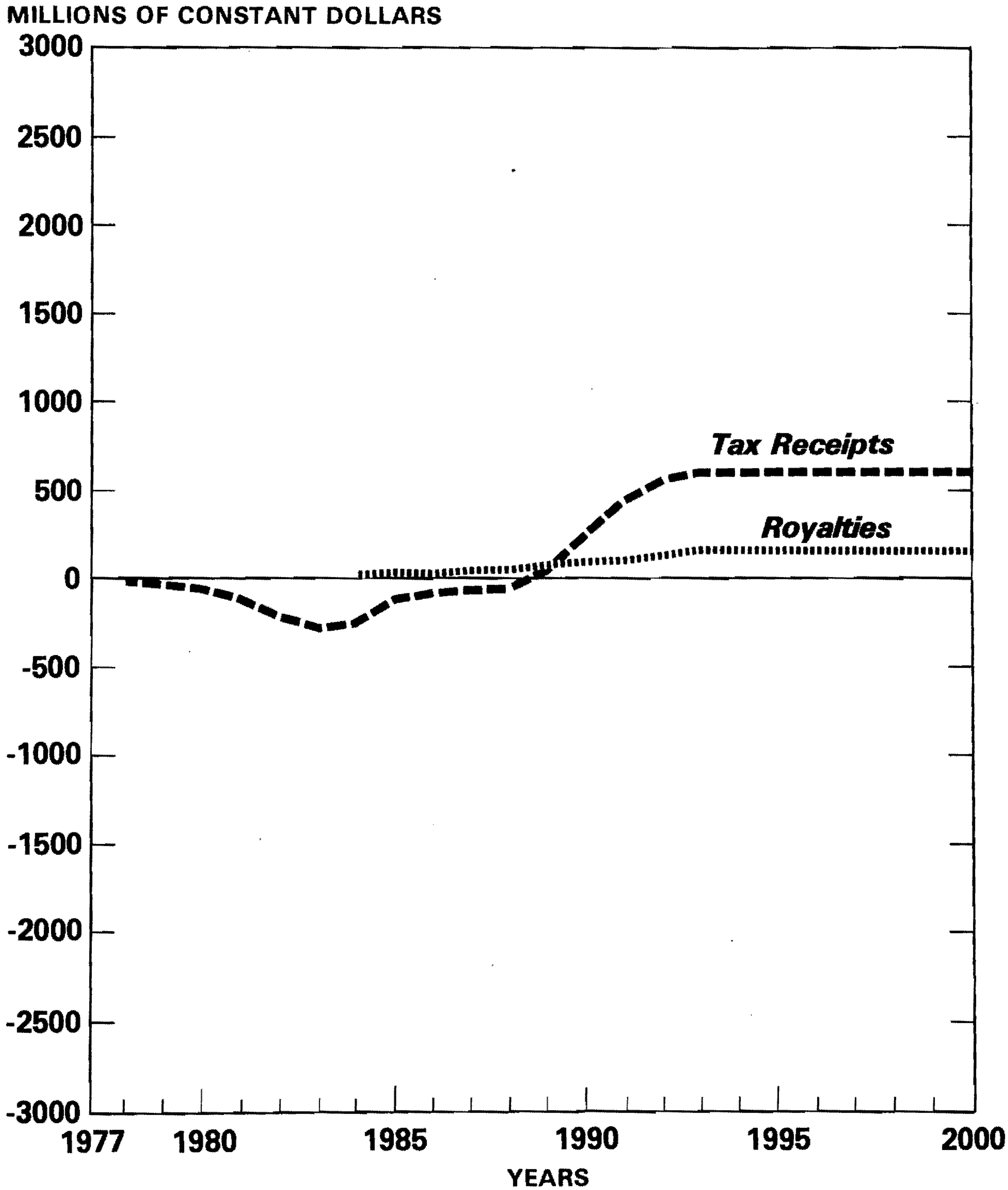
The tax receipts or tax expenditures associated with a privately owned uranium enrichment facility may not represent a net change in total federal revenues from those anticipated with a federally owned facility. Whether total tax revenues will differ between the cases of government and private ownership depends largely on whether government outlays to construct enrichment capacity affect overall federal budget totals. A choice between government and private ownership would not affect the total federal budget if federal outlays not committed to uranium enrichment were committed elsewhere, or vice versa. The amount of stimulus provided the economy by federal expenditures would be the same in either case, and total tax revenues (or tax expenditures) generally would also be the same. That is, tax revenues (and tax expenditures) would also be unaffected by the choice of private or

---

*Annual numerical values for Figures 1 through 4 can be found in Appendix G.

Figure 1

All Private Ownership Royalties and Tax Receipts



government ownership, because if private capital were not used to finance enrichment, it would be invested in other private projects that would provide tax revenues and expenditures. Taken together, these projects should provide the government with about the same overall level of tax revenues.

If, on the other hand, total federal expenditures were raised to accommodate construction by the government, then the level of economic activity, private investment, and tax revenues would also be affected. In this case, the difference in tax revenues between government and private ownership would depend on many factors other than the taxes paid by the private enrichment owners.

In the context of the new Congressional budget process, whereby Congress simultaneously establishes totals for outlays, revenues and the deficit, CBO assumes that enactment of the NFAA would affect neither total tax expenditures nor total tax receipts; these tax impacts are not used in comparing the total costs of the three program options (private, government, and mixed) and are not included in the final estimates in Figure 4. (However, estimates of tax receipts and tax benefits which might be claimed by builders of enrichment plants are included in Figures 1 and 3 for completeness.)

All Government Option

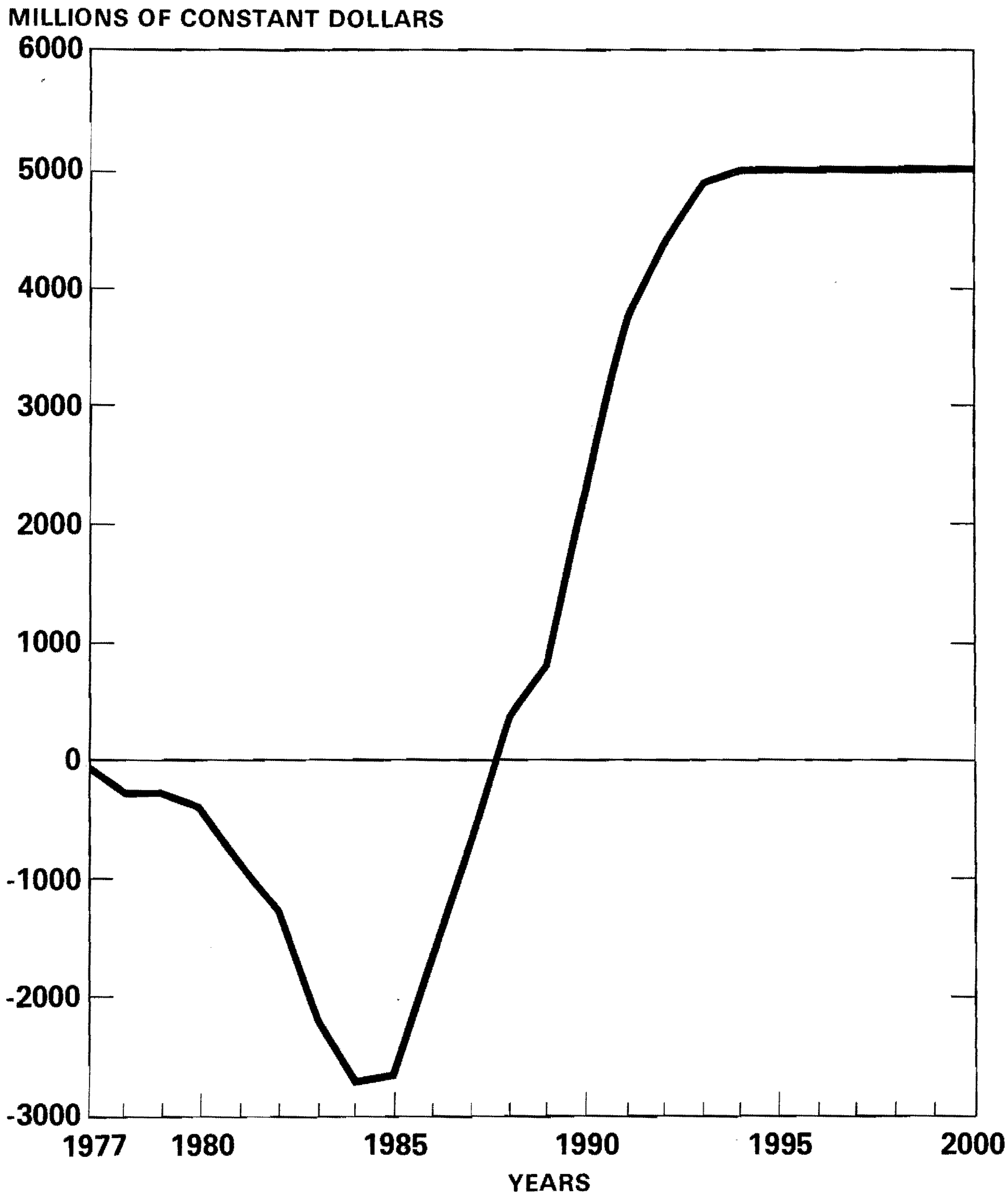
If the government were to own all six of the additional facilities, the estimated net enrichment revenues would follow the pattern shown in Figure 2. This assumes a charge of $125 per SWU and a 6 percent interest rate. Net federal outlays would rise substantially during the next decade, reaching a maximum of $2.7 billion in 1984 ($2.3 billion if interest is excluded), decreasing to a breakeven point (i.e., where revenues begin to exceed outlays) in 1988, and reaching a net surplus of $5 billion per year in 1994. The initial outlays, including interest charges, would be repaid by 1993, and cumulative surplus revenues would reach $38 billion in the year 2000.*

---

*Spreading construction of the six plants more evenly over the remainder of this century, rather than building them all within the next 15 years, would not substantially alter these figures. The breakeven date would remain the same, but the deficit retirement would be delayed by a year or two and cumulative revenues by the year 2000 would be reduced by less than $10 billion.

Figure 2

All Government Ownership: Revenues



Between 1977 and 1991 interest charges--which are not included in program accounts in the budget of the United States (but are calculated in determining the deficit)--would amount to $4 billion.

Mixed Ownership Option

The estimates of government net enrichment revenues, royalties, and tax receipts for one new government owned diffusion plant and five privately-owned centrifuge enrichment plants would follow the pattern shown in Figure 3.

Net government enrichment outlays would rise to a maximum of about $900 million in 1983, reaching a maximum of more than $600 million in annual net revenues by 1990. The initial outlays, including interest, would be repaid by 1993, reaching a cumulative surplus of $4.7 billion in 2000. Interest charges between 1977 and 1989 would be almost $1 billion.

Royalty payments would begin in 1986, reaching a maximum of $125 million in 1993, with cumulative revenues of $1.3 billion by the year 2000.

Figure 4 presents the total of revenues and royalties for each of the options. (Tax receipts are not included in this figure.) Tax receipts would add about $0.6 billion to the maximum returns in the all-private case and about $0.5 billion to those in the mixed ownership case.

Finally, if a government corporation were created to build and own some or all of the new future capacity, effects on the federal budget would depend on the nature of the corporation's structure. If it were required to be entirely self-financing, there would be no direct federal expenditures. If its annual net gains or losses were to be included in the budget, the amounts could vary from year to year. However, such amounts could be much smaller and less variable than the net revenues of the all-federal option shown in Figure 2. Reported gains or losses, especially in early years, would depend on the financial arrangements and accounting practices adopted by the corporation.

Figure 3

Mixed Ownership Government Revenues, Royalties, and Tax Receipts

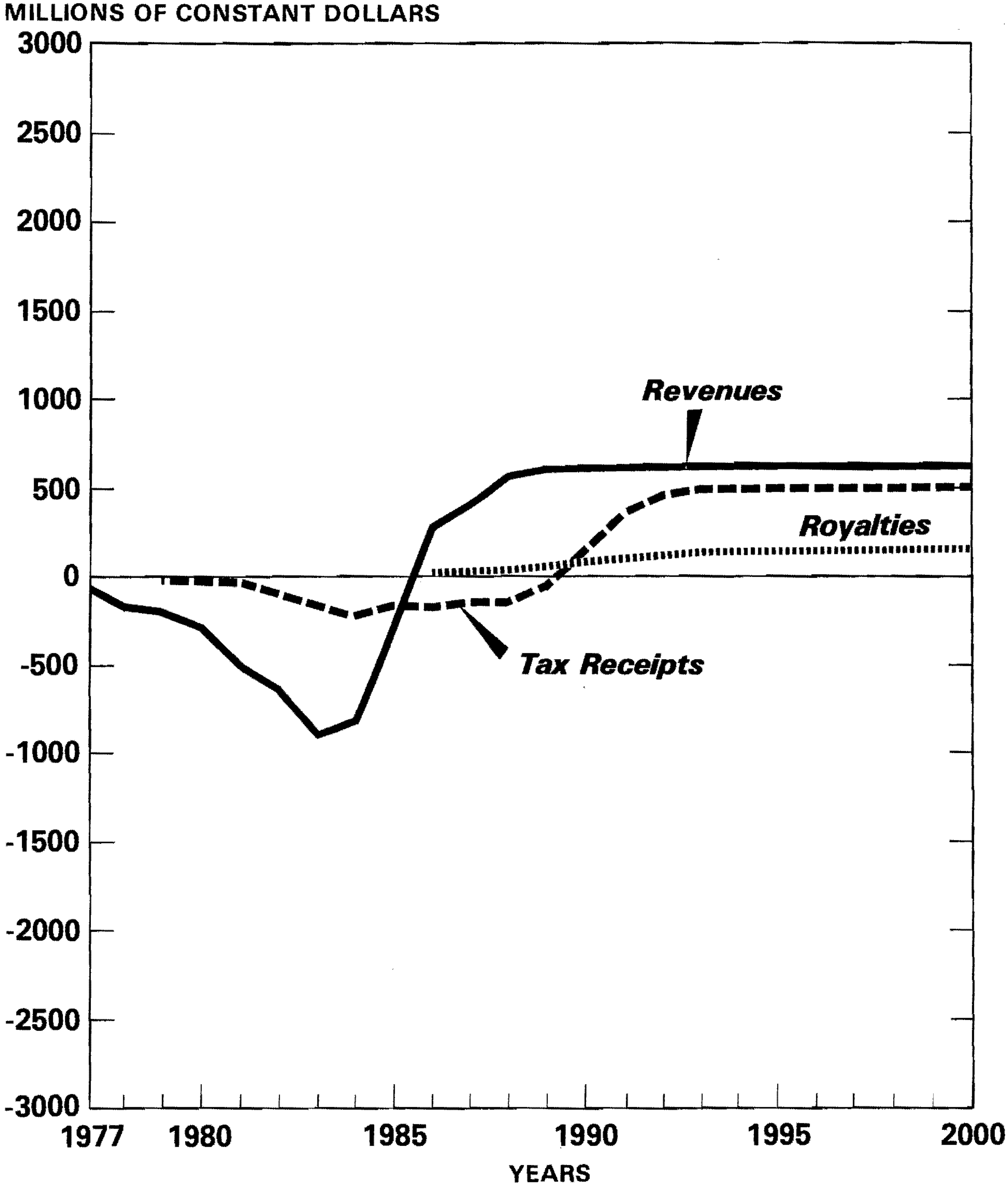
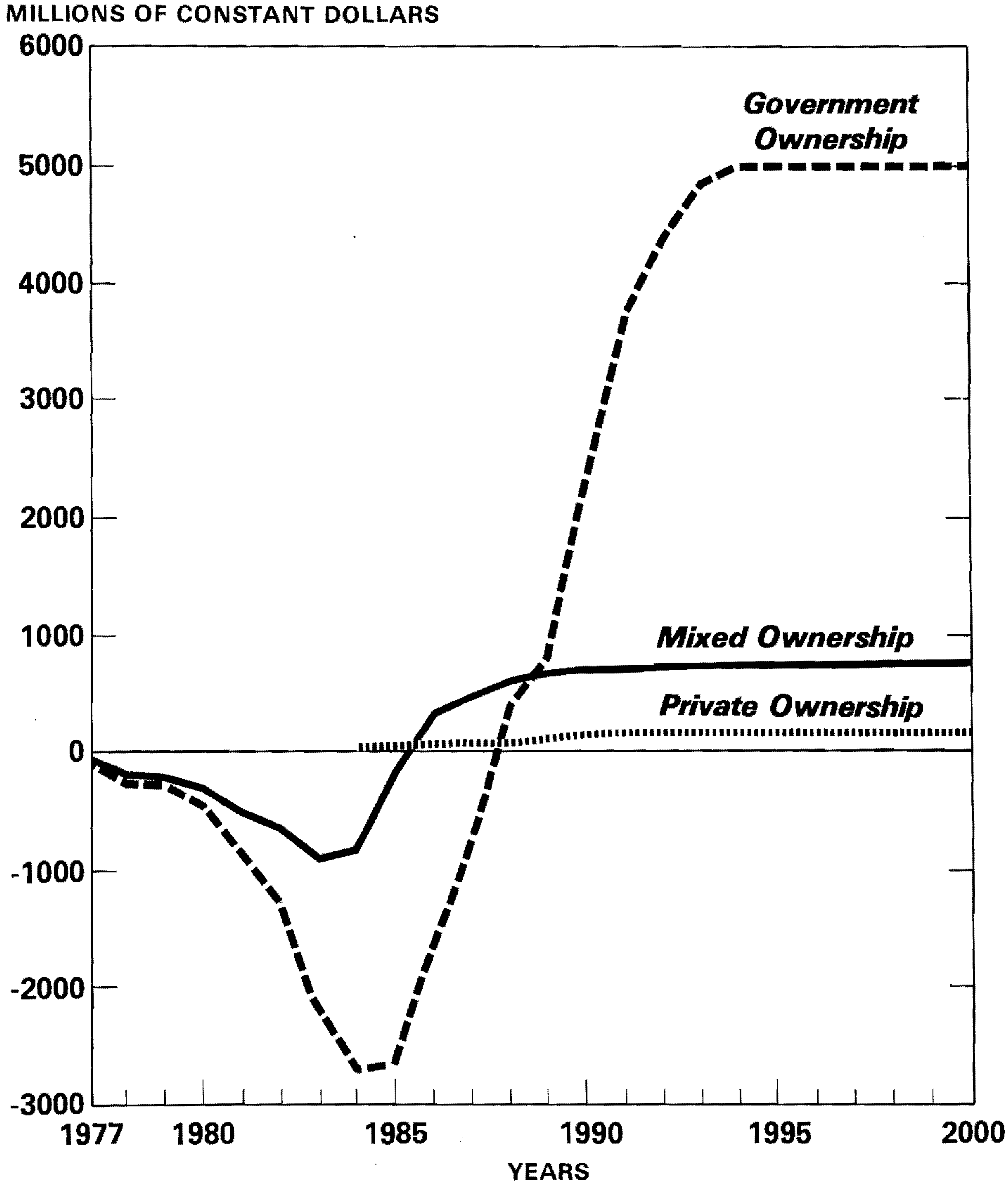


Figure 4

Comparison of Ownership Options Royalties and Government Revenues



Potential Costs of Default

The budget impacts discussed above have been calculated under the assumption that the guarantees that would be authorized in the NFAA in regard to technical or financial failure of private projects would not have to be used. If this assumption were to prove incorrect, the budgetary implications of federal assumption of the projects and related debts could be significant.

Although ERDA is quite confident that there will be no default due to failure of a private facility, the possibility does exist. Should default occur, ERDA would be responsible for assuming the domestic debts and liabilities and possibly purchasing the facilities' domestic equity. In proposals that ERDA and private firms are now discussing in anticipation of the NFAA'S enactment, the cost of such a federal takeover could amount to $1.4 billion of the $3.5 billion total cost for a diffusion facility with 60 percent foreign financing (more if the domestic share is larger than 40 percent) and all costs of each of the smaller $1 billion centrifuge facilities, which anticipate no initial foreign investment. The government would be at risk for this amount from the date of full commercial operation to a date subject to negotiation between ERDA and industry. (For the existing diffusion proposal, ERDA and UEA have agreed on a government guarantee that would extend one year after full commercial operation.)

In addition, the NFAA would authorize ERDA to purchase enrichment services (SWU) from and sell SWU to private firms. ERDA and UEA are now discussing sales and purchases of as much as 6 million SWU. Based on a price of $76 per SWU, this could amount to revenues--or outlays of as much as $450 million. Revenues and outlays for sales and purchases involving other private firms would be subject to negotiation.

CHAPTER VII
DECISIONS FACING CONGRESS

The major decisions concerning the uranium enrichment issues and ownership options will probably come before Congress as a series of specific proposals. The most immediate decision concerns the proposed NFAA, now before the Joint Committee on Atomic Energy.

Approval of the NFAA would signal clear Congressional intent to encourage private ownership of future new uranium enrichment facilities. Several subsequent Congressional decisions about implementation would then be required.

As indicated earlier, the NFAA would authorize ERDA "...to enter into contracts for copperative arrangements... in an amount not to exceed in the aggregate $8,000,000,000 but in no event to exceed the amount provided therefor in a prior appropriation Act." The relationship of this authorization to the provisions of the Congressional Budget Act of 1974 (P.L. 93-344) is unclear. Several alternatives that attempt to conform this authorization to the budget act are described below.

The Office of Management and Budget (OMB) has developed a plan which, OMB believes, would minimize the apparent budgetary impact of commercializing uranium enrichment while satisfying requirements of the act concerning the definition of budget authority, the establishment of budget targets or ceilings, and the prohibition of backdoor spending.

According to OMB's plan, if the NFAA were enacted, ERDA would request that up to $8 billion in contract authority be provided in an appropriations act. In addition, ERDA would request Congressional approval of individual cooperative agreements negotiated with private industry. The total amounts covered by these agreements would be limited by the size of the appropriation. (ERDA believes that $8 billion would be the maximum for which the federal government could become liable if all private ventures failed and the government found it necessary to take them over.)

Because these cooperative agreements involve contingencies that would not necessarily result in outlays, OMB believes that the amounts apprropiated should not appear in the budget as budget authority and therefore not count against budget targets or ceilings.

According to OMB, this would be consistent with the definition of budget authority in Section 3(a)(2) of the Budget Act.* Potential government liabilities incurred pursuant to the NFAA would be contingencies in that the government would be required to take over the domestic debt of a private enrichment company, refund its equity investment, and complete the project at government expense only if private industry were to fail to operate the new enrichment facilities successfully in accordance with the terms of the cooperative agreements. Because the government has successfully operated uranium enrichment services for many years, the Administration believes that it is unlikely that any project failures requiring federal outlays would actually occur.

If, however, it appeared likely at a later date that the federal government would be required to take over a project, ERDA would borrow the necessary funds from the Treasury and then request an appropriation to repay the Treasury. This appropriation would count against budget authority and outlay targets and ceilings in the year in which it occurred.

In response to a request from the Senate Budget Committee, GAO has examined OMB's interpretation and concluded that, while the financial assurances provided by NFAA are not required to be regarded as budget authority as defined by §3(a)(2), to treat such assurances off-budget would "...establish an undesirable precedent."**

---

*Section 3(a)(2) defines budget authority as "...authority provided by law to enter into obligations which will result in immediate or future outlays involving Government funds, except that such terms does not include authority to insure or guarantee the repayment of indebtedness incurred by another person or government."

**Letter to Senate Edmund S. Muskie from Elmer Staats, Comptroller General of the United States, March 16, 1976.

An alternative that appears consistent with the Budget Act calls for the entire $8 billion to be appropriated in a lump sum and counted as budget authority at that time, thus affecting budget targets for that year. Outlays, however, would occur only if the contingencies were to become liabilities.

Another alternative would be the annual appropriation of any required budget authority in the yearly appropriation cycles. This, however, could be interpreted to be backdoor spending.

The NFAA provides an immediate vehicle for Congressional decision in regard to providing enrichment capacity for potential needs beyond 1985. If Congress judged that the private sector should provide future capacity, it could enact the NFAA or other legislation to the same purpose. In this event, the Congress could determine whether the first project (which is likely to use diffusion technology) as well as later projects (possibly using newer technologies) would be transferred to the private sector. It could also establish the appropriate level of incentives and any consequent need for further budget authorizations.

If, however, Congress judged that the government should retain responsibility, it could reject the NFAA proposal and begin federal programs for providing further capacity. In this event, the key issues would probably be the timing of new capacity, the fraction of the foreign market to be served (which would directly affect the amount of capacity needed), and the budget impacts, particularly in regard to increased outlay levels in the early years of an expansion program.

It should be emphasized that other circumstances and policy decisions beyond the scope of this paper could significantly affect the nuclear power industry and, therefore, the need for uranium enrichment services and the way in which they are provided. These separate considerations include decisions in regard to nuclear nonproliferation, materials safeguards, moratoria, and as-yet-unresolved issues about reactor safety and the ultimate disposal of nuclear wastes. Nonproliferation is particularly relevant, since uranium enrichment capacity developed for peaceful purposes can potentially be used to produce weapons materials. Finally, Congress will deal with issues involving the shape of the nation's total energy future, in which the role accorded the nuclear component could vary considerably.

APPENDIX A
THE URANIUM FUEL CYCLE

Uranium, like most raw materials, must be processed before it can be used. After use, it must be disposed of safely. The fuel cycle is that set of processes treating the uranium from mining to use and finally to disposal.

1. <u>Mining</u>

Uranium ore is found embedded in sandstone. The grades of ore currently being mined contain 4 to 5 pounds of uranium oxide per ton of ore. A typical 1,000 million watt (1,000 megawatt) electric power plant will need the uranium from approximately 125,000 tons of ore each year.

2. <u>Milling</u>

The mined ore is taken to a milling facility, where the ore is crushed, ground, leached with appropriate acid solvents (such as sulfuric acid) and purified into the oxide form, U_3O_8, known as "yellowcake." About 125,000 tons of ore must be milled to obtain 240 tons of yellowcake. The price of uranium is usually quoted as dollars per pound of yellowcake. In the last two years, the average price of yellowcake has increased from around $8 per pound to as high as $30 per pound. Recent spot market prices have been even higher.

3. <u>Conversion</u>

The yellowcake is then shipped to a conversion plant. Here it is converted to a hexafluoride form (UF_6) which is solid at room temperature but becomes a gas at a small increase in temperature and pressure. Two hundred forty tons of yellowcake will become 300 tons of UF_6.

4. <u>Enrichment</u>

Although the process will have provided relatively pure UF_6 at this point, the natural uranium contains only 0.7 percent of the fissionable isotope U^{235} and 99.3 percent of the isotope U^{238}.* It is the lighter U^{235} isotope of uranium which provides the energy in the current generation of light water reactors. The concentration of the U^{235} must therefore be raised from the natural occurrence of 0.7 percent to provide a fuel sufficiently "enriched" in U^{235} to

---

* Both isotopes of uranium contain 92 protons, which determine the electron charge of the nucleus. However, the lighter U^{235} has 143 neutrons (92+143=235 atomic weight) while the heavier U^{238} has 146 neutrons (92+146=238).

sustain a controlled chain reaction (and hence generate power). Present light water reactors need fuel enriched to approximately 3 percent of U^{235}. The enrichment process is explained in some detail in Appendix B. The 300 tons of UF_6 will provide about 40 tons of enriched UF_6 and about 260 tons of depleted uranium.

5. Fuel Fabrication

The enriched UF_6 is shipped to fuel fabrication facilities and converted to a solid uranium oxide (UO_2), fabricated in small cylinders roughly 1/2 inch in diameter and at most several inches long. Depending on the design of the reactor in which the fuel will be used, the cylinders are then assembled in varying configurations of fuel rods, and the rods are combined into fuel elements. These fuel elements are then shipped to a nuclear power plant, where they are inserted into the reactor core.

6. Reactor Use

The reactor core contains roughly 100 tons of enriched uranium. Normally one-third to one-fourth of the core will be replaced each year. When removed, the spent fuel units will have lost about four percent of their weight as the U^{235} has fissioned and heated the reactor. Somewhat more than one ton of U^{235} is fissioned each year in a 1,000 megawatt reactor.

7. Reprocessing

Each year roughly 30 tons of fuel will be removed from the reactor for reprocessing. The reprocessing cycle separates the remaining uranium and the plutonium products from the radioactive fission fragments and metal cladding.* The uranium can then be sent back to the enrichment facility to be incorporated in new fuel elements. The plutonium (roughly 50 pounds) will be sent either to storage or for reuse as reactor fuel.

8. Storage

The use and reprocessing of the fuel elements will separate out radioactive wastes. Some low-level wastes such as radioactive pipe fittings, uniforms, etc., are encased in concrete or asphalt for burial. Roughly one ton of high-level wastes will be generated in the reprocessing stage. These wastes contain fission products, such as strontium 90 and cladding from the fuel elements. At present, the United States has no fixed policy on the long-term storage of such wastes. Typically, such wastes are stored above ground in

---

* The cladding is the protective inner metal coating bonded to the shell of the container.

protective containers, pending resolution of the issue of permanent storage.

APPENDIX B
THE ENRICHMENT PROCESS

Two enrichment technologies -- the mature gaseous diffusion technology and the emerging centrifuge technology -- are candidates for use in constructing new uranium enrichment facilities. Other technologies are the subject of research.

1. Diffusion Technology

The gaseous diffusion process, like all separation technologies, exploits the small differences in mass between two isotopes of uranium, U^{235} and U^{238}.

This process pushes gas molecules through membranes which pass the lighter molecules (U^{235}) more easily than the heavy ones (U^{238}). The separation at each stage is very small. Although the amount of gas which can be pushed through each membrane is large, many stages and a great deal of electric power are needed. To enrich uranium to 3 percent U^{235}, for example, requires over 1000 stages.

This system requires many compressors to drive gas through the membranes of each stage. In turn, a great deal of electricity is required to run the compressors; 2300 megawatts of electric generating capacity are necessary to power a 9 million SWU* enrichment plant. On compression, gas heats, giving rise to a requirement for a large cooling water supply to cool the gas: about 20 million gallons per day is needed for a 9 million SWU plant.

Because the diffusion method has been used for so long, the major problems have been worked out, making it a reliable mature technology. Both ERDA and the private uranium industry estimate that the minimum economic size for a commercial operation is about 9 million SWU. In addition, because the separation in each stage is so small, achieving the increased concentrations that are needed by commercial reactors requires a great many stages. This places a limit on the addition to capacity that can be made to an existing plant.

2. Centrifuge Technology

The centrifuge process for enrichment has been actively under development by the U.S. Government since the

---

* SWU -- separative work unit -- is defined in Chapter II.

early 1950s. ERDA has recently increased its development efforts with the construction of a centrifuge test facility and the planning of a centrifuge plant demonstration program.

The centrifuge process relies upon very high speed centrifuges which act to throw the heavier gas molecules to the outside walls. As a result the separation can be quite large; to enrich uranium to 3 percent U^{235} could require fewer than 30 stages. However, the amount of gas which can be placed in any one stage is small; a centrifuge enrichment plant of 9 million SWU could require tens of thousands of stages to make up for the low throughput in each one. Even so, the electric power requirements are estimated at 10 percent of those for a comparably sized diffusion plant. The minimum economic size for a commercial centrifuge facility has been estimated at between one and three million SWU annually, compared with 9 million for diffusion technology. Since the number of centrifuge stages necessary to reach 3 percent enrichment is small, the economic lower limit on the size of additions to capacity of an existing centrifuge plant is much smaller than that for a diffusion plant. Additions of a third of a million SWU or less can be made economically. The capital cost of the two major processes (diffusion and centrifuge) are similar: $3 billion to $4 billion for a 9 million SWU plant.

Because it is new, the centrifuge process has not been technically perfected. For example, the maintenance needed on the large number of centrifuge rotors may be significant, and the process has not been proven on a commercial scale.

3. Comparison of Diffusion and Centrifuge

In its study of uranium enrichment, the Edison Electric Institute compared the two methods and favored the gas centrifuge process, although it has not yet been proven on a commercial scale. This study reported that the "gas centrifuge requires no unusual investment in electric power supply, relatively small but optimum economic plant capacities result in reasonable investment requirements, relatively short construction schedules permit supply to be better matched to demand, and the potential for process improvement is projected as very promising. Gaseous diffusion, on the other hand, while presenting no process concerns, offers no dramatic process improvements, requires equally large capital investments for both minimum and optimum plant size and the necessary electric generating power supply, faces lengthy construction schedules as a result of long lead times for necessary key items such as power supply, large gas compressors, etc., and 'wastes' about 4% of the electricity generation that it is intended to support."*

4. Other Processes

Several other processes are being developed as potential enrichment sources, including jet diffusion, photoexcitation with lasers, and the calutron mass spectrometer. The laser separation process is the only technique of this group being pursued aggressively by ERDA. While the laser technique is very early in the development process and is not yet near a commercial stage, it offers the potential of substantially reducing both power consumption and costs of enrichment activities.

5. Costs

The capital costs of constructing enrichment facilities are approximately the same for diffusion and centrifuge. ERDA estimates the cost, in 1977 dollars, of an add-on diffusion plant of 9 million SWU capacity at $2.8 billion. A new centrifuge plant would cost $3.8 billion for equivalent capacity, although smaller plants could be built, and costs are expected to decline with experience. Also, the initial cost of the centrifuge facility could be reduced by decreasing initial capacity. Private estimates of construction costs are consistent although somewhat higher. Uranium Enrichment Associates (UEA), a private consortium of companies active in nuclear energy production, estimates the cost for a new privately-owned diffusion plant at between $3.3 and $3.5 billion.

Operating costs are likely to be less for a centrifuge than for a diffusion facility; ERDA estimates $200 million annually for a 9 million SWU centrifuge compared with $470 million for diffusion. These figures could, however, underestimate the costs for the centrifuge plant if the maintenance of centrifuge rotors is particularly troublesome.

Translating these capital and operating costs into the eventual price for a SWU is difficult. UEA estimates that the prices, covering all costs and a 15 percent return on equity, will begin around $100 per SWU and drop slowly to as low as $65 per SWU, with an average around $83 per SWU.

---

* Uranium Enrichment Facilities, Edison Electric Institute, Appendix X, June 1974, pp. 16.

In its study, the Edison Electric Institute estimated that, if capital costs for diffusion and centrifuge facilities were approximately the same, the sale price per SWU would be nearly the same.

These costs ultimately impact on electric power costs. A change of $10 per SWU in the charge to utilities for enrichment services will translate into a change in the cost of producing electricity of about 0.25 mills/kwh (present costs of electric production from nuclear power are in the range of 10 to 20 mills/kwh).

APPENDIX C
THE EXTENT AND TIMING OF NEED
FOR ADDITIONAL ENRICHMENT CAPACITY

As indicated in the text (Chapter II), estimates of future demand for nuclear power and for enrichment services are uncertain, depending on (1) the relative costs of nuclear power and alternatives, especially fossil energy; (2) the cost of energy compared with costs of other goods and services; (3) the design and effectiveness of mandatory energy conservation measures; (4) lead times for construction of nuclear power plants; (5) the extent to which the unused uranium and plutonium that is removed during a reloading is reprocessed for use in power plants; (6) the "tails assay" -- the percentage of U^{235} allowed to remain in the depleted uranium (in this analysis and ERDA's assumed to be .3 percent); and (7) the timing and rate of introduction of alternative technologies, especially fission breeder reactors. In the past two years, as costs of all fuel escalated and historic patterns of growth in energy demand changed, previous estimates have been dramatically reduced. This paper uses such revised projections.

Rate of Nuclear Power Growth

A reasonable projection of the growth of nuclear power generation is essential to estimate the increased need for uranium enrichment capacity.

Domestic

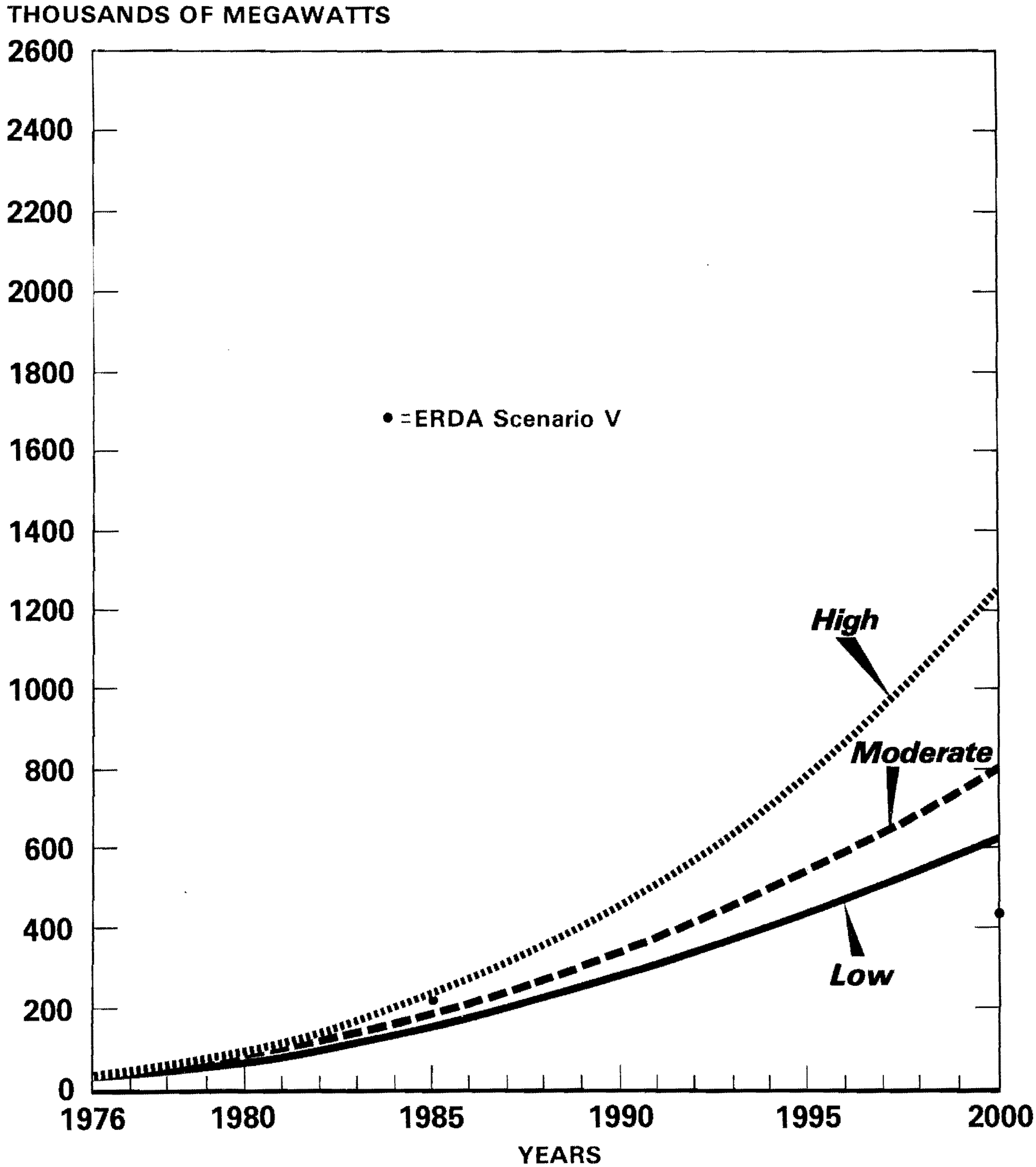
ERDA has investigated three growth patterns for domestic and foreign nuclear power: high, moderate, and low (see Figure C-1).* The high path assumes very fast growth in demand for electricity, a greater cost advantage of nuclear over fossil fuel, and a substantial reduction in nuclear construction delays. The moderate growth assumes moderate conservation in use of electricity, continued cost

---

* Three sources have been used to derive the figures used in this appendix. They are: (1) U.S. Energy Research and Development Administration, Draft Environmental Statement, "Expansion of U.S. Uranium Enrichment Capacity," ERDA-1543, June 1975; (2) U.S. Energy Research and Development Administration, "A National Plan for Energy Research, Development and Demonstration," ERDA-48, June 1975; (3) U.S. Energy Research and Development Administration, "Total Energy, Electric Energy, and Nuclear Power Projections, United States, February 1975.

Appendix C, Figure 1

Revised ERDA Projections of Nuclear Generating Capacity



SOURCE: Energy Research and Development Administration; *Total Energy, Electric Energy, and Nuclear Power* United States, Feb., 1975.

advantage of nuclear over fossil energy, and some reduction in construction delays. The low case assumes low growth in electricity demand and only a marginal cost advantage of nuclear over fossil fuels (resulting from continued delays). ERDA has chosen the moderate growth case as most likely for the purpose of planning additions to enrichment capacity. ERDA's recently proposed National Plan for Energy Research and Development also includes energy growth goals (also shown in Figure C-1).* The goals for the Scenario V preferred in that plan are higher than ERDA's revised moderate growth projections in 1985 but significantly lower in the year 2000. In 1985, for example, according to the moderate growth estimate, generating capacity is projected to be 185 thousand megawatts. By 2000, however, ERDA's moderate estimate is 800 thousand megawatts, while its Scenario V estimate is 448 thousand megawatts.

At present, a typical 1000 MW nuclear generating plant needs roughly 80,000-100,000 SWU (separative work units)** of enrichment services each year, with a tails assay of 0.3 percent. Thus, the estimated generating capacity indicates approximately how much enrichment service capacity will be needed. Using ERDA's moderate growth assumptions, annual domestic requirements would grow from the present level of 5 million SWU to more than 15 million SWU in 1985, 27 million SWU by 1990, and between 45 to 60 million SWU by the year 2000 (see Figure C-2).

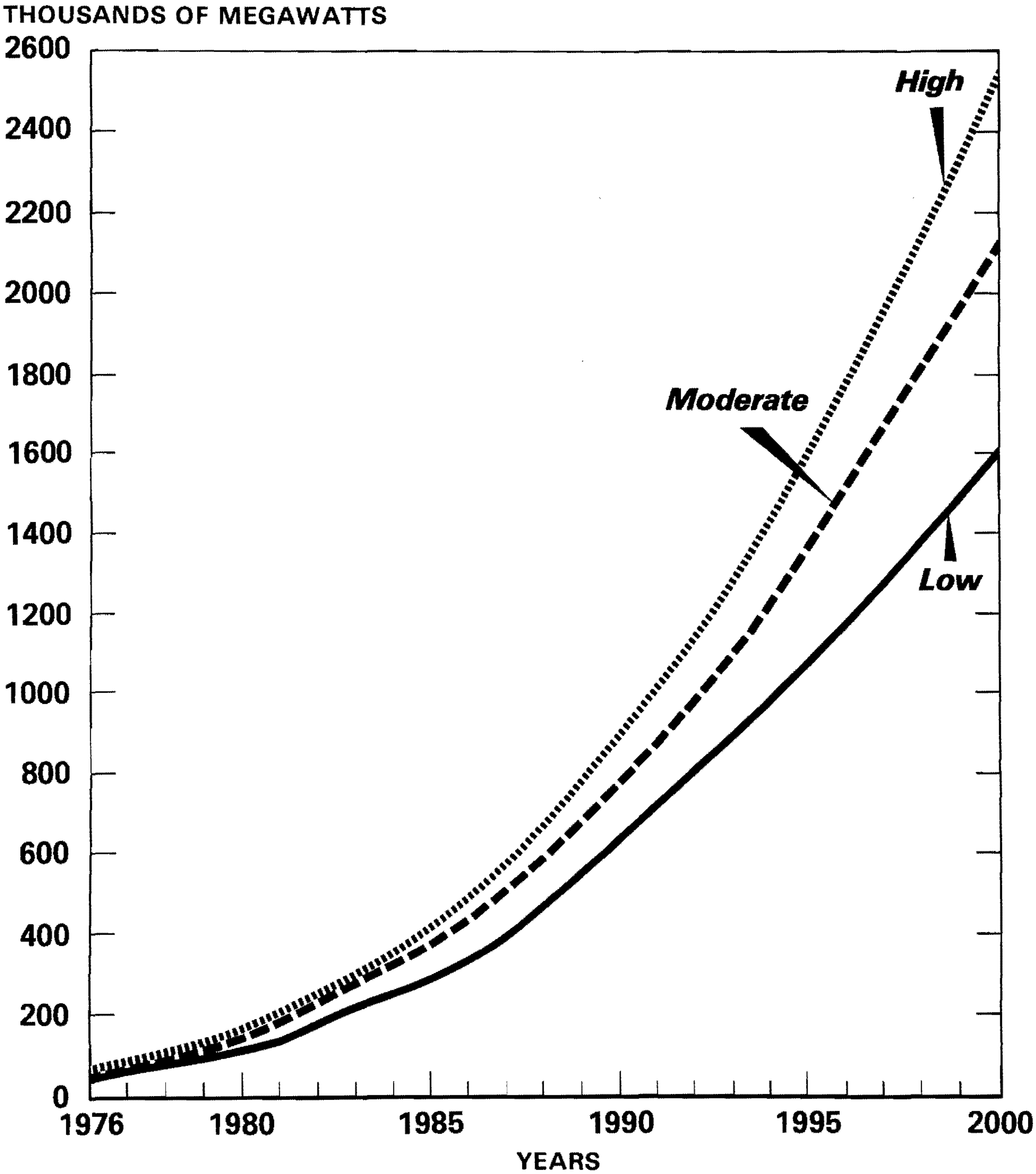
---

* "A National Plan for Energy Research, Development and Demonstration," ERDA-48, Vol. 1, pp. B-20 and 21.

** The capacity of enrichment plants is expressed in a quantity known as Separative Work Units (SWU). These units represent the amount of work necessary to transform natural uranium with only 0.7 percent U^{235} into a reactor-grade fuel with approximately 3 percent U^{235}. Providing a typical 1000 megawatt (MW) nuclear power plant with a year's supply of enriched uranium takes, on the average, 80-100,000 SWU each year. The present capacity of the three existing U.S. plants is 17.2 million SWU per year, sufficient to supply fuel for 172 power plants of 1000 MW capacity each. Presently, the equivalent of 37 thousand-megawatt nuclear power plants are in operation in the United States. Table C-1 shows ERDA's estimates of currently existing or planned SWU capacity and production.

Appendix C, Figure 2

ERDA Projections of Non-U.S. Nuclear Generating Capacity



SOURCE: Energy Research and Development Administration: Draft Environmental Statement, *Expansion of U.S. Uranium Enrichment Capacity*, ERDA-1532, June 1975.

ERDA's present expansion program to achieve an annual capacity of 27.7 million SWU by around 1985 can support the equivalent of 329 1000-MW power plants. This capacity has been fully committed for future deliveries to customers, both domestic (the equivalent of 208 power plants) and foreign (the equivalent of 120 power plants). While the domestic contracts provide for services larger than seems likely to be required in 1985, ERDA must provide for the delivery to all customers currently under contract and thus it can make no more commitments unless the agency either cancels orders from foreign customers (an unlikely strategy) or makes only short-term new commitments. ERDA anticipates that new customers, not now under contract, may wish to purchase enrichment services beginning in 1983-1985, and thus the agency will need additional new enrichment capacity to serve them.

Foreign

Like the United States, foreign countries have been experiencing problems with energy supply and demand. However significantly revised projections of the future growth of world nuclear energy are not available. Thus, ERDA still uses projections made two years ago in analyzing the foreign need for enrichment services.

TABLE C-1
SWU TO BE PRODUCED BY EXISTING AND PLANNED FACILITIES

Year	SWU Production With Expected Power Available	SWU Production With Maximum Power Available
1976	14.8	14.8
TQ	4.1	4.4
1977	18.1	18.6
1978	20.1	20.8
1979	21.9	23.3
1980	24.5	26.9
1981	25.2	27.7
1982	25.3	27.7
1983	25.3	27.7
1984	26.4	27.7
1985 and subsequent years	27.7	27.7

SOURCE: Personal communication from ERDA.

ERDA has also made three projections -- high, moderate, and low -- for foreign nuclear generating growth (see Figure C-3). The moderate growth case projects that foreign nuclear generating capacity will be 385 thousand megawatts in 1985, rising to 2,180 thousand megawatts by the year 2000.

Using its moderate growth projection, ERDA has estimated varying needs for enrichment services, based on the United States meeting different percentages of foreign demand. If the United States were to satisfy 35 percent of foreign enrichment requirements in future years, annual foreign demand for U.S. enrichment services would rise from the present 3 million SWU to about 9 million SWU in 1980, 14 million SWU in 1985, 23 million SWU in 1990, and over 45 million SWU in the year 2000 (see Figure C-4).

Range of Projected Capacity

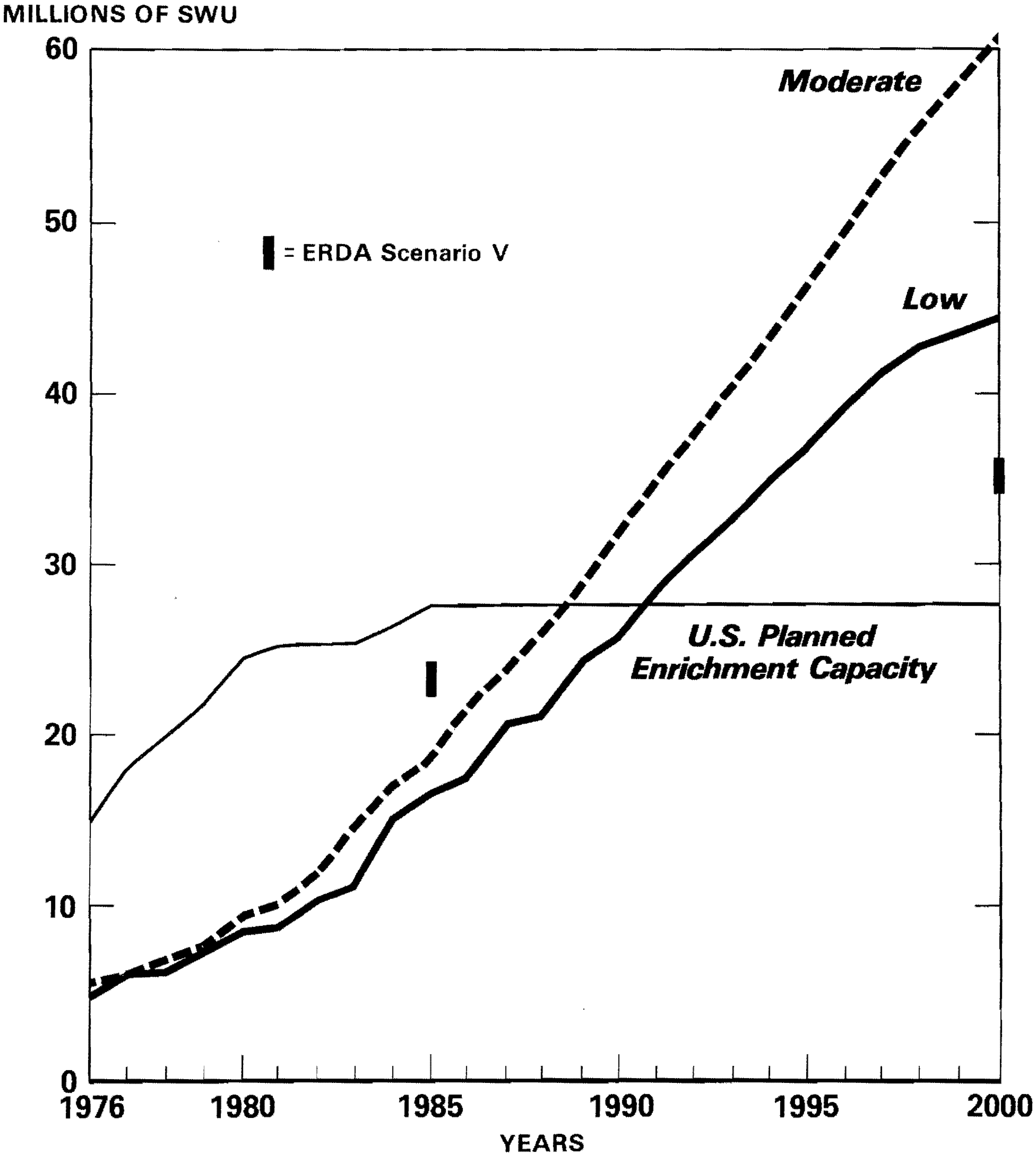
Regardless of who owns or operates domestic enrichment service facilities, several factors will affect the need for, the introduction of, and the ultimate amount of new enrichment capacity. These factors are: the growth in nuclear power and hence in demand for services, the percentage of foreign market served, and the policy on the use of stockpiles.

Growth in Demand

As illustrated in Figure C-5, ERDA currently estimates that based on moderate projections of growth in nuclear power and supplying 35 percent of the foreign market, demand for enriched uranium will exceed the planned domestic capacity in 1983 or 1984. While the entire capacity of planned enrichment facilities is already committed to future customers, contracted deliveries will not equal capacity until 1987 or 1988, when the equivalent of 208 1000-MW domestic customers will be on line as will the equivalent of 121 1000-MW foreign customers. Thus, the year that a utility which has not contracted for services with ERDA wishes to start up a nuclear plant will determine the year that a new enrichment facility should be able to make deliveries. A change in demand growth by 10 percent could alter the operational timing of that next enrichment facility by as much as one year. The length of time to design and construct a new nuclear power plant makes it unlikely that demand in the 1985 period will increase above the current "moderate" projection. A 10 percent decrease or delay in new nuclear power plants would delay the need for a new enrichment facility until 1984 or 1985.

Appendix C, Figure 3

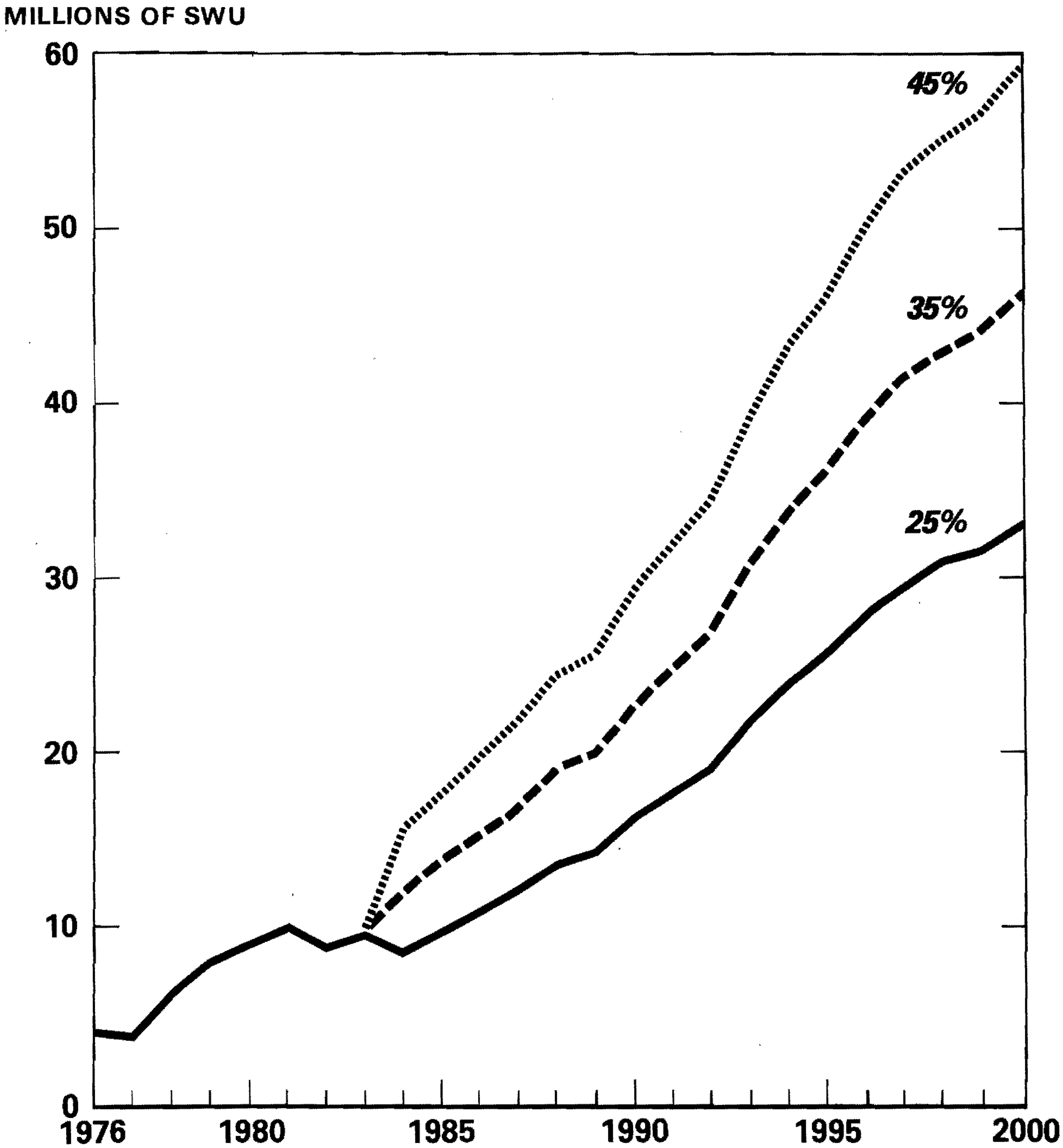
Domestic Enrichment Projections and Capacity Plans



SOURCE: Energy Research and Development Administration: *Total Energy, Electric Energy, and Nuclear Power Projections, United States,* Feb. 1975; and *A National Plan for Energy Research, Development and Demonstration,* ERDA-48, June 1975.

Appendix C, Figure 4

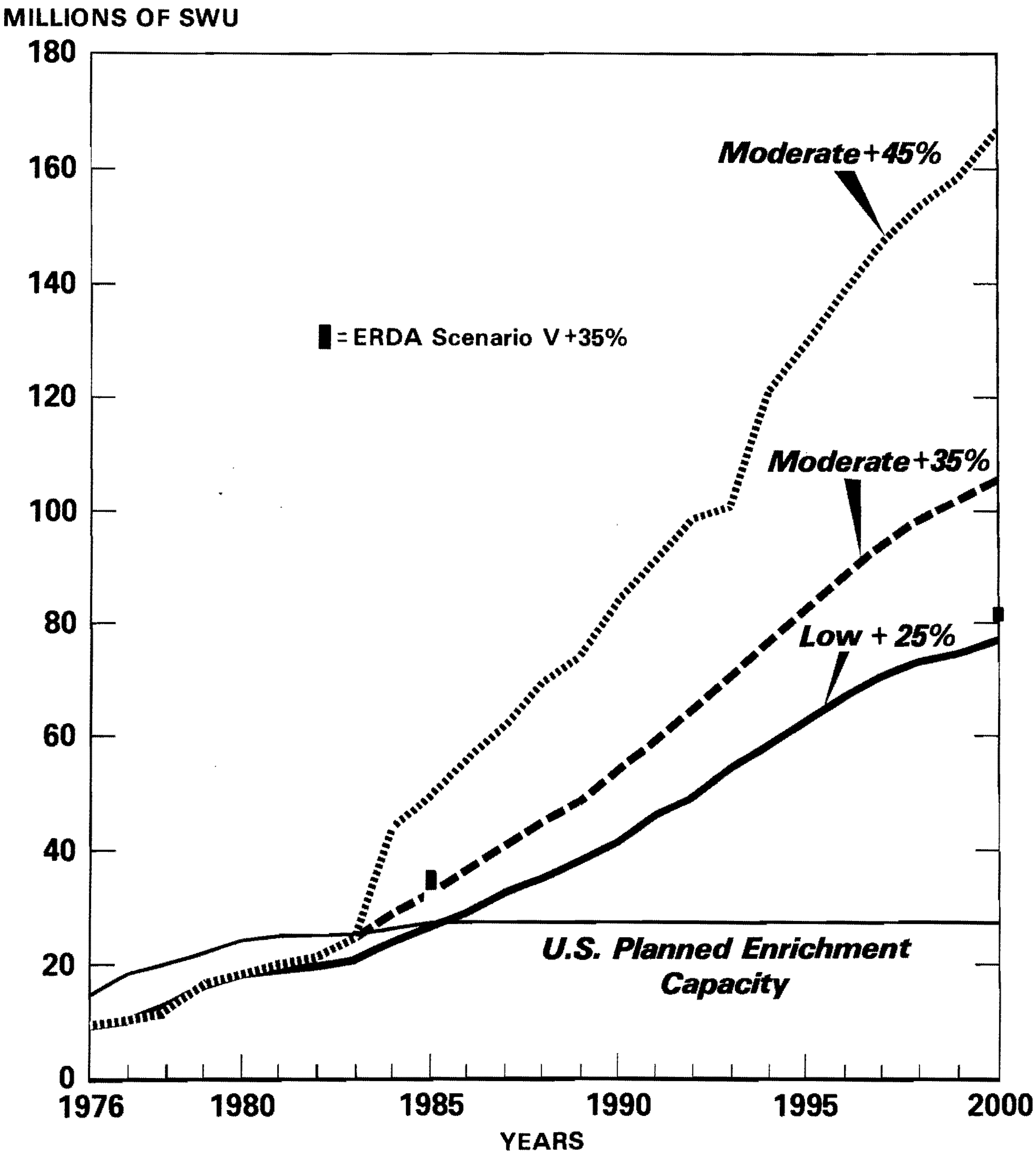
Foreign Enrichment Needs at 25%, 35%, 45% of Demand



SOURCE: Energy Research and Development Administration: *Forecast of Nuclear Capacity, Separative Work, Uranium, and Related Quantities Foreign Moderate Growth, March 1975.*

Appendix C, Figure 5

Total Enrichment Projections and Capacity Plans



SOURCE: Energy Research and Development Administration: *Total Energy, Electric Energy, and Nuclear Power Projections, United States,* Feb. 1975; and *A National Plan for Energy Research, Development and Demonstration,* ERDA-48, June 1975.

The Federal Energy Administration has prepared new projections of nuclear power growth in its 1976 National Energy Outlook. These projections are lower than previous FEA projections and significantly lower than ERDA projections of future nuclear power capacity, indicating that the ERDA projections may be unrealistically high. Thus, present enrichment capacity appears to be adequate for a longer period of time than had been anticipated. A cautionary note must be added: the lack of enrichment services could create a reduction in nuclear growth and thus be a self-fulfilling prophecy.

Foreign Market Served

A second factor of importance is the level of foreign market to be served. A change of 10 percent (from 35 percent to 45 percent or to 25 percent) in foreign demand served would result in about a 13 percent change in total demand in 1985 and subsequent years, affecting both the rate of growth in enrichment facilities and the ultimate capacity needed.

Domestic Stockpiles of Enriched Uranium

Under current expected production plans (with a 0.3 percent tails assay), ERDA expects to be able to produce 161.3 million SWU between fiscal year 1976 and fiscal year 1983. The moderate growth projections would require 72.2 million SWU for domestic and 50.2 SWU for foreign customers, leaving a potential stockpile of 56.2 million SWU. However, contractual commitments currently exceed these projections, and ERDA could be required to sell an additional 11.3 million SWU, reducing the stockpile under ERDA control to 45 million SWU. If, in addition, the anticipated feed of natural uranium is not available, recycling depleted tails will be required, and the stockpile could be further reduced to 30 to 35 million SWU.

The current ERDA stockpile is intended primarily as insurance against unforeseen events. However, if a policy decision were made to expand the stockpile to 45 to 50 million SWU (perhaps by feed purchases), then a sizable fraction of it could be used to smooth discontinuities in bringing new enrichment capacity on-line. By drawing down the stockpile during the years before new capacity were introduced and then repaying some or all from the new capacity, considerable flexibility could be obtained in timing (a possibility contemplated in various proposals made in anticipation of enactment of the Nuclear Fuel Assurance Act).

For example, a 25 million SWU stockpile could absorb incremental U.S. domestic needs for nearly 5 years, and correspondingly less if some foreign needs were met.

Based on ERDA's projection of 20 to 25 new nuclear power plants opening each year, the fuel for critical startup of these plants could use about four million SWU (about 10 percent of the stockpile). Such use of the stockpile would allow about a year's leeway in the introduction of new enrichment facilities.

Capacity

ERDA has originally suggested that 11 new plants with a capacity of 9 million SWU each would be required by the end of the century. CBO's analysis indicates that -- using ERDA's revised moderate growth projections and assuming 35 percent of foreign demand -- 9 plants would be needed, or 10 if 45 percent of foreign demand were served. Using the low projection for domestic nuclear growth and assuming service of only 25 percent of foreign demand would result in a requirement for only 5 to 6 plants by the year 2000. A decision to serve only domestic needs would suggest much smaller capacity additions: 3 to 4 plants using low or moderate growth, and only 2 additional plants if growth is assumed at the level suggested in the preferred Scenario V of ERDA's national energy plan.

To summarize, new capacity (beyond that currently planned) will be needed by 1984 or possibly later.

Several factors could delay the date on which customers would presumably be ready to receive delivery from new capacity.

- The growth in demand could be substantially less than the forecasts which form the basis for ERDA's planning.

- A decision could be made to expand the stockpile more quickly, and to utilize a part of that stockpile to provide for early commitment, thus delaying the requirement for new capacity from one to five years.

The number of new plants (each of 9 million SWU capacity) needed by the year 2000 could range from 2 to 10 depending on demand growth rates and the U.S. share of foreign markets.

APPENDIX D
PROPOSALS SUBMITTED TO ERDA

1. UEA's Proposal

For several years the U.S. Government has been considering the feasibility of joint government-industry ventures in nuclear energy, and ERDA has requested the private sector to submit expressions of interest in financing, building, owning and operating uranium enrichment facilities. In response, Uranium Enrichment Associates (UEA), a consortium of private companies with experience in the energy industry (Bechtel Corporation, Williams Corporation, and Goodyear Tire and Rubber) submitted a proposal in May 1975 to design, construct and operate an enrichment plant using gaseous diffusion technology.

UEA's proposed plant would have an annual capacity of 9 million SWU. It would begin operation in 1981, reach full production in 1983, and cost about $3.5 billion in 1976 dollars. Its current dollar cost, assuming an annual inflation rate of 7 percent, would reach $5 billion. UEA expects to finance the project with domestic (40 percent) and foreign (60 percent) capital, each with 85:15 debt-equity ratio. Because of the large amounts of capital needed and the classified nature of much of the uranium enrichment technology, UEA believes that it needs considerable support and assistance from the U.S. Government to make the project feasible.

The governmental assistance sought by UEA has been discussed at length in a report prepared by GAO for the Joint Committee on Atomic Energy.* The assistance would include (1) the supply of plant components produced by ERDA at cost; (2) a performance guarantee to be given by ERDA that the plant will operate successfully at full capacity, including replacement if necessary; (3) technical information, training of personnel, design assistance, and aid in evaluating potential suppliers, to be provided by ERDA at cost; (4) access to a maximum of 6 million SWU from the ERDA stockpile, beginning at startup and decreasing annually over a 5 year period of operation; (5) ERDA's commitment, which would expire one year after full operation, to assume -- at UEA request -- the domestic assets and liabilities of UEA and,

---

* Comptroller General of the United States. Evaluation of The Administration's Proposal for Government Assistance to Private Uranium Enrichment Groups, RED-76-36, October 31, 1975.

under certain conditions, to purchase all or part of the domestic equity; and (6) commitment by ERDA to purchase up to 6 million SWU during the first 5 years of operation.

These conditions for governmental assistance are subject to negotiation between UEA and ERDA and have not been finalized.

UEA anticipates selling 40 percent of its SWU production to domestic utilities and 60 percent to foreign customers, who may resell subject to U.S. Government approval. The foreign customers would buy in through their participation in the financing of the enterprise.

UEA wants to arrange long-term "take or pay" contracts with utilities which would under some circumstances provide for payment to UEA even in the absence of a product. The contracts would provide for full recovery of UEA's total costs of owning, financing, operating, and maintaining the enrichment project. They would also allow the establishment of a contingency reserve fund and would provide a 15 percent after-tax return on equity investment.

2. Other Proposals

In response to a request for proposal issued by ERDA on June 26, 1975, three other groups have proposed building private enrichment plants, all using the more advanced centrifuge technology. These proposals are still being evaluated by ERDA and are not available for inspection, although GAO has made public some elements in its study. These three groups (Garrett Corporation, CENTAR Associates, and Exxon Nuclear Company, Inc.) would seek government support similar to that sought by UEA.

Through a subsidiary, Texas Regional Enrichment Corporation, Garrett proposes to construct a centrifuge plant with an annual capacity of 3 million SWU. Production would begin in mid-1981 at a rate of .35 million SWU and would expand to full capacity in 1987. Garrett proposes government assistance in (1) process quarantees, (2) completion guarantees, and (3) some access to ERDA's SWU stockpile during the early years of operation. Garrett would seek foreign investment.

CENTAR Associates is a joint venture of Electro-Nucleonics, Incorporated, Nuclear Company, and Atlantic Richfield Nuclear Company. CENTAR proposes to construct a centrifuge plant with an annual capacity of 3 million SWU. Production would begin in 1981 at a rate of .27 million SWU and would expand to full capacity in 1986. CENTAR proposes (1) guarantees of the government process similar to those sought by other companies and (2) access to ERDA's SWU stockpile during the early years of operation. CENTAR proposes a 75:25 debt-equity ratio and does not anticipate foreign investment but would sell to foreign customers.

Exxon Nuclear Company, Inc. proposes to construct a centrifuge plant with an annual capacity of 3 million SWU. Production would begin in 1981-82 at an initial rate of 1 million SWU, with full production expected several years later. Exxon proposes government assistance including (1) process guarantees, (2) access to ERDA's SWU stockpile both for purchase and sale, (3) completion guarantees, and (4) the assurance that the government would cover any utility defaults. Although Exxon does not anticipate any initial foreign investment, it would sell to both domestic and foreign customers.

APPENDIX E
COMPETITION IN URANIUM ENRICHMENT

1. Competition and Economic Performance

Two criteria by which the performance of a private uranium enrichment industry could be judged are efficiency and innovation. Competition is a prerequisite of efficiency: only if an enterprise is faced with numerous competitors likely to lure away its current or prospective customers will it necessarily provide ample supplies at the minimum currently achievable cost.

The degree of competition in an industry is commonly held to depend on the number and relative size of its members, as well as other factors such as the existence of close substitutes for the products of the industry and the difficulties which a new enterprise would face in trying to enter the industry. Although a monopoly--by definition an industry with but one member--is unlikely to be established in uranium enrichment, a concentrated industry with relatively few members is a strong possibility. A common measure of concentration is the concentration ratio--the share of the market held by the largest four, eight, or twenty firms. As concentration increases, other things being equal, an industry is less likely to have performance close to the competitive norm.

No such definitive statement about the relation between competition and innovation--the process of technological advance which progressively lowers the cost of enrichment services--can be provided. Whereas a competitive environment creates greater stimulus and need for innovation to avoid falling behind one's competitors, a noncompetitive environment may create greater resources for and ability to capture the rewards of innovation. On balance, it is likely that a very concentrated industry--one containing only three or four firms--would not be conducive to rapid technical advance. In the past such industries have rarely been leaders in innovation. Much more progress has come from industries containing a moderate number of independent members, and especially from industries easily entered by an outsider who has developed a superior process.*

---

* Frederic M. Scherer, Industrial Market Structure and Performance, Chicago, 1971, pp. 277-278.

2. The Importance of the Number of Competitive Producers

The degree of competition which will face a uranium enrichment enterprise depends almost exclusively on the degree of concentration in the industry. Other factors which can make a concentrated industry behave competitively--easy entry and close substitutes for its product--are largely non-existent in the case of uranium enrichment.

a. Close Substitutes

There is no substitute for uranium enrichment in the process of producing fuel for current generation nuclear reactors. However, in the long run utilities have a choice between building nuclear or fossil fueled generating plants. If neither offers a substantial cost advantage over the other, fossil fuel could be a long-run substitute for nuclear fuel. Different authorities give widely varying estimates of the future cost of electricity generated by nuclear and fossil plants: some claim near equality while others claim a substantial advantage for nuclear. Although irrelevant to the degree of competition enrichment services will face in the near future, the degree of superiority of nuclear plants is crucial to long run competition. If nuclear power were substantially less expensive than any feasible substitute, the enrichment industry would face little external competition.

b. Ease of Entry

The number of firms actually operating in an industry is indicative of competition if no others can be expected to enter that industry whenever its actual members succeed in charging prices high enough to provide unusually large profits. If entry is relatively easy, however, even an industry with few members may behave competitively.

The difficulties (described in Chapter V) of entering the uranium enrichment industry make it unlikely that potential competition can police the behavior of a concentrated enrichment industry. The very large investment required to construct a 9 million S.W.U. plant represents a substantial barrier to entry, since only 30 manufacturing corporations have assets larger than that $4 billion total. The barrier to entry would be lower if a firm could enter by building a smaller (3 million SWU) centrifuge plant. However, if the centrifuge process dominates future growth of the industry, as is expected, an advantage to early entrants may exist. Additional capacity can be added to centrifuge plants in units about one-tenth as large as the minimum size of a new plant. Thus existing centrifuge plants could be expanded without large initial capital investments, while new entrants might be blocked out by the relatively greater difficulties of raising the $1 billion required to construct a new centrifuge plant. However, the government could continue to assist new ventures and thus help overcome the barrier of high capital costs.

c. Number of Actual Competitors

The number of ventures in the uranium enrichment industry will be restricted by the number of plants required. The fact that each venture may involve several firms is irrelevant to competition in supply of uranium enrichment: only the number of independent ventures, each of which may own one or more plants, should be counted. The size of the smallest economically efficient plant is crucial to the long-run competitiveness of the industry: if only large (9 million SWU) plants were constructed, only one-third as many plants could exist as would be the case if smaller (3 million SWU) plants were constructed. These estimates place an upper bound on the number of independent ventures in the industry, since more than one plant may be owned by a single firm.

The initial round of private construction of new enrichment capacity will probably include three or four facilities--one large diffusion plant and two or three small centrifuge plants. If there were no increase in foreign sales, and if domestic demand followed the low projection, no more capacity would be required by the year 2000. If foreign sales were to increase and domestic demand to grow more rapidly, the industry could support three more small (3 million SWU) centrifuge plants by 1990. By the year 2000 there might be 15 to 30 plants, all but one of which would be small centrifuge plants.

However, the relative ease with which centrifuge plants can be expanded--compared to the large initial investment needed to construct a new plant--suggests that successive increments to capacity would take the form of expansion of existing facilities, unless the government intervened to bring in new entrants. Under these circumstances, all plants in the industry might ultimately be quite large, perhaps 9 million SWU in annual capacity. Such an industry could support at most three independent firms by 1990, and perhaps five to ten by the year 2000. A similar industry structure would also result from continued use of diffusion technology.

No clear dividing line between a competitive and non-competitive industry can be drawn. An industry containing nine or more independent enterprises would resemble the average of U.S. manufacturing industries in terms of the share of the market held by the four largest firms. An industry with as few as three independent enterprises would be among the most concentrated of U.S. industries, and probably one of the least competitive.

3. Scope of Competition

The type of contracts-- ranging from "take or pay" to "hell or high water"*-- which some potential suppliers have proposed to potential customers would make competition impossible in the sense of one firm trying to attract to it the committed customers of another by offering better terms and thus would preclude the type of competition that gives the clearest incentive to continued efficiency and innovation.

The only competition likely to exist in the early years of the industry is in arranging contracts with potential customers prior to the construction of the first plants. Since plants may go on line with committed customers totalling only 80 to 90 percent of capacity, there may be competition for a while to "fill up order books" with additional customers. Such competition "on the margin"

---

*A "take or pay" contract requires the customer to pay for the contracted services, if they are available, whether or not delivery is taken; a "hell or high water" contract also requires the customer to make some payment--for example, to service the debt of the project--even if services are <u>not</u> made available.

can present effective incentives for efficiency and innovation, with benefits passed on to all customers under certain contract provisions regarding cost flow-through.

Initial competition for customers, prior to construction, would determine the terms on which contracts are drawn up. At that stage, there may be more potential enrichment ventures than will succeed in amassing sufficient customers to proceed to construction. Such a situation would tend to create a buyer's market and offer customers initial advantages. Currently, however, only four ventures appear interested in uranium enrichment.

These limitations on the scope of competition suggest that the industry may be even less competitive than would normally be implied by the number of firms engaged in uranium enrichment.*

4. Competition in the Total Energy Industry

If the corporations which enter the uranium enrichment industry are not among the larger corporations in the oil, gas, and coal industries, some decrease in concentration in the total energy industry will occur. If nuclear fuel actually competes with other fuels, some increase in the degree of competition in the industry can be expected. Although a government enterprise could set its prices at a competitive level and thus discipline the pricing behavior of producers of other fuels, an aggressive policy of innovation and cost-cutting could encounter substantial political opposition. A competitive private enrichment industry might be more free of restraint.

---

*However, Paul MacAvoy of the Council of Economic Advisors and Thomas Kauper, Assistant Attorney General in charge of the Justice Department's Antitrust Division, in testimony before the Joint Committee on Atomic Energy on December 3 and 4, 1975, expressed the belief that a private enrichment industry would be adequately competitive.

5. Potential Effects of Lack of Competition

Lack of competition is likely to result in a higher price for separative work than would be the case with a competitive industry. However, inefficiency results only from inappropriate customer choices in response to prices. If the price of enrichment services were to have little effect on electric utility decisions, little efficiency would be lost through inappropriate pricing.

Two factors make it appear that the response to differing enrichment charges would be relatively small:

- The design of nuclear power plants is fixed and will not change significantly in response to cost changes. Regulatory requirements and the technical objective of attaining the maximum feasible heat rate appear to dominate economic optimization.

- The cost of uranium enrichment is less than ten percent of the kilowatt-hour cost of electricity. Hence, a 90 percent change in the cost of separative work would alter the cost of electricity by only five percent, and the demand for separative work derived from the demand for electricity will be insensitive to small changes in price. On the other hand, if fossil fueled and nuclear fueled power plants can generate electricity at roughly equal cost per kilowatt/hour when enrichment services are sold at competitive market prices, inappropriate pricing of separative work could lead to inefficiency by biasing the choice of electric utilities to the less desirable type of plant.

If an alternative to nuclear power with nearly the same cost per kilowatt-hour exists, the ability of uranium enrichers to raise prices would be limited, in the long run, by the tendency of electric utilities to eschew nuclear power in favor of the alternative. There would be a cost in efficiency, however, due to the choice by utilities of an alternative inferior in terms of real cost. If no close alternative existed, utilities would continue to use nuclear power even if the price of enrichment services were increased. In this case the loss in economic efficiency could be small, but simultaneously substantial sums could be transferred from electricity consumers to uranium enrichers. Current disagreement about the relative cost of power from new nuclear and fossil plants makes it difficult to decide which outcome would occur.

APPENDIX F
CAPITAL NEEDS FOR PRIVATE DEVELOPMENT

The purpose of this discussion is to consider the need for equity capital in a representative proposal for private construction of an uranium enrichment plant using the gaseous diffusion process.

This analysis is based on several assumptions about cost and financing, and calculations use data supplied by Uranium Enrichment Associates. The total net cost of the plant is estimated at $3.2 billion in 1975 dollars. Of this amount, we assume $2.5 billion could be borrowed without subjecting the builder to personal liability beyond loss of the plant. The balance would be raised from capital contributions ($320 million, not including a $100 million cash reserve) and from operations ($380) which would commence in the seventh year of construction but which would not reach full operation until the tenth year. Also, to illustrate a variable, we have assumed that as much as 60 percent of the capital and product might be committed by and to foreign interests.

There are also several assumptions about the legal structure of the organization. Since a partnership passes its tax attributes through to its partners, and since there are substantial tax benefits during the construction period, a partnership probably would be created to construct and hold the plant until construction terminated in the ninth year.

Estimates of cash costs and the deductibility of expenses are as follows (in millions of dollars):

Years	Total Payments	Deductible Portion	Capital Portion
1-6	1,659	235	1,424
7-9	1,544	(125)[a]	1,316

a - Indicates estimated net income in excess of deductible costs. This amount probably overstates the taxable income.

Analysis

This analysis is based on current tax law or reasonably probable alternatives. No special tax provision or incentive is anticipated.

Two variables complicate the analysis. First, the rate and timing of the investment tax credit are uncertain. The rate is now 10 percent but is due to fall to 7 percent at the end of the year. Most observers, including Chairman Al Ullman of the House Ways and Means Committee, believe that the 10 percent rate will be permanently extended. The timing is affected by a provision added in 1975 which ultimately will allow the credit to be obtained for the full amount of progress payments under long-term construction contracts as they are made rather than being delayed until operations commence. That provision is, however, being "phased-in" and, until 1979, the credit for progress payments is only partial. Thus, the amount and timing of the credit for construction progress payments are not clear. Reasonable assumptions are that the entire capital cost of the plant would be eligible for the credit, that the life would be in excess of 7 years and the full credit would be allowable, and the credit would be entirely allowable during the construction period as progress payments were made or as carry-overs.*

---

*. The amount of the credit is determined by multiplying the credit rate by the "eligible investment." This latter term is one-third of qualified costs if the property is expected to be kept (i.e., its life) for more than three but less than five years; two-thirds if the life is more than five but less than seven years; and all of the cost if the life is more than seven years. If the property is not retained for the life on which the eligible investment was computed, there is a "recapture" (a repayment to the government) of the amount by which the credit taken exceeds the amount which would have been allowable if the period for which the property was held had been used in computing the eligible investment. The holding period for construction progress payments begins when the property is placed in service. For prior progress payment in the assumed case, that would seem to be when operations commence in the seventh year. Depending on the circumstances, the government's assumption of the builder's or operator's responsibilities might be a disposition resulting in "recapture" to the extent that progress payment property had not been held seven years.

The second variable that makes calculations uncertain is treatment of foreign interests that may participate. Foreign participants would likely not be able to utilize the tax credits and deductions. These tax attributes would have substantial value to domestic investors, however. Thus, the organization probably would be structured so as to confer all of the tax attributes on the U.S. participants. Indeed, any other structuring would waste these valuable tax attributes.

For example, the tax deductions and credits discussed here are attributable to "owners." Since the partnership would be the "owner," tax credits and deductions are allowable to it and through it to its partners. The partnership agreement could allocate them to the partners. The sole constraint would be that the allocation not have as a principal purpose the avoidance or evasion of tax. Thus, if U.S. interests were the general partners, and if foreign interests supplied their contributions as debt, only the U.S. participants would be entitled to the tax credits and deductions. A ruling from the Internal Revenue Service on the allocation would probably be sought and obtained.*

These variables, the rate and timing of the credit and the amount of tax attributes which would be claimed by U.S. participants, are combined to make two cases. The first assumes a 7 percent credit with the U.S. participants claiming only a proportionate part of the tax attributes. It states the highest amount of capital contributions. The other assumes a 10 percent credit and assumes that U.S. interests would receive all the tax benefits during construction. This case then results in far smaller capital contributions.

---

*. In reviewing an earlier draft of this report, UEA stated that "the portion of ITC (investment tax credit) ascribable to non-U.S. participants was not expected to be used" by that venture, and that "tax credits taken after incorporation would be passed through to the benefit of utility customers", thus implying an approach close to that of Case 1.

Case 1 - During the first six years, the investment credit at 7 percent would amount to $100 million and the construction period deductibles would be $235 million which would confer a tax savings of $113 million when applied against income which would otherwise be taxed at a marginal rate of 48 percent.*

The next three years (years 7-9) would result in an investment credit of $90 million, making the cumulative nine-year total $190 million. Construction period deductibles during the last three years should be at least $254 million. However, some $379 million of cash income is expected during this period if operations start as planned. The net of the deductibles and the expected cash income could leave a balance of $125 million** which, if taxed at a 48 percent corporate rate, would result in a $60 million tax liability. This liability would be offset by the investment tax credit to the extent of $90 million, leaving a net tax benefit of $30 million.***

---

*. The maximum tax rate on corporate income is now 48 percent. The President proposes to reduce it 46 percent.

**. This amount probably exceeds taxable income, but it is used here for lack of other data and to present the case which would yield the highest tax liability.

***. This analysis treats the last three years as a single period. In fact, the tax benefits of the first two of those three years would be substantially in excess of tax liabilities.

Given the first set of assumptions and allocating only 40 percent of the tax benefits to the U.S. interest, the financial and tax attributes realized during the construction period could appear as follows (in millions of dollars):

	Total	Foreign Interests 60%	U.S. Interests 40%
Capital contribution (net of cash reserve)	$320	$192	$128
Tax benefits (first six years):			
Investment Tax Credit	$100	$ 60	$40
Construction period deductibles (40% of $235 cumulative deductions)	113	68	45
Tax attributes (years 6-9)			
Income tax on net income (income less construction period deductibles)	(60)	(36)	(24)
Investment Tax Credit	90	54	36
Total Tax Benefits	$243	$146	$ 97
Capital Contribution Reduced by net tax benefits	$ 77	$ 46	$ 31

Since the tax expenditures might not be utilized by the foreign investors, the equity requirements for foreign interests would not be reduced in the fashion shown above but would remain at $192 million.

Case 2 - If the second set of assumptions operate, then the investment credit will be at 10 percent and the domestic interests will find a way of allocating all tax attributes to them. The picture would be as follows (in millions of dollars):

	U.S. Interests 100%
Capital Contributions - No Change	$128
Tax Benefits (first six years)	
Investment Tax Credit	$143
Construction Period Deductibles	113
Tax Attributes (years 6-9)	
Income tax on net income (income less construction period deductibles)	(60)
Investment Tax Credit	132
Total Tax Benefits	$328
Capital contributions reduced by net tax benefits	($200)

If this optimistic set of assumptions were to be realized, the tax benefits available to U.S. interests would exceed the capital contributions. There would be capital from the retained earnings which were used to defray construction costs.

Probably neither set of assumptions would be proven entirely accurate. Much would depend on matters to be negotiated in the future. Reasonable assumptions, however, demonstrate that the capital contributions would be greatly reduced by tax benefits. The contribution by U.S. participants (based on 40 percent participation could reach $31 million (if they were to realize only a proportionate share of tax attributes and the investment tax credit were 7 percent) or be a negative of $200 million (if the investment tax credit were 10 percent and all tax attributes were allocated to U.S. participants.

These tax benefits are not unusual. They are available for any similar investment. They do, however, lower considerably the amount of risk.

APPENDIX G
Royalties, Tax Receipts and Enrichment Revenues
For Three Major Ownership Options
(millions of constant dollars)

Year	ALL PRIVATE Tax Receipts	ALL PRIVATE Royalties	ALL GOVERNMENT Enrichment Revenues	MIXED OWNERSHIP Tax Receipts	MIXED OWNERSHIP Royalties	MIXED OWNERSHIP Enrichment Revenues
1977			-90			-70
1978	-10		-260			-170
1979	-30		-260	-10		-190
1980	-50		-410	-20		-290
1981	-120		-860	-40		-500
1982	-220		-1270	-100		-630
1983	-280		-2220	-160		-910
1984	-250	10	-2730	-230		-840
1985	-130	20	-2680	-170		-200
1986	-80	20	-1670	-180	10	280
1987	-50	50	-730	-150	25	410
1988	-50	50	340	-150	25	560
1989	40	75	790	-60	50	600
1990	230	100	2230	130	75	610
1991	450	100	3750	350	85	610
1992	570	125	4360	470	100	610
1993	600	150	4890	500	125	610
1994	600	150	5000	500	125	610
1995	600	150	5000	500	125	610
1996	600	150	5000	500	125	610
1997	600	150	5000	500	125	610
1998	600	150	5000	500	125	610
1999	600	150	5000	500	125	610
2000	600	150	5000	500	125	610