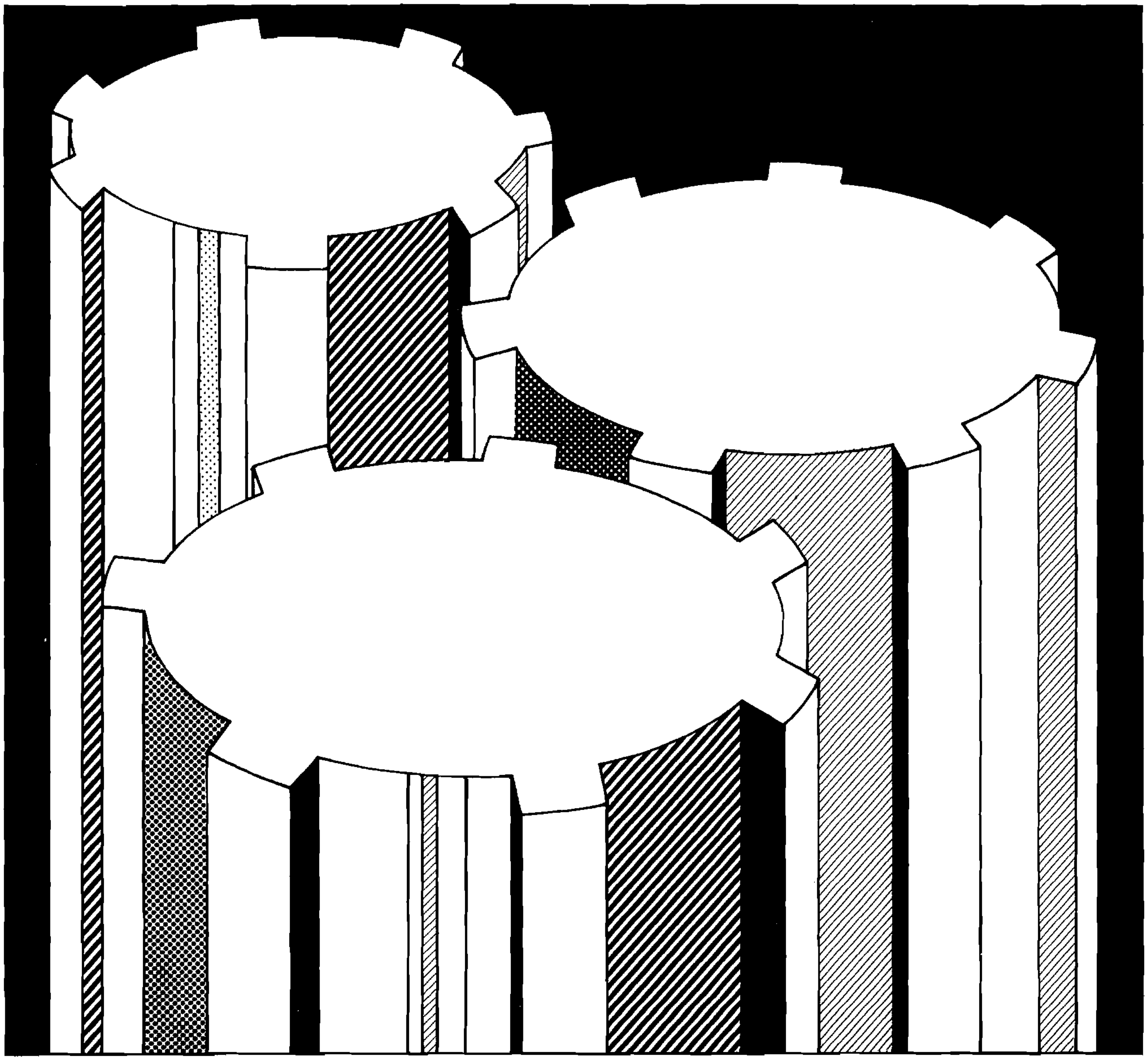
CONGRESS OF THE UNITED STATES
CONGRESSIONAL BUDGET OFFICE

OCTOBER 1985

U.S. Uranium Enrichment: Options for a Competitive Program



CBO STUDY

U.S. URANIUM ENRICHMENT:
OPTIONS FOR A COMPETITIVE PROGRAM

The Congress of the United States
Congressional Budget Office

NOTE

All costs and projected prices are in fiscal year 1986 dollars, unless otherwise noted.

PREFACE

The federal government provides uranium enrichment services to both domestic and foreign commercial nuclear utilities and to U.S. national defense programs. Enriched uranium is the fuel used by most nuclear power reactors to generate electricity. Once able to monopolize the world enrichment market, the United States has lost a large share of its business to European suppliers, who offer more competitive contract terms and prices than does the U.S. Department of Energy (DOE), which manages the program. Currently, the DOE is trying to become more competitive by lowering enrichment prices and investing in more efficient technology. At the same time, however, it faces increased pressure to reduce program spending and to repay past investment costs, which may keep prices high or delay the introduction of advanced enrichment capacity.

To evaluate the trade-offs between achieving a more competitive federal enrichment program and maximizing net program receipts over the next decade, the Congressional Budget Office analyzed alternative pricing and investment options. Don Fuqua, Chairman of the House Committee on Science and Technology, requested the study. In keeping with CBO's mandate to provide objective analysis, the paper offers no recommendations.

Mollie V. Quasebarth, of CBO's Natural Resources and Commerce Division, wrote this report under the supervision of David L. Bodde, Everett M. Ehrlich, and John B. Thomasian. The author thanks Gene Schmitt and Howard Huie of the Department of Energy for their cooperation and contributions, as well as Warren Donnelly of the Congressional Research Service, Kathy Gramp of CBO, and Mary Spaeth of the Lawrence Livermore National Laboratory. Patricia H. Johnston edited the paper, which was typed and prepared for publication by Patricia M. Joy.

Rudolph G. Penner
Director

October 1985

CONTENTS

SUMMARY

The U.S. government operates a uranium enrichment service that provides nuclear fuel to both domestic and foreign civilian reactors, as well as to U.S. national defense programs. In reviewing this program, the Congress faces the difficult task of balancing competing goals. The United States could best achieve the goal of improving its position as a major world enrichment supplier with lower, more competitive prices, but this might require net federal spending over the next decade. Alternatively, the current pricing policy would provide high net revenues for the federal program in the short term, thus reducing the need for additional net federal spending, but it would also maintain high, uncompetitive U.S. prices and probably further erode the U.S. share of the world enrichment market.

This report examines alternative pricing and investment policies for the U.S. enrichment program, their effects on U.S. enrichment sales in the world market, and their budgetary implications. As the report points out, no one pricing policy can effectively achieve the two, sometimes divergent, objectives of the U.S. enrichment program.

BENEFITS OF A MORE COMPETITIVE U.S. ENRICHMENT PROGRAM

Into the 1970s, U.S. leadership in nuclear power technologies strongly influenced the development and uses of nuclear power by other countries. It also helped to create the combination of treaties, voluntary agreements, and inspections that are relied on today to keep civilian use of nuclear power well-separated from nuclear weapons capabilities. U.S. influence in the world nuclear cycle has declined, however, as other countries have become nuclear suppliers and have begun to undercut U.S. enrichment prices.

These other nations invested in uranium enrichment facilities primarily to increase their energy independence and to assure a continued supply of nuclear fuel for their civilian nuclear power programs. Many of these investments were planned in view of optimistic projections of nuclear power growth and uncertainty over the reliability of U.S. enrichment services. (In 1974, the United States temporarily stopped accepting any new orders for enrichment contracts as a result of projected capacity limitations.) Moreover, many nations were uncomfortable with the restrictions on nuclear fuel use that were enforced through U.S. enrichment contracts.

These developments raise a central question for U.S. policy: to what extent is U.S. national interest served by preserving some influence over nuclear supplies, particularly the supply of enrichment services? It has been suggested that the United States should offer more competitive enrichment pricing for two related reasons: first, to discourage other countries from building their own enrichment plants; and second, to stop the decline of U.S. influence over policies of other countries regarding their nuclear energy programs and their nuclear exports.

Furthermore, a more competitive U.S. pricing policy should increase U.S. enrichment sales, and thus program revenues, particularly during the 1990s and beyond. While such a pricing strategy might reduce net program revenues in the short term, it would probably have a positive budgetary impact over the long term. It could, therefore, eventually allow greater recovery of both past and future federal program investments.

THE WORLD ENRICHMENT MARKET

The dominant characteristic of today's world enrichment market is oversupply, in terms of both capacity to produce separative work units (SWUs) and stockpiles of enriched uranium. (The separative work unit measures the amount of energy that is required to enrich uranium from its natural state of 0.7 percent of the fissionable U-235 isotope to about 3 percent, so that it is usable as power reactor fuel.) The four major suppliers--the United States, Eurodif, Urenco, and the Soviet Union--have a combined annual capacity of 43 million SWUs. (Eurodif and Urenco are European consortiums that produce enriched uranium for domestic and world markets.) In addition, almost 29 million SWUs of excess inventory are now available at prices below the current contract prices offered by the major enrichment suppliers. By contrast, current demand is about 22 million SWUs, and is projected to increase to roughly 33 million SWUs by 1995, suggesting continued long-run overcapacity.

Implications of Overcapacity

With global overcapacity now a reality, the large fixed costs of the enrichment plants provide a strong incentive for producers to retain or expand their share of the market. Thus, price competition is likely to be severe, and many segments of the market, already committed to foreign suppliers, appear unlikely customers for U.S. enrichment at any price.

Nevertheless, it is estimated that about 20 percent of projected annual free world demand--some 5 million to 7 million SWUs per year between 1990 and 2000--is potentially available to the United States in additional enrichment sales if its prices are competitive. This estimate is composed mostly of currently uncommitted demand in Japan, Korea, Switzerland, and Yugoslavia. Some domestic utilities, however, have recently contracted for foreign enrichment supplies, suggesting that this domestic market of 10 million to 12 million SWUs per year is also price sensitive.

PRICE COMPETITION AMONG THE WORLD ENRICHMENT SUPPLIERS

The price structure of the major competitors is an important factor in evaluating the competitive position of the U.S. enrichment program. Eurodif currently charges about $115 per SWU. Urenco, which uses a more efficient enrichment technology, charges about $90. (There are reports that both these suppliers have offered contracts recently for as low as $80 per SWU.) The fiscal year 1985 U.S. price is $135 per SWU.

According to the Department of Energy (DOE), which operates the federal enrichment program, these same competitors could lower production costs, if Eurodif introduces the laser enrichment technology and if Urenco deploys advanced centrifuges. With lower production costs, their prices could drop to $60 and $70 per SWU by the year 2000. Taken together, these prices can be thought of as establishing a range within which the U.S. enterprise must compete if it is to retain or expand its share of the price-sensitive market.

This competitive price range, which is based on likely production costs in the future, however, must be viewed with an important uncertainty in mind: a world market characterized by high fixed costs and strong price competition could lead producers to cut their prices to levels approaching out-of-pocket operating cost, rather than lose market shares. This could push actual prices below the ranges currently projected, perhaps even to a level that would make full cost recovery impossible for any supplier.

INVESTMENT OPTIONS FOR U.S. ENRICHMENT PROGRAM

The DOE must choose between two investment options: rely on the current technology, making no new capital investment; or further develop and deploy the Advanced Vapor Laser Isotope Separation (AVLIS) technology.

The DOE's current enrichment capacity consists of three gaseous diffusion plants (GDP) built in the 1950s to meet the enriched uranium requirements of the U.S. military program. These plants provide more than enough capacity to meet DOE's projected commercial and military enrichment demand through the year 2000. The gaseous diffusion process requires large amounts of electricity, however, resulting in very high operating costs.

On the other hand, in June 1985, the DOE selected the AVLIS process for further development, demonstration, and potential deployment. (Both this technology and the Advanced Gas Centrifuge (AGC) process were judged to be similarly efficient, but the AVLIS process has much lower capital costs and is more adaptable to small scale deployment as needed to meet the future demand requirements of the enrichment program.) If the DOE eventually deployed the AVLIS process, operating costs would drop dramatically. It would entail a large capital investment, however, which might require additional net federal spending in the next decade since current revenue projections would not fully cover these outlays. The two technology programs are summarized in Summary Table 1.

PRICING OPTIONS AND PROJECTIONS FOR U.S. ENRICHMENT

In addition to investment policy, pricing strategy is the other key factor in determining which program goals will be achieved. This report evaluates

SUMMARY TABLE 1. TECHNOLOGY PROGRAM OPTIONS

GDP-Only a/	AVLIS/GDP b/
The DOE would operate two diffusion plants through 1991, keeping the Oak Ridge, Tennessee, plant in standby status. It would be reopened in 1992 to meet higher production requirements. All future AVLIS development plants would be abandoned.	An AVLIS plant would begin operation in 1995, at a rate of 1 million SWU. Production would reach maximum capacity of 9.8 million SWU per year in 1999. Two GDP facilities would remain in operation.

SOURCE: Congressional Budget Office.

a. Gaseous Diffusion Plants.

b. Atomic Vapor Laser Isotope Separation.

the pricing and budgetary effects of current policy and three pricing options. Pricing and investment options must be analyzed together to estimate U.S. competitiveness in the world enrichment market and budgetary consequences under alternative program strategies.

Option I--Current Pricing Based on Full Cost Recovery

The DOE calculates its annual enrichment price by summing the next ten years' estimated operating costs, capital depreciation charges, and interest costs on unrecovered government investment. This sum is then divided by the amount of SWUs to be sold over that period. Thus, DOE's operating costs are recovered over 10 years and capital investment over 25 to 37 years, depending on the depreciation schedules for individual facilities.

Price Projections. U.S. enrichment prices under the current pricing strategy would not be competitive under either technology program. The price paths for the two investment programs are superimposed over the projected range of world market prices in Summary Figure 1. Although prices would be below those of Eurodif in the short term, most of the potential market responses to future DOE prices will occur in the mid-1990s and beyond, when U.S. prices would be higher than both the European suppliers under this option.

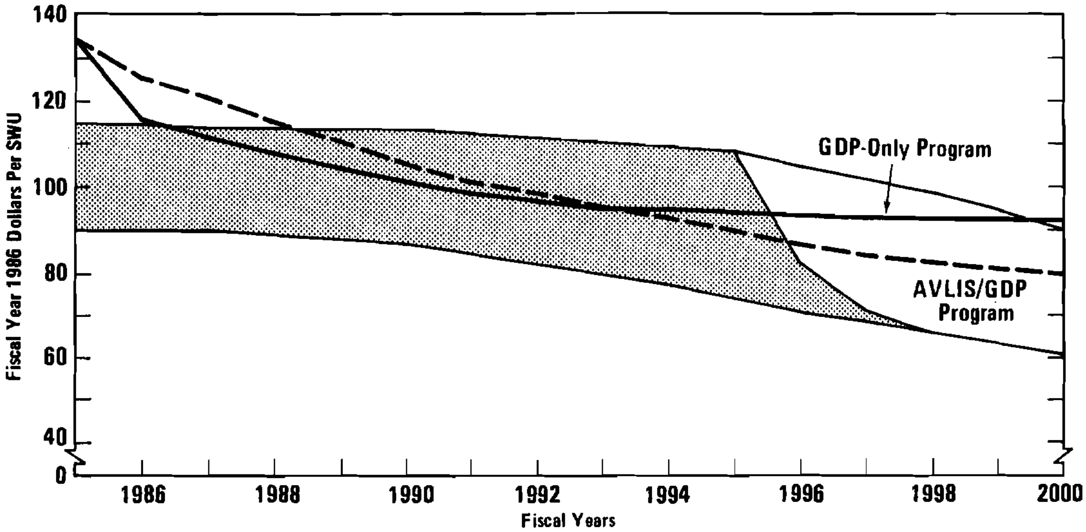
A decision to make no new investment but to continue to rely only on the current gaseous diffusion plants would allow the constant dollar SWU price to drop from the fiscal year 1985 price of $135 to about $93 by the mid-1990s, with little further decline after that (see Summary Table 2). Prices under the AVLIS program would be lower in the long term--about $80 per SWU by the year 2000--but would still not achieve a competitive U.S. position. (All pricing and budgetary projections reflect the technology cost and deployment schedules used to evaluate the economic and technologic merits of the alternative enrichment technologies for the June 1985 technology selection decision.)

Option II--Current Pricing with Reduced Interest Rate

Currently, the DOE charges an interest rate of 10.5 percent on unrecovered federal investment. This rate, based on a combined nominal Treasury rate, is considerably above the historical cost of long-term government borrowing of 2 percent to 3 percent. In recent years, that rate has been unusually high and volatile. Assuming more normal circumstances in the future, however, a real rate averaging 5 percent would be closer to long-term borrowing costs.

Summary Figure 1.

Prices Under Option I

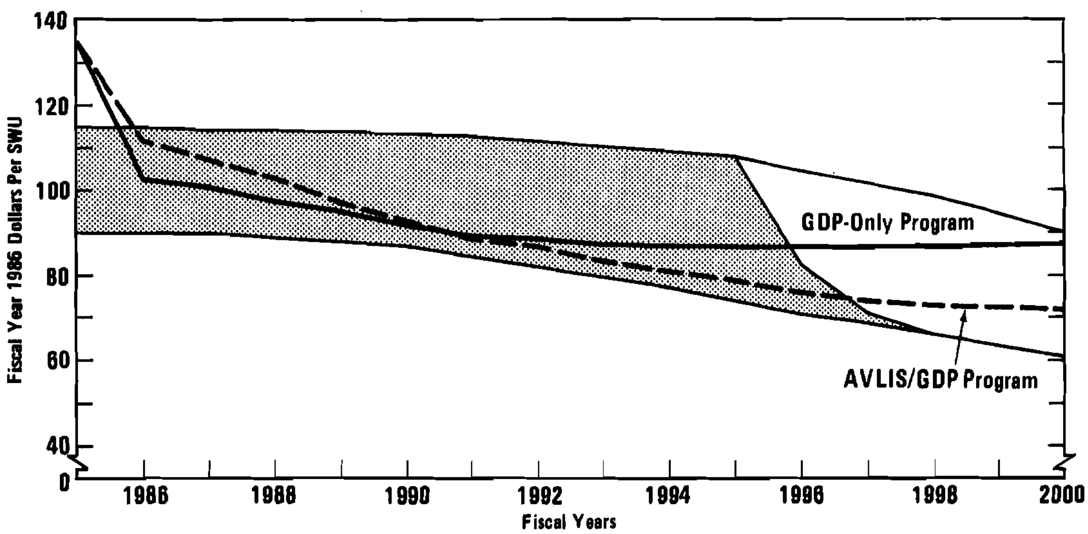


SOURCE: Congressional Budget Office.

NOTE: The shaded area represents the range of projected Eurodif and Urenco prices, based on their projected production costs.

Summary Figure 2.

Prices Under Option II



SOURCE: Congressional Budget Office.

NOTE: The shaded area represents the range of projected Eurodif and Urenco prices, based on their projected production costs.

Price Projections. By reducing the interest rate used to calculate annual enrichment prices, U.S. prices would drop significantly, compared with the current pricing strategy. Assuming that the DOE deploys an AVLIS plant in 1995, prices would fall below $80 per SWU by the mid-1990s, allowing for fairly competitive U.S. prices on the world market (see Summary Figure 2). (Beyond the late 1990s, the DOE might have to deploy additional AVLIS capacity to replace GDP production, if it was to remain competitive.) While prices under the GDP-only program also would decline--to about $87 per SWU by 1993--this program would not provide competitive U.S. prices in the long term.

SUMMARY TABLE 2. PRICE PROJECTIONS UNDER ALTERNATIVE PRICING AND INVESTMENT OPTIONS (By fiscal year, in fiscal year 1986 dollars per SWU)

	Program Technology Option	
Pricing Policy	GDP-Only	AVLIS/GDP
Option I--Current Pricing		
1990	101	106
1995	94	90
2000	92	80
Option II--Revised Current Pricing		
1990	92	93
1995	87	79
2000	87	72
Option III--Marginal Cost Pricing		
1990	76	77
1995	75	67
2000	79	63
Option IV--Two-Phased Pricing		
1990	NA a/	135
1995	NA a/	65
2000	NA a/	62

SOURCE: Congressional Budget Office.

NOTE: These prices reflect DOE's latest demand projections based on its current contracts, and do not account for potential market responses to DOE's prices.
NA = not applicable.

a. Option IV asssumed that the AVLIS program would be pursued to enable DOE prices to be very competitive in the long term.

Option III--Marginal Cost Pricing

This option would forgive the program's outstanding $4.5 billion undepreciated investment in the gaseous diffusion and AGC technologies. The DOE would set prices according to its long-run marginal costs, including recovery of all operating costs and capital outlays after fiscal year 1984. All future investment would be charged interest at an annual rate of 5 percent.

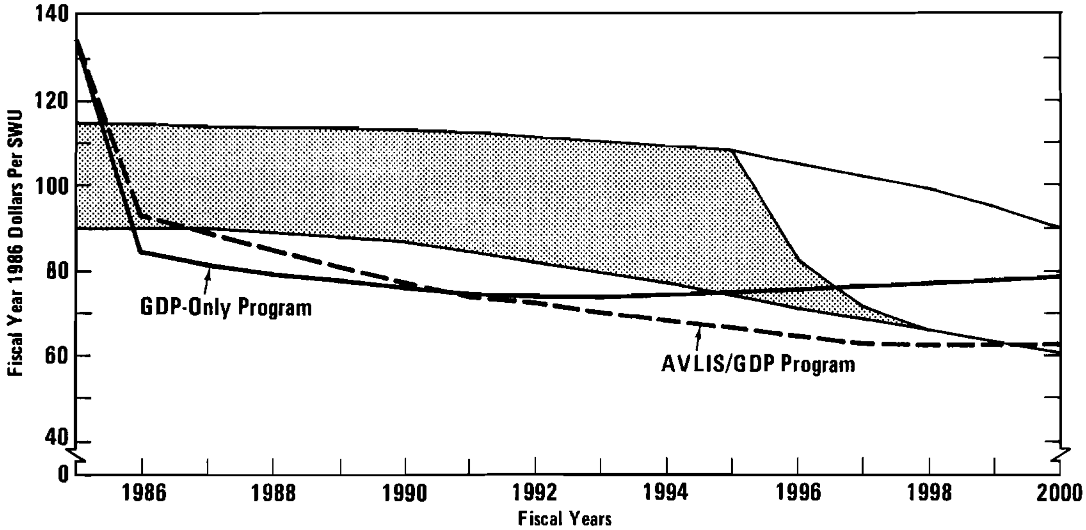
Price Projections. A pricing strategy based on marginal cost pricing would yield the lowest price of any option, since depreciation and interest charges for past capital investments would be eliminated. Both the GDP-only and the AVLIS program prices would be well below the competitive range in the short term, reaching a constant dollar SWU price of $74 by 1991 (see Summary Figure 3). The competitive price position of the GDP-only program, however, would begin to deteriorate, especially beyond 1995. By contrast, the AVLIS program should enable the DOE to remain a competitive world supplier in the long term, especially if additional AVLIS capacity is eventually deployed.

Option IV--Two-Phased Pricing Structure to Increase Short-Term Revenues and Long-Term Competitiveness

This option would charge DOE's maximum ceiling price of $135 per SWU through 1991, after which most current customers would be free to terminate their contracts with little penalty. This price would maximize DOE's net revenues over this period. From 1992 on, assuming deployment of AVLIS so as to lower operating costs dramatically, prices would be based on marginal costs, thus dropping significantly to enable the DOE to be very competitive in the long term. The effects on market demand of maintaining the high $135 price into the 1990s are uncertain, however. (This option was not evaluated for the GDP-only program because, although this would maximize net program revenues through 1991, U.S. prices would not be competitive in the long term, and the U.S. market share would probably decline significantly during the 1990s.)

Price Projections. This two-phased pricing option would keep U.S. prices well above those offered on the world market until 1991, but would make them very competitive beyond that time (see Summary Figure 4). These prices, which assume the deployment of an AVLIS plant in 1995, should fall to $65 per SWU by the mid-1990s, thereby probably increasing the level of DOE enrichment sales in the long term. Many current DOE customers might terminate their contracts in the early 1990s, however, in response to being

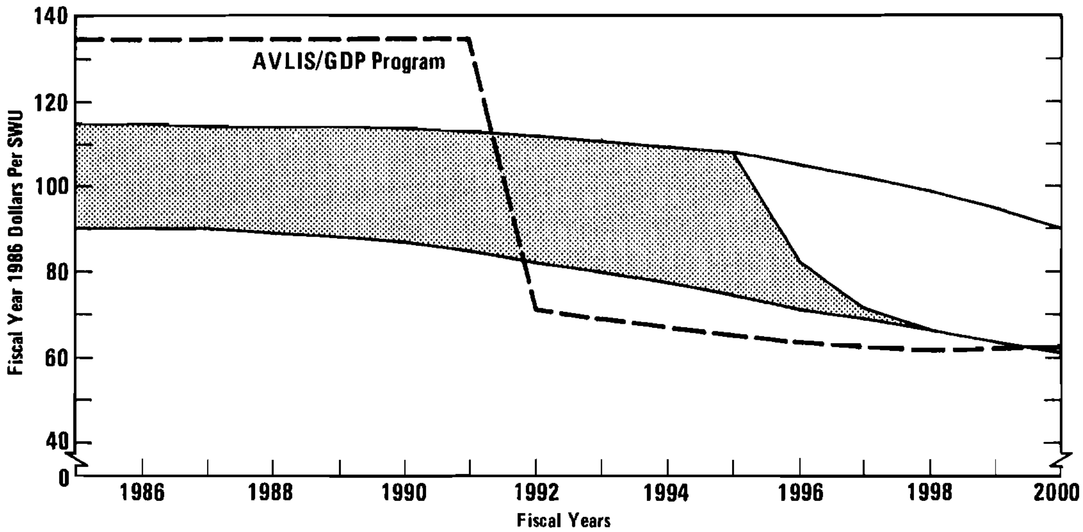
Summary Figure 3.
Prices Under Option III



SOURCE: Congressional Budget Office.

NOTE: The shaded area represents the range of projected Eurodif and Urenco prices, based on their projected production costs.

Summary Figure 4.
Prices Under Option IV



SOURCE: Congressional Budget Office.

NOTE: The shaded area represents the range of projected Eurodif and Urenco prices, based on their projected production costs.

charged the artificially high $135 ceiling price through 1991. It is uncertain whether these customers would re-sign U.S. contracts when the DOE lowered its prices.

BUDGETARY PROJECTIONS FOR THE U.S. ENRICHMENT PROGRAM

The uranium enrichment program could contribute a small amount to deficit reduction in the next decade by maintaining high prices and by reducing program outlays through postponing or cancelling the AVLIS program. Alternatively, lowering prices and introducing AVLIS would allow the DOE to compete more successfully on the world enrichment market, with the likelihood of increasing net federal program receipts in the long term. Annual net receipts--the difference between program receipts and outlays--are a measure of the program's effect on the federal budget. A negative cash flow balance would indicate additional net federal spending, while positive net receipts could be used to repay the program's unrecovered investments to the Treasury, thereby reducing the deficit.

In general, the current pricing policy (Option I) under the GDP-only program would provide the largest net revenues both in the short term (through the year 2000) and over the 1985 to 2020 period. If the DOE adopted Options II or III and deployed AVLIS, however, it should increase its level of sales because of lower prices, thereby resulting in higher annual net program receipts after the late 1990s. Thus, in the very long term (beyond the year 2020), the DOE would probably achieve larger budgetary benefits under these alternative pricing strategies.

Through the year 2000, total discounted net receipts should be roughly $2.9 billion under Option I, for the GDP-only program, assuming no loss in DOE sales as a result of these relatively uncompetitive prices (see Summary Table 3). Under Options II and III, with AVLIS deployment, the program would require additional net spending of $0.02 billion and $2.0 billion, respectively, even assuming higher SWU sales resulting from the more competitive U.S. prices. Option IV would earn net revenues of $0.6 billion over this period, assuming the DOE base-case demand schedule, which reflects projections of current contract sales.

If price competitiveness and long-term budgetary effects of the program were emphasized, it might be necessary to deploy AVLIS and alter the current pricing structure to become a competitive world supplier. Summary Table 4 presents discounted net revenues for the different program strategies both over the long term (1985 through 2020) and over the 2001 through 2020 period.

SUMMARY TABLE 3. SHORT-TERM NET RECEIPTS OF THE ENRICHMENT PROGRAM UNDER FOUR PRICING OPTIONS AND TWO INVESTMENT STRATEGIES, FISCAL YEARS 1985-2000 (In millions of discounted fiscal year 1986 dollars)

	Investment Strategy	
Pricing Policy/ Market Scenario	GDP-Only	AVLIS/ GDP
Option I		
Base-case demand a/	2,910	1,335
Moderate market loss	2,740	950
Option II		
Base-case demand a/	1,755	-291 b/
Moderate market gain	NA c/	-19 b/
Option III		
Base-case demand a/	-168 b/	-2,169 b/
Very favorable market gain	NA c/	-1,970 b/
Option IV		
Base-case demand a/	NA d/	645
Market loss in 1990s, market gain thereafter	NA d/	304

SOURCE: Congressional Budget Office.

NOTES: NA = not applicable.

Discounting is a way to calculate, in today's dollars, the value of a future expenditure or future stream of annual expenditures. The result is called present value. A future expenditure is discounted to its present value using the following formula:

$$\text{Present Value} = \text{Future Value}/(1 + i)^n,$$

where n = the number of years between the present year and the year in which the expenditure is made, and i = the discount rate. The cash-flow estimates assume an annual discount rate of 5 percent in real terms.

a. The DOE base-case demand schedule reflects projections of current contract sales.

b. Negative program cash flows represent discounted net federal spending requirements.

c. Market response scenarios were not developed for the GDP-only program under Options II and III, in which prices would be competitive in the short-term, but not beyond the mid-1990s. Most likely, net program revenues would be lower than those assumed under the base-case demand schedule, since any significant market response should occur after the mid-1990s, when the DOE enrichment sales probably would fall.

d. Option IV assumed that the AVLIS program would be pursued to enable DOE prices to be very competitive in the long term. If Option IV were adopted while continuing to rely on the GDP-only capacity, net program revenues would be maximized through 1991 ($2,551 million). But over the 1985 through 2000 period, net receipts would be $2,874 million, assuming the base-case demand schedule, less than those projected for the GDP-only program under Option I. Furthermore, actual net revenues would probably be significantly smaller because of contract cancellations in the 1990s resulting from the high $135 charge through 1991.

SUMMARY TABLE 4. LONG-TERM NET RECEIPTS OF THE ENRICHMENT PROGRAM UNDER FOUR PRICING OPTIONS AND TWO INVESTMENT STRATEGIES, FISCAL YEARS 1985-2020 (In millions of discounted fiscal year 1986 dollars)

	Investment Strategy			
	1985-2020		2001-2020 a/	
Pricing Policy Market Scenario	GDP- Only	AVLIS/ GDP	GDP- Only	AVLIS/ GDP
Option I				
Base-case demand b/	4,261	3,370	1,351	2,035
Moderate market loss	3,179	2,351	709	1,401
Option II				
Base-case demand b/	2,736	1,084	981	1,375
Moderate market gain	NA c/	2,587	NA c/	2,606
Option III				
Base-case demand b/	395	-1,058 d/	563	1,111
Very favorable market gain	NA c/	-294 d/	NA c/	1,676
Option IV				
Base-case demand b/	NA e/	1,662	NA e/	1,017
Market loss in 1990s, market gain thereafter	NA e/	1,936	NA e/	1,632

SOURCE: Congressional Budget Office.

NOTES: NA = not applicable.

Discounting is a way to calculate, in today's dollars, the value of a future expenditure or future stream of annual expenditures. The result is called present value. A future expenditure is discounted to its present value using the following formula:

$$\text{Present Value} = \text{Future Value}/(1 + i)^n,$$

where n = the number of years between the present year and the year in which the expenditure is made, and i = the discount rate. The cash flow estimates assume an annual discount rate of 5 percent in real terms.

a. Net revenues over the 2001 through 2020 period are broken out to show the likely budgetary advantage of pursuing more competitive prices in the long run, which are not clearly evident when examining the net revenue projections over the entire 1985 through 2020 period.

b. The DOE base-case demand schedule reflects projections of current contract sales.

c. Market response scenarios were not developed for the GDP-only program under Options II and III, in which prices would be competitive in the short-term, but not beyond the mid-1990s. Net program receipts probably would be lower than those assumed under the base-case demand schedule, since any significant market response should occur after the mid-1990s, when the DOE likely would see a drop in its enrichment sales.

d. Negative program cash flows represent discounted net federal spending requirements.

e. Option IV assumed that the AVLIS program would be pursued to enable DOE prices to be very competitive in the long term. If Option IV were adopted while continuing to rely on the GDP-only capacity, long-term prices would not be competitive, and U.S. enrichment sales would probably be lower than those assumed in the moderate market loss scenario. In the long term, net revenues for this program would be lower than those under Option I, assuming the GDP-only program.

Through the year 2020, Option I under the GDP-only program would still achieve the largest cash balance (about $3.2 billion), even assuming a drop in U.S. enrichment sales. Assuming that AVLIS is deployed, Option II would result in a slightly smaller program cash flow (about $2.6 billion) over this period. Options III and IV would achieve considerably smaller net revenues, even if associated increases in sales are assumed.

To assess the full merits of pursuing more competitive prices (and thus the AVLIS program) in the long term, however, one must consider program net receipts during the 2001 through 2020 period. Over this time frame, the DOE would realize the largest budgetary benefits by adopting Option II or III ($2.6 billion or $1.7 billion), assuming the increased sales projected for these options under the AVLIS program. On the other hand, the GDP-only program would achieve much lower net revenues in these years under any pricing option. Thus, if the period of analysis were extended beyond 2020, the AVLIS program under Option II probably would achieve the largest net program revenues and allow for the greatest recovery of past and future program investments.

Option III would provide the most competitive prices and probably achieve the largest world market share for the U.S. enrichment program. The higher sales, however, probably would not offset the very low SWU prices that would be charged, and thus the overall net proceeds of this alternative would be smaller than the Option II pricing strategy.

CHAPTER I

INTRODUCTION

Since the 1960s, the United States has been a major supplier of nuclear fuel to civilian power reactors throughout the free world. In fact, until the mid-1970s, foreign competition in producing enriched uranium--the fissionable material used in nuclear plants--was nonexistent. The motivation underlying the U.S. role as a prime provider of this fuel has been twofold: to encourage the development of a "clean" and economic power source for peaceful purposes, and to play a major role in preventing the proliferation of nuclear weapons by placing restrictions on how and by whom nuclear fuels and production technology can be used.

To a large extent, these efforts were successful in the past. But they also have been costly from a budgetary perspective; since 1977, annual appropriations for the enrichment program have run well over $1 billion (in current dollars), often exceeding the revenues that the Department of Energy (DOE) collects from its enrichment customers. Unrecovered capital investment in the program now totals roughly $5 billion. Moreover, competition from foreign enrichment suppliers has grown so that the United States today supplies only about 47 percent of the world's enrichment needs, compared with 100 percent 10 years ago. To increase U.S. competitiveness and, therefore, market share, the DOE is attempting to lower its enrichment price, and is considering building a facility using new technology to reduce production costs. At the same time, it is facing increased demands to repay its past investments costs. Thus, the U.S. enrichment program today stands at a crossroads: should it embark on new investments, lower its prices, and possibly increase its market share in the future; or should it forgo any new capital investments, retain the current pricing structure, and try to maximize net revenues in the short term?

THE ROLE OF NONPROLIFERATION AS A POLICY GOAL

One of the key motivations for maintaining or even increasing the U.S. share of the world enrichment market is to use the leverage of a major world supplier to prevent the diversion of nuclear fuels (or technologies) to nuclear weapons. Many countries look to nuclear power to provide reliable, low-cost

54-074 O - 85 - 2

electricity. But the spread of nuclear power technologies could lead to the proliferation of nuclear weapons technology in nations that do not now have it. The United States and other countries have endeavored to create various treaties, voluntary agreements, and an international organization--the International Atomic Energy Agency (IAEA)--to separate the means of producing civilian nuclear power from nuclear weapons. The Treaty for Nonproliferation of Nuclear Weapons (NPT) is the backbone of the nonproliferation strategy, with its no-nuclear weapons pledges and safeguards verified by international inspectors of the IAEA.

U.S. leadership and influence contributed greatly toward establishing this nonproliferation network. Into the 1970s, U.S. nuclear power technology was well ahead of that of other countries, and the United States was virtually the only supplier of enriched uranium to free world nations. That technological leadership was of great value in creating the IAEA, in establishing the principle that nuclear importing states should pledge not to use nuclear fuel for weapons, in creating the NPT, and in persuading major nuclear supplier states to agree voluntarily to exercise restraint in the supply of sensitive nuclear technologies. 1/ By the early 1970s, U.S. influence had begun to lessen as nuclear power industries emerged in Europe and Japan. West Germany contracted with Brazil to supply a complete nuclear fuel cycle, including enrichment and reprocessing plants, while France agreed to supply reprocessing plants to Pakistan. 2/ (The accompanying box explains the nuclear reactor fuel cycle.) Neither Brazil nor Pakistan signed the NPT, and thus were not subject to full IAEA safeguards. The Ford and Carter Administrations successfully sought agreements with West Germany, France, and other major nuclear suppliers to adhere to the guidelines mentioned above. Nevertheless, economic pressures to export nuclear technology, including enrichment services, remain quite strong.

Today, the United States is no longer the primary supplier of nuclear power plants or enrichment services. Eurodif and Urenco, the other major suppliers of enriched fuel, have been increasing their share of world enrichment sales and Japan is preparing to start construction of an enrichment

---

1. Sensitive nuclear technologies are those for enrichment, reprocessing, heavy water production, and plutonium fuel fabrication.

2. France, however, proposed unacceptable design changes to Pakistan which caused that contract to come to a halt. West Germany has continued its contract, but economic difficulties have greatly slowed progress in Brazil.

THE NUCLEAR REACTOR FUEL CYCLE

The nuclear fuel cycle consists of six essential fuel processing stages that begin with uranium mining and end with long-term storage of depleted nuclear fuel. Most of the world's uranium ore deposits are found in the United States, Australia, Africa, and Canada. After mining, uranium ore is put through a milling process, whereby it is concentrated into a commercial product referred to as "yellowcake," usually in the form of uranium oxide, or U_3O_8.

The yellowcake is then sent through a fuel conversion process, in which the U_3O_8 uranium ore is converted to a gas, uranium hexafluoride, or UF_6. The uranium gas is packaged into feed cylinders which are then sent to an enrichment facility. The enrichment enterprise actually operates as a nuclear fuel service--enrichment customers own the uranium feed and deliver it to the enrichment plant for processing. At the plant, the fuel is "enriched" to bring the fissionable isotope, U-235, up to roughly 3 percent. The enriched material is then repackaged in its gaseous UF_6 state into smaller fuel cylinders. DOE enrichment customers have the option of claiming the depleted uranium feed waste stream from the process, but most of the waste streams are retained by the DOE at its three enrichment plants.

From the enrichment stage, the nuclear fuel is delivered to a fuel-fabricating plant. This process converts the enriched uranium gas into ceramic uranium dioxide pellets. These cylindrical fuel pellets are encased in long, slender, sealed rods, which are arranged into the fuel assemblies actually placed within the nuclear reactor.

On average, a typical 1 gigawatt reactor will refuel about every 18 months, requiring about 195 kilograms of enriched fuel. During each refueling, about one-third of the reactor's fuel supply is replaced, and the complete core contains roughly 585 kilograms of nuclear fuel.

When the enriched fuel has been depleted, the spent fuel assemblies must be removed from the reactor core and stored indefinitely. In the United States, most commercial utilities store their spent fuel underwater in temporary storage pools at the reactor sites. Because the spent fuel will remain highly radioactive for thousands of years, the federal government has taken responsibility for providing for permanent disposal of all commercially generated spent fuel. The Department of Energy manages the federal high-level radioactive waste disposal program, and will operate one or two underground repositories scheduled to begin accepting nuclear wastes from U.S. utilities by 1998.

plant large enough to supply about one-third of its domestic requirements.[3] This weakening of U.S. leadership in nuclear supply could diminish U.S. ability to influence the programs and activities of the IAEA. As other nuclear supplier states offer comparable nuclear power technologies and cheaper enrichment services, the U.S. position may carry less weight in the IAEA, both with respect to the provision of technical assistance and to the agency's safeguards activities.

Although it seems unlikely that the United States can ever regain the technological leadership it had until the 1970s, a fundamental policy question remains: to what extent is it in the U.S. national interest to preserve at least some influence in world nuclear supplies, in particular the supply of enrichment services? The answer to this question will influence whether future DOE pricing policy and investments in enrichment technology should be governed exclusively by economic and budgetary considerations, or whether they should also consider U.S. nonproliferation and foreign policy goals.

THE ROLE OF INVESTMENT AND PRICING POLICIES

Decisions by the Congress and the DOE on investment and pricing policies will strongly affect the future role of the federal enrichment program. The Congress could authorize the DOE to invest in new, more efficient technologies and to lower its price in order to reclaim a larger share of the world enrichment market. A more competitive U.S. enrichment enterprise might provide the largest net revenues to the government because of greater sales. In the long run, this would improve the financial health of the U.S. enrichment program, possibly leading to greater cost recovery of past investments than the current program would allow. Moreover, maintaining a strong and competitive program would assure low-cost fuel supplies to U.S. nuclear utilities in the future, and would indicate federal commitment to the importance of a strong domestic nuclear energy program. But this approach probably would require net federal outlays during the next decade.

3. Eurodif is a French-owned enrichment company with equity partners composed of Spain, Italy, and Belgium. It currently provides about 22 percent of free world enrichment demand. Urenco is also a European consortium, made up of partners from the United Kingdom, West Germany, and the Netherlands. Its share of the world enrichment market is about 5 percent.

Alternatively, the DOE could continue to rely on its current enrichment plants and forgo any further investments in new technologies. This approach would maximize net revenues in the short term, by minimizing additional program outlays. But it would cause U.S. enrichment prices to remain high and uncompetitive and eventually lead to the loss of both foreign and domestic customers.

The DOE has attempted to become more competitive in the world market through reducing its price and developing new technology. It has taken important steps recently to lower its enrichment price. In January 1984, DOE introduced a new utility services contract which includes more favorable terms for DOE customers. Also, the DOE has lowered its operating costs by purchasing cheaper power to run its enrichment plants and by selling off much of its excess inventory of enriched fuel to meet production requirements. U.S. enrichment prices still remain higher than those of its major foreign competitors, however.

To lower its enrichment prices even further, the DOE also has been developing new technologies to replace the current process. The original gaseous diffusion process now in use is not only expensive to operate but has become outdated. In June 1985, the DOE chose the Atomic Vapor Laser Isotope Separation (AVLIS) process for continued development and demonstration, and discontinued further development of the Advanced Gas Centrifuge (AGC) process. 4/ Either of these advanced technologies would reduce operating costs dramatically, but initial construction costs would be expensive. The proposed AVLIS facility would cost about $2.3 billion to build, while completing the AGC project would have cost roughly $5.4 billion in addition to the $2.3 billion already spent on initial construction. Although the AVLIS facility would increase program expenses over the next 10 years, it should eventually lower prices and increase sales.

ISSUES NOW FACING THE CONGRESS

Because of the emphasis on reducing the federal deficit, the Congress has placed tighter budgetary restrictions on the enrichment program in recent

4. The Congressional Budget Office previously has made two economic comparisons of the two technologies. The first report, *Uranium Enrichment: Investment Options for the Long Term*, was published in October 1983. CBO updated the results of that study in a memorandum prepared for the House Subcommittee of Energy Conservation and Power (December 6, 1984).

years. From fiscal years 1982 through 1985, the enrichment program's appropriations were set equal to projected DOE enrichment revenues. Recently, the Office of Management and Budget (OMB) has proposed that the DOE should begin to repay the Treasury for past federal investment in the program. [5]

If the Congress decides that continued stong U.S. participation in the world market is important, then a commitment to build advanced technology probably would be necessary. To do so could require substantial net spending over the next decade, especially if the DOE changes its pricing policy in order to offer more competitive prices.

On the other hand, if the Congress required the DOE to make significant repayments to the Treasury over the next decade and maintained its current budget policy of zero net appropriations, the DOE might have to eliminate or postpone the deployment of any new technology to reduce future outlays, or maintain or increase the current enrichment price. Either measure would probably cause DOE's current market share to decline further. The federal government still would remain a source of enriched fuel for the domestic nuclear power industry and for the U.S. military program, but could not compete on the world market.

The Congress, therefore, faces a choice between two seemingly incompatible goals. The first goal would have the United States lower enrichment prices to better compete in the world market. To achieve it, the United States probably would need to invest in new technology (as the DOE has planned) to lower production costs. Moreover, a change in current pricing law might be necessary to further DOE's flexibility in the world market. The benefits of this plan might be the maintenance of a strong U.S. position in the world market and continued influence in deciding nonproliferation policy. The disadvantages, however, could include the possible need for net appropriations over the coming years and the delay, if not cancellation, of significant repayment to the Treasury for past capital investments.

The second goal would have the U.S. maximize net proceeds in the short term (the next 15 years), aiming to recover past investments. To achieve it, the DOE would likely not be able to invest in new technology, and would need to keep prices relatively high while using current enrichment facilities. The disadvantages would be the probable continued loss of U.S. sales in the world enrichment market, including the loss of more U.S. customers.

---

5. The OMB and the DOE are now negotiating the appropriate amount to be repaid to the Treasury, and discussing a repayment schedule.

The following chapters examine how well the current enrichment program or alternatives can recover costs and, concurrently, which pricing and technology choices can achieve greater competitiveness in the world market. Specifically, this study looks at the following:

- The current DOE pricing formula and program plans, including use of new technology;
- Revisions to the interest rate calculation contained in the current pricing formula; and
- New pricing strategies--such as a two-tiered system and one based on forgiveness of past investment debt--that might require changes to current law.

Each of these options would elicit different results in the marketplace and, over time, exert different effects on the budget.

CHAPTER II

THE WORLD ENRICHMENT MARKET

Today's world market for enriched nuclear fuel is a buyers' market. Annual enrichment capacity of roughly 43 million "separative work units" (or SWUs) is almost twice the level of demand of about 22 million SWUs in fiscal year 1985. (See box on next page for discussion of SWUs.) In addition, 29 million SWUs of excess inventory are now owned by commercial nuclear utilities and provide a secondary market for enriched uranium. World enrichment demand depends on the size of the nuclear power industry, which has not met the expectations of the 1960s and 1970s, particularly in the United States. Because capacity should continue to outpace demand well into the 1990s, suppliers will have to compete for uncommitted purchasers, and the price charged for enrichment services will be important. (See box on p. 11 on contracts for enrichment services.) Thus, the future market for U.S. enrichment services will depend on the portion of world demand--including domestic sales--that is open to price competition. While the United States may never regain its position as the dominant world supplier, it could retain or even increase its current market share, depending primarily on the price it offers.

WORLD DEMAND FOR ENRICHED URANIUM FUEL

Civilian demand for enriched uranium fuel is determined by the total generating capacity and operating rates of commercial nuclear power reactors worldwide. Growth of this energy source is uncertain, however. While several countries, such as France and Japan, continue to encourage strong domestic nuclear power industries, many others have slowed development. In particular, nuclear plants in the United States, Italy, and Spain have experienced numerous delays and cancellations in recent years, and the role of nuclear power in these countries continues to be reassessed. Nevertheless, nuclear generated electricity remains a significant energy source for many developed countries, and continued growth in worldwide electricity use may encourage the construction of new plants.

WHAT IS A SWU?

The separative work unit--or SWU--is a measure of the work required to enrich uranium from its natural state of 0.7 percent U-235 to roughly 3 percent U-235, so that it is usable as power reactor fuel. The SWU is not an output measure, but rather represents the energy used to separate the U-235 and U-238 isotopes, and collect the concentrated U-235 stream. Typically, utilities supply the "enricher" with a certain amount of raw uranium, and receive back an agreed upon quantity (in kilograms) of fissionable fuel. Instead of paying for the fuel as a final product, utilities instead pay for the enrichment service.

The enrichment process can be compared with a press used to make apple cider. A bushel of apples is fed through the press, using moderate energy or muscle, to produce a gallon of cider. The waste product consists of crushed apples, cores, and seeds. If apple prices increased, fewer apples could be fed into the press, but more muscle would have to be used to get the same amount of cider. As a result, the amount of apple waste products would be lower. Conversely, if the price of apples fell, more could be put into the press and less work done to squeeze them. The result would be the same amount of cider, but more waste.

The enrichment process allows a similar trade-off between the amount of natural uranium feed and the amount of energy used to make a given amount of enriched uranium. The amount of waste product is determined by the tails assay, which represents the percentage of U-235 remaining in the depleted uranium feedstock waste stream. This tails assay determines how much feed and how much energy will be required. The tails assay generally ranges from 0.2 to 0.3 percent, depending on the relative costs of uranium feed and energy.

If the price of uranium were high, one would choose a lower tails assay (thus leaving less U-235 in the waste stream) and use more energy to extract the needed U-235 from the smaller amount of uranium feedstock. Alternatively, if natural uranium prices were depressed and energy expensive, one would use a higher tails assay. The latter strategy is used by DOE in operating the diffusion plants today, since they require large amounts of electric power while uranium prices are relatively low. The advanced enrichment processes require very little energy to operate, however, and thus would probably be run with a lower tails assay.

DOE CONTRACTS FOR SUPPLYING ENRICHED URANIUM

Contracts for supplying enriched uranium fuel for nuclear power plants have unusually long lives--covering 30 years in the United States and 10 to 15 years for European suppliers. In 1984 the U.S. Department of Energy initiated new contract terms that provide better prices and more flexible terms than those offered in earlier contracts. Under the new contracts, the DOE will provide enrichment services for all its customers' commercial nuclear facilities that were in operation when the contract was signed. The contract will remain effective for 30 years, although a customer may terminate it without penalty with 10 years' notice. The contract specifies the obligations of both the DOE and its customers regarding the scheduling of customers' fuel requirements and deliveries of unenriched uranium feedstock to the DOE enrichment facilities, DOE's shipments of the enriched fuel, and contract price and payment schedules, including termination charges and late payment penalties.

A 10-year ceiling price of $135 per SWU was established, with allowances for annual adjustments for increases in electricity rates and inflation. The DOE can revise its price annually according to its established policy, although it cannot increase the $135 price above the inflationary adjustments for 10 years.

The flexible terms of this contract allow customers to purchase up to 30 percent of their annual SWU requirements from non-DOE suppliers or on the open secondary SWU market. Through 1986, however, this 30 percent would have to be purchased from excess SWU inventories which originated with the DOE. Customers must contract for the percentage of their annual demand that they will purchase from the DOE at least five years in advance.

Projections of Nuclear Power Capacity

In calendar year 1983, the free world's installed nuclear power capacity was 167 gigawatts electric (GWe), producing roughly 887 billion kilowatt-hours of electricity. 1/ The Department of Energy projects that worldwide installed nuclear capacity will reach 324 GWe by 1995, which is about 16 percent lower than a similar projection made in 1981. Table 1 shows nuclear generating capacities for the major nuclear power nations in 1983, with projections for 1995.

The United States is still the largest user of nuclear energy, with over twice the nuclear capacity of France, which ranks second. Furthermore,

1. For comparison, in 1983 the United States consumed roughly 2.3 trillion kilowatt hours of electricity from all power sources.

U.S. nuclear generating capacity (including all nuclear plants now under construction) should almost double in the next 10 years, increasing the nuclear share of total generated electricity from 13.6 percent in 1984 to about 19 percent by 1995 (in calendar years). The U.S. nuclear power industry has suffered serious setbacks in the past decade, however. In 1978 the DOE projected that U.S. nuclear capacity would increase to 208 GWe by 1995, but in 1984 it lowered this estimate by 43 percent to 119 GWe. The

TABLE 1. FREE WORLD NUCLEAR ENERGY CAPACITY IN 1983 AND PROJECTIONS FOR 1995 (In calendar years)

	1983		1995 a/	
Country	Net Gigawatts-Electric	Percent of World Total	Net Gigawatts-Electric	Percent of World Total
United States	64.4	39	119.2	37
France	27.2	16	57.4	18
Japan	19.0	11	32.2	10
West Germany	11.1	7	21.8	7
United Kingdom	8.8	5	14.8	4
Canada b/	7.6	5	15.4	5
Sweden	7.3	4	9.4	3
Spain	3.8	2	8.5	2
Belgium	3.5	2	6.7	2
Taiwan	3.1	2	5.8	2
Other	11.2	7	32.8	10
Total	167.0	100	324.0	100

SOURCE: Congressional Budget Office from Department of Energy, Energy Information Administration (EIA), *Commercial Nuclear Power 1984, Prospects for the United States and the World* (November 1984).

a. Projections for 1995 represent the middle case forecast prepared by EIA.

b. Canada is the only country with a large commercial nuclear power program that relies primarily on heavy-water nuclear reactors, fueled by natural (unenriched) uranium.

major reasons for this decline are lower electricity demand, higher than expected capital costs for nuclear power plant construction, an uncertain regulatory environment, and public concern over the potential health hazards of nuclear power.

Demand for Enriched Uranium

Parallelling its position as the world's largest consumer of nuclear power, the United States uses the most enriched uranium, accounting for 34 percent of world SWU demand in fiscal year 1985. France, Japan, and West Germany also consume large amounts of enriched fuel, and their annual requirements will increase steadily to match their expanding commercial nuclear programs. Table 2 shows the annual SWU requirements of the major nuclear power countries in 1983 and U.S. and total SWU demand projections for 1995.

The free world enrichment demand rose from 17.8 million SWUs in 1983 to 22 million SWUs in 1985 and is projected to rise to 28 and 33 million SWUs by 1990 and 1995, respectively.[2] A decade ago, however, the DOE projected that world demand would reach almost 50 million SWUs by 1985, and well over 100 million SWUs annually by 1995. Again, the decline in nuclear power growth, particularly in the United States, explains the substantially lower SWU demand.

WORLD ENRICHMENT SUPPLY

Four major suppliers sell enrichment services to the world market today, with a combined annual capacity of almost 43 million SWUs (see Table 3). The U.S. federal enrichment enterprise is the largest supplier, providing about 47 percent of the free world's current annual requirements. Two European enrichment organizations, Eurodif and Urenco, supply 22 and 5 percent of world demand, respectively, and the Soviet Union's enrichment agency, Techsnabexport, provides another 9 percent. The remaining 17 percent of world demand is met primarily by sales of surplus enriched uranium owned by utility customers of the DOE and Eurodif.

---

2. The amount of fuel required by a nuclear power plant reactor depends on several factors: the type of reactor, the capacity utilization rate, and the fuel consumption and reloading cycle. Typically, a 1 GWe nuclear reactor operating at about 65 percent of its capacity will use about 110,000 SWUs per year.

TABLE 2. FREE WORLD ENRICHMENT REQUIREMENTS, ACTUAL 1983 AND PROJECTED 1995 USE (In calendar years)

Country	Millions of Separative Work Units	Percent of World Total
Actual 1983 Use		
United States	7.9	44
France	3.3	19
Japan	2.0	11
West Germany	1.7	10
Sweden	.6	3
United Kingdom	.5	3
Other	1.8	10
Total	17.8	100
Projections for 1995		
United States	11-12	33-36
Other	21-22	64-67
Total	32-34	100

SOURCE: Congressional Budget Office, based on data from the Nuclear Assurance Corporation and the Department of Energy.

By 1995 total world enrichment capacity should increase to nearly 46 million SWUs per year, still well in excess of that year's estimated demand of 33 million SWUs. The DOE projects that the United States will provide about 41 percent of this demand, and Eurodif and Urenco will supply 28 and 7 percent, respectively. Techsnabexport is projected to provide another 4 percent. Most of the remaining demand--about 6 million SWUs--is uncommitted to any supplier at this time and represents the portion that the DOE is trying to capture. 3/

3. Recent reports suggest that Cogema, the French nuclear fuel marketer for Eurodif, is about to conclude a major enrichment contract with South Korea that would reduce the remaining market. See "France Mounts Bid for Nuclear Fuel Business in Far East," *The Energy Daily*, vol. 13, no. 148, August 5, 1985.

TABLE 3. CURRENT AND PROJECTED WORLD ENRICHMENT CAPACITY, CALENDAR YEARS 1985 AND 1995 (In millions of SWUs)

Country	Type of Process	1985	1995
United States	Gaseous Diffusion a/	27.3	27.3
	Atomic Vapor Laser Isotope Separation (AVLIS) b/	0.0	1.0
Sub-total		27.3	28.3
Eurodif	Gaseous Diffusion c/	10.8	10.8
Urenco	Gas Centrifuge	1.4	2.1 d/
Techsnabexport e/	Gaseous Diffusion	3.0	3.0
Japan	Laser	f/	1.0 g/
South Africa	Helicon	f/	0.3
Brazil	Jet Nozzle	f/	0.2
Argentina	Gaseous Diffusion	f/	0.1
Total		42.5	45.8

SOURCE: The Congressional Budget Office, based on data from the *Proceedings of the Tri-Committee Business Advisory Panel on Uranium Enrichment*, Joint Hearings before the Committee on Science and Technology, Committee on Energy and Commerce, and Committee on Interior and Insular Affairs, U.S. House of Representatives, 98:2 (August 16, 17, 1984); and Department of Energy, Energy Information Administration, *Commercial Nuclear Power 1984* (November 1984).

a. Although the three U.S. gaseous diffusion plants have a combined capacity of 27.3 million SWUs, the Oak Ridge, Tennessee facility was put in standby status in mid-1985; the two plants currently operating have a combined capacity of 19 million SWUs.

b. The Department of Energy selected the AVLIS process in June 1985 for continued development. No commitment has been made to build an AVLIS plant, but a 10 million SWU capacity plant was evaluated by the DOE in making this selection decision. If this process begins operation in 1995, the Oak Ridge gaseous diffusion plant probably would be shut down permanently by the late 1990s, when the AVLIS plant would reach full capacity.

c. Eurodif is developing the laser enrichment technology for deployment possibly in the 1990-2000 period. This new capacity will probably replace current diffusion capacity, however, so no additional capacity is expected.

d. Urenco can increase its capacity in small increments as needed to meet additional demand. The DOE projects that Urenco's capacity will be 2.1 million SWUs per year by 1990; it may be slightly larger by 1995 if its enrichment sales increase.

e. Techsnabexport has traditionally had about 3 million SWUs per year available for sale to non-Communist countries.

f. Currently no commercial enrichment capacity has been deployed.

g. Japan plans to build enrichment capacity to meet one-third of its annual requirements by the year 2000. Thus, it should be able to produce about 2 million SWUs per year by that time.

The U.S. Federal Enrichment Program

U.S. enrichment plants have an annual capacity of 27.3 million SWUs, enough to support DOE's expected demand through the end of this century. Total civilian sales in 1985 will be only about 9.9 million SWUs, however. The DOE also provides enrichment for the U.S. national defense programs, which generally use about 1 million to 2 million SWUs per year. Some of this is used for weapons, but most is used to fuel nuclear-powered submarines and warships and for other defense nuclear reactors. Military demand could increase substantially during the late 1980s and 1990s, if Congress funds requested defense programs. But even with this additional military demand, DOE's total enrichment demand should not exceed 25 million SWUs annually through 2000, which is still below current U.S. enrichment capacity.

The DOE now operates two gaseous diffusion plants to enrich uranium, located in Paducah, Kentucky and Portsmouth, Ohio. The DOE has recently discontinued production at its third plant in Oak Ridge, Tennessee, maintaining this facility in a standby status in case it needs this additional capacity in the future. The DOE also has been developing two new technologies: the Advanced Gas Centrifuge (AGC) process and the Advanced Vapor Laser Isotope Separation Process (AVLIS). In June 1985 the DOE chose the AVLIS process for further development, demonstration, and potential deployment. Although the DOE has made no commitment to build an AVLIS facility, a 10 million SWU capacity plant was evaluated in the technology selection process with deployment assumed for the mid-1990s.

DOE's Enrichment Customers

DOE's current customers include most U.S. nuclear utilities (45 of the 52 U.S. nuclear utilities converted to DOE's new contract in 1984) and 27 foreign utilities located in 13 countries (see Table 4). The domestic customers will account for 50 percent to 60 percent of total civilian SWU sales over the next decade. Figure 1 shows the breakdown of DOE's current contracts by major consumer groups through 1995. It also presents DOE's sales to the U.S. military program over this period, based on their firm projections of military demand.

By 1995 81 percent of DOE's foreign enrichment sales will go to nuclear utilities in the Far East. Japan, DOE's largest foreign customer, will account for over 60 percent of the foreign market. Taiwan and South Korea are its next largest foreign customers. Continued DOE sales in Western Europe appear unlikely, with the exception of Sweden and Switzerland, which are not aligned with either of the European enrichment consortiums.

Compared with the mid-1970s--when the United States held a monopoly on the world enrichment market and was projecting annual sales levels approaching 50 million SWUs by 1985--the U.S. role in the world market has sharply diminished. In fact, the U.S. share of enrichment sales to foreign customers could fall from 32 percent in 1985 to 25 percent by 1995, although the actual amount of foreign sales should rise somewhat. This drop in market share can be traced mainly to the aggressive marketing strategies of DOE's competitors, Eurodif and Urenco.

The Eurodif Consortium

Eurodif is the world's second largest enrichment supplier, with a current capacity of 10.8 million SWUs per year. Like the DOE, Eurodif's capacity significantly exceeds its committed sales, which totaled roughly 5.4 million SWUs in 1985 and are projected to increase to about 8 million SWUs by 1990. Eurodif's share of world enrichment sales has grown from 10 percent in 1979 to about 22 percent today, and the DOE projects that it will climb to 28 percent by 1995.

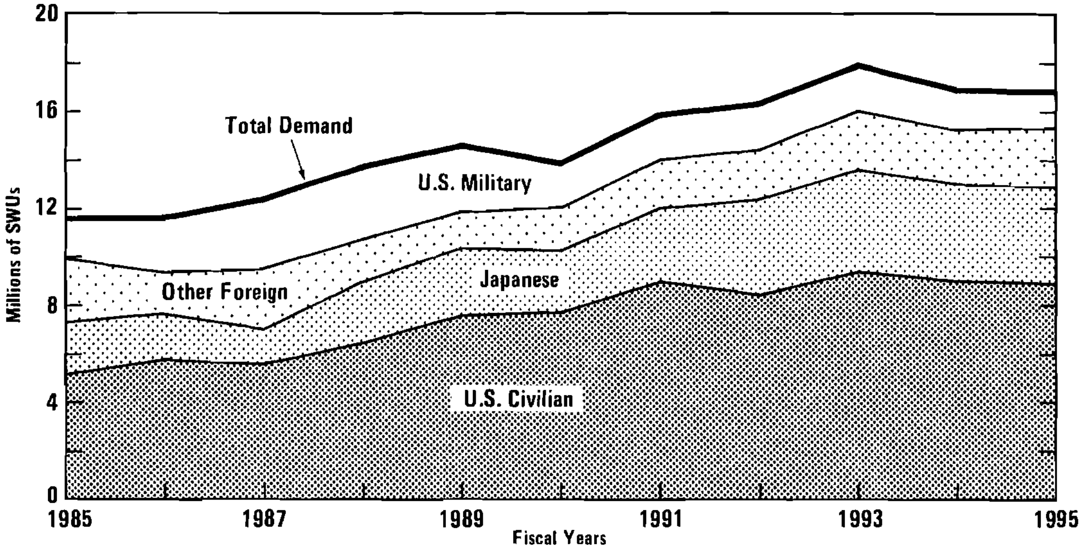
TABLE 4. NATIONAL ORIGIN OF UTILITIES WITH CURRENT ENRICHMENT CONTRACTS, BY MAJOR SUPPLIERS

U.S. DOE	Eurodif	Urenco	Techsnabexport
United States	France	United Kingdom	West Germany
Japan	Belgium	West Germany	Spain
South Korea	Japan	Brazil	France
Sweden	Spain	Netherlands	Finland
Taiwan	Italy	Switzerland	Sweden
West Germany	West Germany	United States	United Kingdom
Switzerland	Switzerland		
France	South Korea		
Spain	Taiwan		
Netherlands	United States		
Philippines			
Yugoslavia			
Egypt			
Mexico			

SOURCE: Congressional Budget Office, based on information from the Department of Energy and the Nuclear Assurance Corporation.

NOTE: Countries are listed by the amount of SWU demand per year serviced by each supplier, roughly in descending order.

Figure 1.
DOE Projections for U.S. Enrichment Services, by Customer Group



SOURCE: Congressional Budget Office, based on data from the U.S. Department of Energy.

Eurodif is a French company that originally consisted of equity partners representing the governments of France, Spain, Italy, Belgium, and Iran. The company was formed in 1973 and began production in 1979. Its partners expected to use about 90 percent of Eurodif's total capacity, but because of either cancelled or greatly diminished nuclear power programs in Spain, Italy, and Iran, Eurodif has been seeking non-partner customers to use its excess capacity. Cogema, a nuclear fuel cycle supplier owned by the French government, now owns over 50 percent of Eurodif, and is responsible for marketing its enrichment sales. Cogema has aggressively pursued new customers, especially in the United States where four domestic utilities, former DOE customers, recently signed long-term contracts with Eurodif. 4/ Eurodif's largest customer, in addition to its French and Belgian partners, is Japan (see Table 4).

Eurodif's enrichment facilities, located in Tricastin, France, use the gaseous diffusion process, with on-site nuclear power plants providing low-cost (possibly government-subsidized) electricity. Since energy costs make

4. At least eight other domestic utilities also arranged to purchase enrichment services from Eurodif, but only on a short-term basis. These utilities have signed long-term contracts with the DOE for at least 70 percent of their annual requirements.

up the bulk of total operating costs for the gaseous diffusion plants, Eurodif's operating costs are somewhat lower than those of the DOE. Eurodif is also developing a laser enrichment technology which could become operational in the 1990s, even further reducing its operating costs and SWU prices.

The Urenco Consortium

Urenco is a European consortium consisting of government and privately owned partners from West Germany, the United Kingdom, and the Netherlands. The group was organized in 1970 and began production in 1976. Urenco now has two enrichment facilities--one in the Netherlands and the other in the United Kingdom--using gas centrifuge technology, although the Urenco technology is not as technologically efficient as the U.S. AGC process. Its current enrichment capacity is about 1.4 million SWUs per year, with plans for additional capacity of 0.7 million SWUs by 1987. Unlike the DOE and Eurodif, Urenco can easily add incremental capacity in response to increases in demand. Urenco's share of total world demand has increased from 2 percent in 1979 to 5 percent today, and probably will increase to about 7 percent by 1995.

Urenco's major enrichment customers include Brazilian and Swiss utilities in addition to its member nations (see Table 4). One U.S. utility has signed a long-term contract with Urenco, and another has bought SWUs from Urenco on a short-term basis.

Techsnabexport--the U.S.S.R. Supplier

Techsnabexport is the marketing agent for enriched uranium produced by the Soviet Union. It chiefly provides enrichment services for the Soviet nuclear weapons program and the nuclear power utilities of Communist bloc countries. But it also sells up to 3 million SWUs per year to the free world, mainly to obtain hard currency and to improve its trade balance (see Table 4). The Soviet Union traditionally undercuts U.S. enrichment prices, but it has not indicated any intentions of increasing its market sales beyond the current 3 million SWUs per year.

Other Nations with Potential Enrichment Capability

Several other nations are developing domestic enrichment capabilities. Japan is exploring both the gas centrifuge and laser enrichment processes, and plans to build a 1 million SWU capacity plant by 1990. It hopes to meet at least one-third of its domestic enrichment requirements by the year 2000, and to diversify its imports among several suppliers. This could lower DOE sales significantly in the next century, since Japan is now DOE's largest foreign customer. Japan currently has no plans to market its future enrichment capacity to foreign customers, but it is conceivable that Japan could be an enrichment competitor in the next century.

South Africa, Brazil, and Argentina also are pursuing domestic enrichment capabilities, although their planned capacities are quite small (see Table 3). None of these programs will compete strongly in the world enrichment market for foreign sales.

EXCESS WORLD SWU INVENTORY

By early 1985, nuclear utilities worldwide had accumulated almost 29 million SWUs of excess inventories. Of this amount, about 8.1 million SWUs originated from DOE sales to its utility customers. The remaining 21 million SWUs belong primarily to Eurodif customers, particulary in France, Spain, and Japan. Current DOE contract provisions allow its customers to take up to 30 percent of their annual SWU requirements from the DOE-origin inventory, which should be depleted by the end of 1987. After 1986, DOE customers can obtain 30 percent of their annual SWU requirements from any source.

Since the early 1980s, utilities have been actively trading their unneeded SWUs on the secondary SWU market. Recent sales prices range from about \$85 to \$100 per SWU, compared with DOE's fiscal year 1985 contract price of \$135 per SWU. Through 1984, the DOE had lost over \$2 billion in sales through partial contract terminations, as customers purchased part of their supplies on the secondary SWU market. If the DOE is to capture the full 100 percent of its customers' annual requirements, rather than the 70 percent minimum, its price will have to at least meet that of other sources, including non-DOE originating inventories or other enrichment suppliers.

It is unclear when the 21 million SWUs of non-DOE originating inventory will be depleted. Eurodif can supply any additional demand requirements either by increasing production or by selling off its customers' excess inventories. Eurodif is aggressively seeking new enrichment sales, and is now marketing these inventories at favorable prices to attract potential customers.

POTENTIAL MARKET FOR U.S. ENRICHMENT SALES

One of DOE's primary program goals is to increase or at least maintain its share of the world enrichment market. It could capture a considerable amount of uncommitted foreign demand if it becomes a more competitive supplier. The availability of this foreign market is subject to several uncertainties, some of which are not price related. Nevertheless, CBO estimates that the potential market for additional DOE sales could range from 5 million to 7 million SWUs per year between 1990 and 2000. This range excludes uncommitted demand from member nations of Eurodif and Urenco and from countries that historically have purchased their nuclear fuel from non-DOE suppliers mainly because of political alignments with the supplier nation. 5/

In 1985 free-world enrichment requirements are about 4 million SWUs more than the amount currently under contract with the four enrichment suppliers. The secondary SWU market is expected to supply most of this uncommitted demand, but its role in the world market should diminish by the early 1990s. Based on projections of world demand and current long-term contracts as of early 1984, roughly 12 million SWUs in excess of existing contracts will be required in 1990, and 27 million SWUs will be needed in 1995.

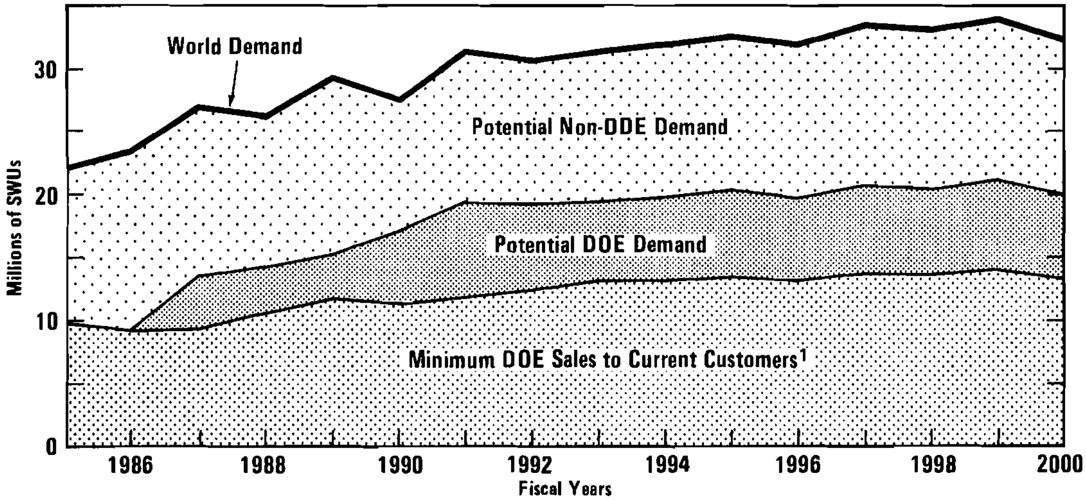
Figure 2 shows DOE's currently committed civilian enrichment demand, its potential market, and total free-world civilian demand projections through 2000. If the DOE can compete aggressively in the world enrichment market, it might be able to capture slightly over 60 percent of the total world market, compared with its current share of 47 percent. Its civilian sales would thus increase from 10 million SWUs per year to between roughly 17 million and 20 million SWUs per year between 1990 and 2000.

What Price Must DOE Offer to Compete in the World Market?

The DOE has projected its competitors' future prices based on their current pricing practices and projected production costs, incorporating their plans for deploying more efficient technologies in the future. If the DOE hopes to increase or even maintain its current sales base in the 1990s and beyond, its

5. In addition, 30 percent of the annual SWU requirements of DOE's current customers can be considered price-sensitive, assuming that the DOE will capture only this portion of its customers' demand if its prices become competitive.

Figure 2.
Potential Market for Enrichment Services



SOURCE: Congressional Budget Office, based on data from the U.S. Department of Energy and the Nuclear Assurance Corporation.

NOTE: These SWU projections reflect enrichment demand for commercial nuclear reactors only.

[1] Minimum DOE sales reflect 70 percent of the annual SWU requirements of current DOE contract customers, assuming no contract terminations.

price must fall to under $90 per SWU by the early 1990s and to the $60 to $70 range by about the year 2000. Figure 3 shows the projected range of future prices that the DOE will have to compete with, based on assumed Eurodif and Urenco price paths. 6/

These price projections reflect the probable marginal production costs of Eurodif and Urenco, assuming that they will continue to offer these prices to potential new customers in order to gain additional sales. The competitors' governments might be willing to subsidize their prices even further, however, to stay competitive, although it seems unlikely that they would price below actual operating costs over a long period. Eurodif's production costs are projected to remain roughly $15 per SWU higher than Urenco's through the mid-1990s. At that time, if Eurodif deploys the laser enrichment process to replace its gaseous diffusion capacity, its marginal production costs should fall dramatically so that it can lower its prices to the $60 to $70 per SWU range, equal to Urenco's projected prices. If Eurodif does not introduce laser technology before the year 2000, its prices may remain above $90 per SWU. Because both Urenco and Eurodif are aggres-

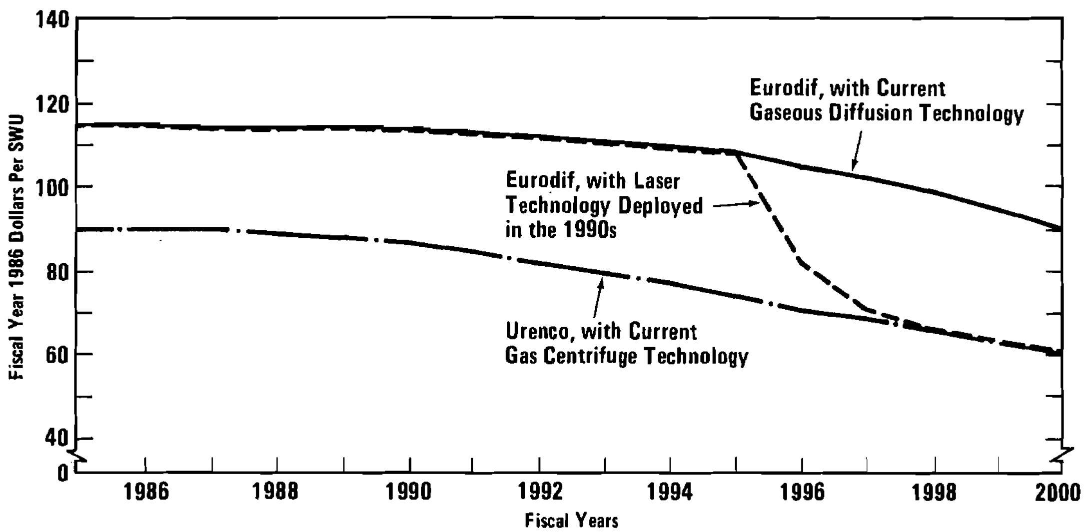
6. Technsnabexport generally offers its SWUs on the world market at prices 5 to 10 percent below DOE's stated prices when it has excess SWUs available for sale, and is not represented in the graph.

sively seeking new sales, U.S. enrichment prices would have to fall to the range represented by the lower line in Figure 3 if the DOE is to maintain its current demand. Because of Urenco's low enrichment capacity, however, it could not absorb a great deal of additional demand without building substantial new capacity. Thus, if DOE's prices fall between the competitive range shown in Figure 3, the DOE may lose some of its current demand to Urenco, but the lost market would be much greater if DOE's prices remain above those of both Eurodif and Urenco.

Since about 1981, the prices offered by both Eurodif and Urenco have been below DOE contract prices, for several reasons. A major reason has been the high dollar exchange rate, which greatly discounts European currencies against the U.S. dollar and makes the U.S. SWU more expensive relative to foreign SWUs. Also important, however, are that the production costs of both Eurodif and Urenco are lower than those of the DOE, and that these suppliers do not include research and development costs in their prices as the DOE is required to do. Moreover, both Eurodif and Urenco are able to tailor their contract prices and terms to individual customers, often pricing below production costs to "win" new sales. By law the DOE even-

Figure 3.

Competitive Price Range Based on Projected Eurodif and Urenco Production Costs



SOURCE: Congressional Budget Office, based on Department of Energy data.

tually must recover the full costs of the enrichment program through its sales revenues. Thus, the U.S. price must reflect all capital investment expenditures including interest charges, research and development costs, and operating costs, and "tailoring" prices for marketing reasons is prohibited.

If the DOE maintains its current price, many of its customers may terminate their current contracts beginning in the early 1990s, taking the minimum 70 percent requirement from the DOE until their contracts expire. Almost all current DOE contracts were signed in 1984, and, with a 10-year notice, customers can terminate these contracts without incurring a penalty. Even with a seven- or eight-year termination notice, the penalty is small, and if the DOE does not lower its price significantly by the early 1990s many customers probably will give termination notices within the next few years.

The analysis in Chapter III relates pricing and investment options for the U.S. enrichment program to the competitive range of world enrichment prices. This range, however, suggests one important uncertainty: a market characterized by high fixed costs and strong price competition could lead producers to cut their prices to levels near or below operating cost rather than lose market share. This could push actual prices to a level that would make full cost recovery impossible for any supplier.

CHAPTER III

PRICING POLICIES FOR THE U.S. ENRICHMENT PROGRAM

If the United States is to compete successfully in the world enrichment market, the price of its enrichment services must decline substantially from the fiscal year 1985 price of $135 per SWU charge to the more competitive level of $60 to $70 per SWU by the end of the century. 1/ At the same time, however, budgetary constraints may impede achievement of this objective in two ways. First, the DOE may have to operate the enrichment program without receiving the net appropriations that may be needed to introduce new and more efficient technology. Second, the DOE may have to begin repaying the Treasury for past investments.

Two separate elements of the enrichment program--choice of technology and pricing strategy--will help to determine future costs, prices, market share, and budgetary effects. The DOE has already chosen a new technology with the selection of the Atomic Vapor Laser Isotope Separation (AVLIS) technology for possible future deployment as a replacement for the current Gaseous Diffusion Plants (GDP). (See box for discussion of these technologies.) The AVLIS program should reduce DOE's operating costs dramatically by the mid-1990s, if the program is deployed according to the schedule envisioned by the DOE Process Evaluation Board (PEB), which evaluated the AVLIS and Advanced Gas Centrifuge (AGC) technologies for the recent process selection decision. If these operational savings were passed on to consumers as lower prices, the DOE might increase its market share. Building an AVLIS plant, however, would require considerable capital outlays over the next decade, exacerbating the current unrecovered investment costs of the enrichment program.

TECHNOLOGY OPTIONS AND PRODUCTION COSTS FOR THE U.S. ENRICHMENT PROGRAM

The technology program that the DOE pursues will have important effects on both future enrichment prices and federal government costs. CBO has

1. The DOE recently announced a lower fiscal year 1986 price of $125 per SWU, effective on October 1, 1985. The contract ceiling price will remain at $135 per SWU through fiscal year 1994, however.

54-074 O - 85 - 3

U.S. ENRICHMENT TECHNOLOGIES

Gaseous Diffusion Technology

The three U.S. gaseous diffusion plants--in Oak Ridge, Tennessee; Portsmouth, Ohio; and Paducah, Kentucky--were built by the federal government in the 1940s and upgraded during the 1970s. The gaseous diffusion process works by exploiting the different masses of the U-235 and U-238 molecules found in natural uranium. Gaseous uranium hexafluoride is passed through a series of chambers with porous walls, and the lighter U-235 molecules move more rapidly and are concentrated on the outside of the chamber wall. Each pass through a series of chambers further increases the U-235 concentration, until the final product is enriched to roughly 3 percent U-235 from the 0.7 percent found naturally in uranium ore. Because of the very large gas flow that must be pumped through the porous membranes, the diffusion process uses a great deal of electricity, which increases the operating costs.

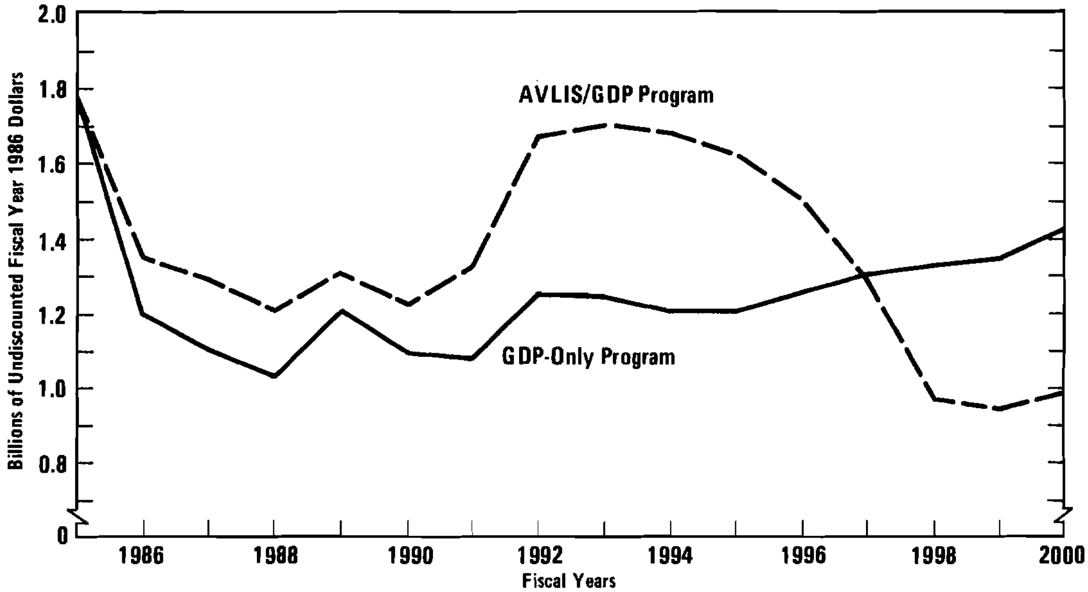
Atomic Vapor Laser Isotope Separation (AVLIS) Technology

Before selecting the AVLIS process for further development in 1982, the federal government had explored three laser and plasma enrichment technologies. All three of these Advanced Isotope Separation (AIS) processes were based on the concept that different uranium isotopes selectively absorb radiation at different energies. The AVLIS process uses lasers to "excite" the U-235 isotope in uranium metal feed, rather than uranium hexafluoride gas that the other two technologies use. As the U-235 atoms absorb the radiation at a different frequency from the U-238 isotopes, these fissionable atoms can be separated out and collected very efficiently, using only minimal amounts of electricity, thus reducing operating costs.

Advanced Gas Centrifuge (AGC) Technology

The federal government began research on the gas centrifuge enrichment process over 25 years ago, and development of the AGC technology is well advanced. This process uses a series of tall, cylindrical centrifuge machines spun at very high speeds to separate out and collect the desirable U-235 isotopes from the more abundant U-238. The product, slightly "enriched" in the U-235 element, is sent through repeated stages of the centrifuge process until is is enriched to roughly 3 percent U-235. The advanced centrifuge machines, referred to as Set V centrifuges, are made of a much stronger material than the prototype Set III machines, which have been fully demonstrated. Because the Set V machines can operate at much faster speeds, they are twice as efficient as the earlier Set III centrifuges.

Figure 4.
Total Program Outlays for U.S. Enrichment Services



SOURCE: Congressional Budget Office.

projected total program outlays for either a GDP-only or an AVLIS/GDP program based on the cost and production data used by the PEB to evaluate the different investment options for the federal enrichment program (see Table 5). 2/

Through fiscal year 1994, relying on GDP capacity only and abandoning any further development of the AVLIS process would require the lowest federal outlays, since the additional research and capital investments would be forgone. By the mid-1990s, however, annual program outlays under the AVLIS option--which would still rely on partial GDP capacity--would be lower because most of the capital construction would be completed and the AVLIS plant, with its lower operating costs, would be nearing full-scale operation (see Figure 4). The outlays required to operate only the GDP facilities after 1997 would be well above those of the AVLIS program, mainly because of the higher GDP power costs.

2. The federal costs and prices associated with the AGC program alternative are presented in the appendix. The pricing and budgetary effects of this alternative program are based on the AGC technology schedule and cost data used by the PEB. These are no longer accurate, however, since the DOE already has cancelled many AGC contracts and essentially terminated the project.

TABLE 5. COST ESTIMATES FOR THE AVLIS AND GASEOUS DIFFUSION TECHNOLOGIES FROM 1985 THROUGH 2000 (In fiscal year 1986 dollars)

Cost	AVLIS Undiscounted	AVLIS Discounted [a]	Gaseous Diffusion Undiscounted	Gaseous Diffusion Discounted [a]
Capital Investment-- 1985-2000 (In billions of dollars)	2.3	1.5	0.6	0.5
Dollars per SWU [b]	9.4	6.1	0.9	0.7
Research & Development (In billions of dollars)	1.0	0.8	0.0	0.0
Dollars per SWU [b]	4.1	3.3	--	--
Annual Operating Cost (In millions of dollars)	253.0 [c]	128.0 [d]	611.0 to 1,376.0 [e]	307.7 to 959.0 [f]
Dollars per SWU	25.8	13.1	55.3 to 67.9 [g]	27.7 to 53.0 [g]
Total Dollars per SWU	39.3	22.5	56.2 to 68.8	28.4 to 53.7

SOURCE: The Congressional Budget Office, based on the technology cost projections used by the Process Evaluation Board of the Department of Energy, obtained from the Office of Uranium Enrichment and Assessments in June 1985.

a. Discounting is a way to calculate, in today's dollars, the value of a future expenditure or future stream of expenditures. The result is called present value. A future expenditure is discounted to its present value using the following formula:

$$\text{Present Value} = \text{Future Value}/(1 + i)^n,$$

where n = the number of years between the present year and the year in which the expenditure is made, and i = the discount rate. The discount rate used in this analysis is 5 percent in real terms.

b. The capital and research and development charges per SWU are based on the plant's total SWU production, assuming maximum capacity over a 25-year operating life. The maximum production would be 245 million SWUs for the AVLIS facility and 683 SWUs for the diffusion plants.

c. The annual operating cost for the AVLIS plant includes both fixed and variable power costs, and represents the plant's long-term annual operating cost when producing at maximum capacity.

d. This discounted AVLIS cost represents the present value of the plant's operating cost in 1999, the year it would begin producing at maximum capacity.

e. The diffusion operating costs include both the fixed costs of running either all three plants ($191 million per year) or two plants with one plant on standby ($161 million per year), plus annual power costs. Power costs vary dramatically depending on the annual SWU production from the diffusion plants, and include energy demand penalties for power that DOE has contracted for but will not use.

f. These discounted operating costs reflect the range of present value GDP fixed and operating power costs between the years 1985 and 2000.

g. The per SWU GDP operating costs do not include demand penalties for power that the DOE has contracted for but no longer needs because of lower than projected demand.

Relying Only on the Gaseous Diffusion Plants

DOE's three gaseous diffusion plants were built over 30 years ago to provide enriched uranium for U.S. military needs. During the late 1960s, they also began to produce enriched fuel for both domestic and foreign commercial nuclear utilities. In the 1970s, the federal government spent about $1.5 billion (in current dollars) to increase the overall capacity of the three diffusion plants to 27 million SWUs per year and to upgrade the facilities. With only minimal additional capital expenses, the plants could remain operational past the year 2000.

Table 6 shows the five-year undiscounted outlays for a federal enrichment program that would continue to rely on GDP capacity only. Most of the expense would reflect GDP power costs. Annual program outlays would range from about $1.0 billion to $1.2 billion over the next decade, gradually increasing to about $1.4 billion by the year 2000. The outlay schedule, as well as that of the AVLIS program, assumes no real increases in future power costs. (Because of the GDP's larger use of power, any increases in power rates above the expected rate of inflation would tend to affect the GDP-only program outlays more than those of the AVLIS program.) In addition, the electricity cost estimates assume that the DOE can continue to purchase some seasonal and off-peak power from its three electric utility suppliers. Capital costs of about $25 million per year to maintain the GDP facilities--plus additional operating and administration costs--account for the rest of projected GDP-only program outlays.

These cost projections, and those of the AVLIS program, are based on the production schedules dictated by DOE's current customer contracts and associated SWU demand, and do not reflect any change in customer demand that might occur (see Figure 5). Both foreign and domestic DOE customers are concerned about long-term U.S. prices, and a decision by the DOE to abandon the cheaper, more efficient AVLIS technology might encourage some contract cancellations in the future.

The AVLIS Technology Program

Much of the engineering and design work for the AVLIS technology has been completed and partially demonstrated, but the process has not yet been tested on a commercial scale. The DOE's June 1985 selection of the AVLIS program over the AGC project was based on engineering and economic comparisons of the two advanced technologies carried out by the PEB. While the DOE has not announced any decision to deploy AVLIS, the schedule assumed by the PEB would begin commercial operation in 1995 with 1 million SWUs, reaching a maximum capacity of 9.8 million SWUs per year by 1999 (see Figure 5). This AVLIS program would require continued use of two diffusion plants, with the Oak Ridge diffusion plant remaining on standby.

TABLE 6. FIVE-YEAR PROGRAM OUTLAYS UNDER THE GDP-ONLY PROGRAM (By fiscal years, in millions of fiscal year 1986 dollars) a/

Years	GDP Capital	GDP Power b/	GDP Other Operating	AGC c/	AVLIS d/	Other e/	Total
1985-1990	352	5,080	1,055	741	82	162	7,472
1991-1995	125	4,758	949	0	0	135	5,967
1996-2000	125	5,449	955	0	0	135	6,664
Total	602	15,287	2,959	741	82	432	20,103

SOURCE: Congressional Budget Office, based on technology cost projections used by the Process Evaluation Board of the Department of Energy, obtained from the Office of Uranium Enrichment and Assessment in June 1985.

NOTE: The GDP-only program would operate the Paducah and Portsmouth diffusion plants from 1986 to 1991, with the Oak Ridge plant on stand-by. From 1992 on, all three plants would operate because of higher production requirements.

a. The first yearly group covers six years.

b. The GDP power costs are based on DOE's assumption that they can continue to purchase some off-peak power to run the diffusion plants. Estimates based on DOE's power costs assuming only its firm power contracts would increase total power costs by about $670 million through the year 2000. Demand penalty charges for power that DOE originally contracted for, but no longer needs because of lower demand, are also included.

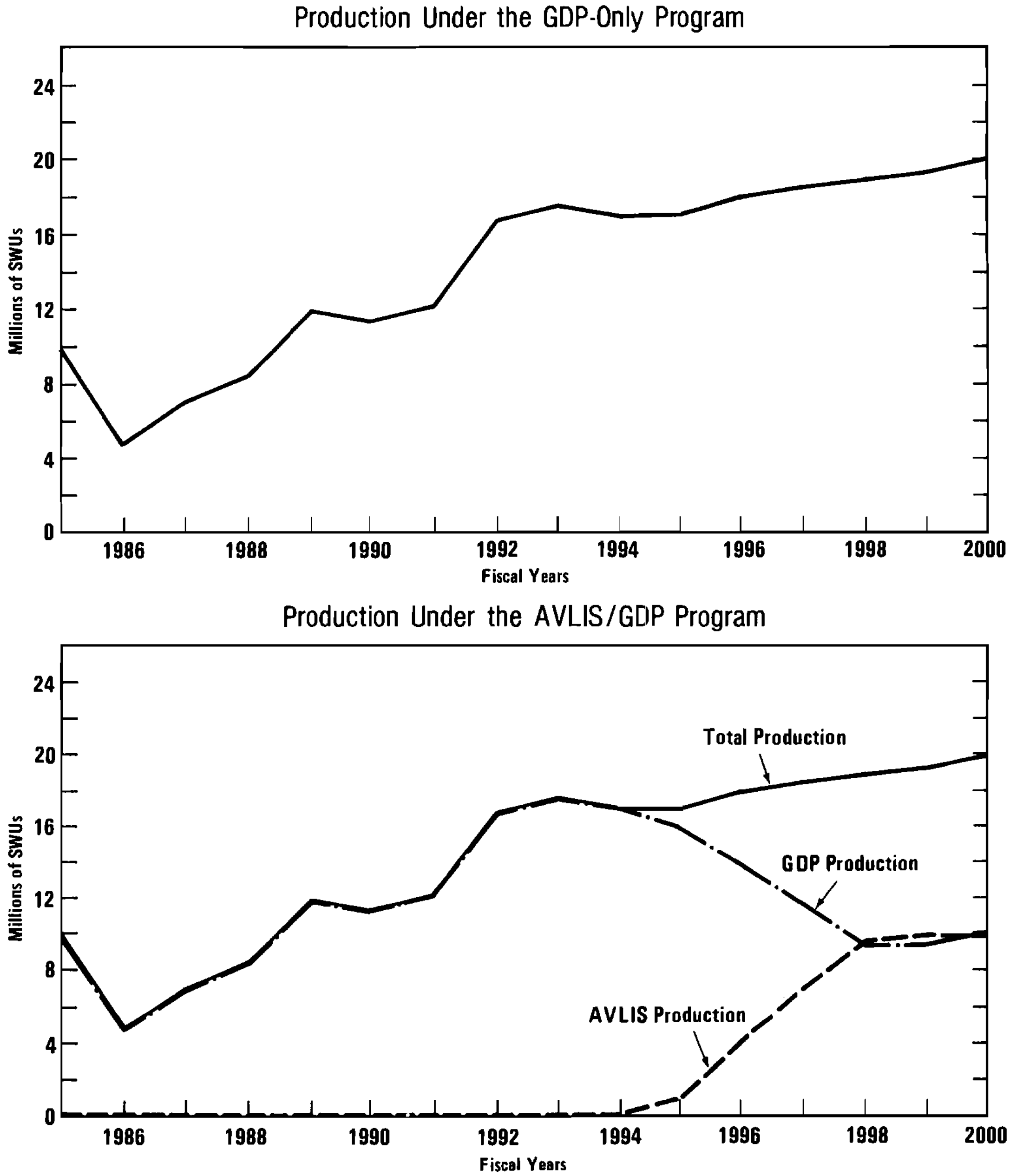
c. The AGC costs represent the capital development and operating costs associated with the AGC program in fiscal year 1985, and the cost of closing down the partially built AGC facility in 1986.

d. The AVLIS costs reflect research and development outlays for this program in 1985.

e. Other program costs reflect the administration costs of managing the enrichment program.

Figure 5.

Production Schedules Under the Two Technology Programs



SOURCE: Congressional Budget Office.

NOTE: Total SWU production would be roughly equal under both programs.

AVLIS' big advantage over the AGC process was its significantly lower capital requirements--$2.3 billion compared with an additional $5.4 billion that the AGC program would have required. (At the time of the AVLIS decision, $2.3 billion had already been invested in AGC.) AVLIS capital costs would range from $70 million to $350 million per year through fiscal year 1997 (see Table 7). Total annual outlays for the enrichment program would range from about $1.2 billion to $1.3 billion from fiscal years 1986 through 1991, and then jump to over $1.6 billion per year through 1995. 3/ Costs will then drop dramatically, falling to about $1.0 billion in the year 2000. GDP power costs would account for the bulk of total program outlays between now and the year 2000, but would begin to decline by 1996 as AVLIS capacity replaces some GDP production. Once the AVLIS facility is producing at full capacity, its operating costs should be about $26 per SWU, significantly less than GDP's power and operating expenses of about $55 to $68 per SWU (see Table 5).

PRICING POLICY FOR DOE'S ENRICHMENT SERVICES

In addition to deciding if and when to deploy the AVLIS technology, the choice of pricing policy is also important to program goals. No one pricing strategy, however, can achieve all the goals of the federal enrichment program, which include:

- o Increasing DOE's share of the world enrichment market through long-term competitiveness;
- o Maximizing the budgetary receipts of the program in the short term; and
- o Striving for full cost recovery in which revenues match outlays over the long term.

The United States will need to post a price in the $60 to $70 per SWU range by the end of the century if it is to successfully compete in the world market. Accordingly, this study examines four pricing alternatives:

- o **Option I.** Retain the current pricing formula of full cost recovery, under which all customers are charged the average costs of

---

3. In Table 7, total outlays from 1985 through 1990 are higher than those for 1991 through 1995 because the first period includes six years.

TABLE 7. PROGRAM OUTLAYS UNDER THE AVLIS/GDP PROGRAM (By fiscal year, in millions of fiscal year 1986 dollars)

	AVLIS Outlays			GDP Outlays					
Year	Capital Construction	Research & Development	Operating	Capital	Power a/	Other Operating	AGC b/	Other c/	Total
1985-1990	82	737	--	352	5,076	1,055	741	162	8,205
1991-1995	1,621	127	173	125	4,982	815	--	135	7,978
1996-2000	624	125	1,162	125	2,716	815	--	135	5,702
Total	2,327	989	1,335	602	12,774	2,685	741	432	21,885

SOURCE: Congressional Budget Office, based on technology cost projections used by the Process Evaluation Board of the Department of Energy, obtained from the Office of Uranium Enrichment and Assessment in June 1985.

NOTE: The AVLIS program assumes that two diffusion plants remain operational, with the Oak Ridge plant on standby. The proposed AVLIS facility would have an annual capacity rate of 9.8 million SWUs, and would begin production in 1995, reaching full production by 1999.

a. The GDP power costs are based on DOE's assumption that they can continue to purchase some off-peak power to run the diffusion plants. Estimates based on DOE's power costs assuming only its firm power contracts would increase total power costs by about $287 million through the year 2000. Demand penalty charges for power that DOE originally contracted for, but no longer needs because of lower demand, are also included.

b. The AGC costs represent the capital development and operating costs associated with the AGC program in fiscal year 1985, and the cost of closing down the partially built AGC facility in 1986.

c. Other program costs reflect the administration costs of managing the enrichment program.

production, including all investment and interest recovery on an annual basis. This option would provide large near-term revenues but would also entail high prices, which might not be competitive with other enrichment suppliers, even if the AVLIS process were inaugurated.

- **Option** II. Decrease the interest charge contained within the current pricing policy, thereby lowering prices but still recovering all past investment over a longer period. (This option might not require a change in current law.) Although this alternative would allow the DOE to offer fairly competitive SWU prices if the AVLIS technology were deployed, it would also require additional federal net spending in the next decade. This option would also lower short-term prices for the program even if it continued to use only GDP capacity, but prices would not be competitive beyond the mid-1990s.

- **Option** III. Permit DOE to price according to its long-run marginal costs, thus recovering only investment costs incurred since 1984--forgiving roughly $4.5 billion in past GDP and AGC capital investments. 4/ This would allow much lower future prices. (Such a change would probably require approval by the Congress). This option would almost certainly elicit additional enrichment demand for U.S. production, but would be costly to the federal government over the next decade because of lower revenues.

- **Option IV.** Charge the $135 per SWU contract ceiling price through the early 1990s, while DOE's current customers are essentially locked into their contracts, to maximize short-term revenues; from 1992 on, the DOE would price according to marginal production costs as in Option III to achieve maximum market penetration. This option would attempt to achieve maximum near-term revenues and long-term competitiveness. The long-term demand effect of maintaining the current DOE ceiling price into the 1990s is uncertain, however.

Each of these changes would have different implications for the price of DOE enriched fuel. More important, each would alter the balance of costs and revenues in the enrichment program, as well as the program's net effect

4. The $4.5 billion capital investment debt includes $2.3 billion in AGC capital costs and $2.2 billion in unrecovered GDP capital investment. DOE has already written off 60 percent of this $2.2 billion GDP debt, however, in calculating its current SWU price. The Office of Management and Budget has not yet determined if DOE must repay this full GDP and AGC investment to the U.S. Treasury.

on the budget deficit. The heart of the issue is whether success in the marketplace is more important than the short-term budgetary implications of the program.

Option I--Continue Current DOE Pricing Policy

This option would continue the basic principle governing DOE's current pricing strategy: full cost recovery. Under this policy, all federal costs should be reimbursed from revenues received from sales of enrichment services over a "reasonable period of time." This time period was originally established--and has since been recognized by the DOE and the Congress--as about 10 years. Essentially, DOE's charges are based on long-run average costs, which are simply total program costs divided by the number of SWUs produced. In accordance with section 161(v) of the Atomic Energy Act of 1954, the DOE published the Uranium Enrichment Services Criteria, which specifies those production and nonproduction costs that are factored into the enrichment price. 5/

The SWU price in any year equals the estimated total program costs over the next ten years plus the production costs of the SWU inventory existing at the beginning of the pricing year, divided by the estimated total SWUs to be sold over the ensuing 10 years plus the projected SWU inventory at the end of that period. Total costs include power charges, operating costs, administrative expenses, research and development funds, depreciation on capital investments, any use of the DOE uranium feed stockpile, and interest costs on unrecovered federal investment in capital plant, equipment, and inventories. Most of these costs are straightforward, but the depreciation component, interest costs, and period of cost recovery require more detailed explanation. The way in which these factors interact forms the basis of alternative pricing formulas.

Depreciation Costs on Capital Investment. The depreciation issue concerns how completed investments in the GDP, AGC, and AVLIS processes are to be recovered, if at all, through the price of future SWU sales. The DOE now recovers its GDP capital outlays in equal payments over a 37-year period. Through fiscal year 1984, the DOE had depreciated over $2 billion of its total $4.2 billion capital investment in the three diffusion plants, leaving $2.2 billion yet to recover. Of this amount, the DOE plans to recover only 40 percent ($900 million) through future revenues, since it is operating the plants only at about 40 percent of their combined capacity. To date, about

5. U.S. Department of Energy, *Uranium Enrichment Services Criteria* (1979).

$2.3 billion from AGC plant investment (most for the prototype AGC) is also still outstanding. Future SWU rates will be affected by how much of this debt is recovered through prices.

Following standard accounting practices, the DOE recovers its capital investment on enrichment facilities by including a depreciation charge in the SWU price once the plants have begun operation. The GDP depreciation schedule is based on the straight-line depreciation method: the annual depreciation charge reflects total investment divided by the operating life of the plant. The GDP depreciation charge in 1985 was $76 million, and the DOE estimates that the outstanding $900 million GDP investment will be recovered by the mid-1990s. Any future GDP capital outlays will be fully recovered over 37 years.

The DOE would also depreciate the AVLIS plant, if built, using the straight-line method, assuming a plant life of 25 years, shorter than that assumed for the GDP facilities which were upgraded in the 1970s. The DOE would begin to include AVLIS depreciation costs in its price when the plant begins commercial operation, possibly in 1995. At that time, the DOE would divide the total AVLIS investment to date ($1.35 billion) by the 25-year recovery period to get the annual AVLIS depreciation charge. (Capital costs are projected in constant dollars, and thus no inflation correction is included in the depreciation charge.) Any additional AVLIS capital costs would also be depreciated over 25 years and added to the initial depreciation cost.

At this time, it is still unclear how or whether the DOE will recover the $2.3 billion already spent on capital costs for AGC, which has been discontinued in favor of AVLIS development. The CBO analysis assumes that under the current pricing code, the DOE would recover this past investment in equal amounts over a 25-year period, beginning in 1986. Other options would allow the DOE to write off this cost completely, to delay the recovery of the investment until an AVLIS facility becomes operational, or simply to recover the capital costs without imputing an interest charge. These alternative recovery schemes, including complete debt forgiveness, are evaluated in the appendix.

Interest Charge on Unrecovered Government Investment. The DOE includes in its pricing formula an interest charge for the enrichment program's unrecovered investment. The DOE refers to this cost as "imputed interest," and the revenue it generates from enrichment sales becomes part of DOE's annual enrichment budget and is used to cover other costs of the enrichment program.

To calculate the annual imputed interest charge, the DOE first calculates its current unrecovered investment by subtracting any current profits from total capital investment, less cumulative depreciation, and uranium feed and finished SWU product inventory values. It then multiplies this investment by an annual interest rate.

Currently the unrecovered investment on which the DOE charges imputed interest does not include the $1.3 billion in undepreciated GDP capital costs that the DOE has written off. As mentioned earlier, it is still unclear whether the sunk AGC investment will have to be recovered through future enrichment revenues, although the DOE did include imputed interest on this $2.3 billion in the fiscal year 1985 $135 per SWU price.

The interest rate that the DOE charges on its unrecovered investment is based on a combined nominal Treasury rate, which includes a component for inflation. By contrast, the DOE's projections of unrecovered investment are made in constant dollars, which exclude any inflationary effects. By applying a nominal interest rate to constant dollar investment costs, future SWU prices and interest revenue tend to be much higher than if both costs and rates were adjusted for inflation. In fact, DOE interest charges have been based on nominal rates of 6 percent to 10.5 percent in past years, compared with the historical real interest rate on long-term federal borrowing of 2 percent to 3 percent. Currently, this real interest rate is about 7 percent, while DOE's interest rate for calculating its 1985 SWU price was 10.5 percent. This high rate contributes significantly to DOE's high SWU price, especially because of the large investments associated with this program. Aside from GDP power costs, the imputed interest charge is the largest portion of the $135 DOE SWU price, accounting for 33 percent.

<u>Cost Recovery Period</u>. The Atomic Energy Act requires the federal enrichment program to recover its costs over a "reasonable period of time". The DOE depreciates capital costs over a period of 25 to 37 years, but attempts to recover operating, research and development, and other program costs within 10 years. The DOE periodically adjusts its enrichment price to reflect the projected program costs (including depreciated capital and yearly operating expenses) over the next 10 years, and the 10-year recovery schedule has been recognized by the Congress as an acceptable period. This practice reflects the true operating life of the facilities by recovering capital costs over a period greater than 10 years.

<u>Recent Changes in DOE's Current Pricing Policy</u>. The DOE has recently introduced a new pricing incentive aimed at capturing the full 100 percent of its current customers' demand. Under the terms of the current contract, DOE customers are required to take only 70 percent of their enriched uranium at the DOE 1985 contract price of $135 per SWU. The DOE has offered to sell its customers the other 30 percent for $90 per SWU from 1987 through 1990. Alternatively, DOE customers may seek other suppliers for this 30 percent.

Twenty-seven DOE customers have signed up for DOE's "incentive pricing" offer, increasing DOE's total sales by about 5.6 million SWUs from 1987 to 1990, assuming that these sales would have otherwise gone to other enrichment suppliers. At $90 per SWU, this would increase DOE's gross revenue by over $500 million. The DOE estimates that it will cost roughly $45 per SWU to produce these additional SWUs, and thus its net revenue from this pricing arrangement should be about $250 million. Since under DOE's original contracts with some of these customers, the DOE would have sold more than the minimum 70 percent of their requirements at the original contract price of $135 per SWU, DOE's total net revenues from this pricing arrangement will probably be somewhat less than $250 million.

Option II--Revised Current Pricing Policy

As in Option I, this strategy would follow the current DOE pricing equation, based on long-run average cost pricing. The major revision would be imputing an interest rate of 5 percent on all unrecovered government investment, rather than the 10 percent rate the DOE now uses. This 5 percent rate represents CBO's long-term projection for the inflation-adjusted Treasury bond yield. [6]

Another, rather minor change, would simplify the depreciation schedules of existing and future capital investments. Capital investments for both the GDP and AVLIS facilities would be depreciated over 25 years. Like current policy, pricing would be based on recovery of depreciated capital and all operating costs over the next 10 years.

---

6. The Uranium Enrichment Services Criteria states that DOE will include an imputed interest charge in its enrichment price, but does not specify the interest rate that this charge will be based on. While the Government Accounting Office (GAO) has recommended that federal agencies use the Treasury market rate in assigning interest cost (Title 2, subsection 16.8(e) of GAO's Policy and Procedures Manual for Guidance of Federal Agencies), a change in DOE's interest rate assumptions may not require amending the pricing statute contained in the Uranium Enrichment Services Criteria, as long as DOE's prices would still allow for eventual full cost recovery.

   CBO's current long term projections for the nominal Treasury bond rate and the implicit GNP price deflator are 9.6 percent and 4.2 percent, respectively. Thus, the real long-term Treasury borrowing rate assumed in this analysis is 5 percent. See Congressional Budget Office, *The Economic and Budget Outlook: An Update* (August 1985).

Option III--Establish Marginal Cost Pricing Policy

According to economic theory, competitive markets yield prices approximating marginal cost--that is, the cost of producing an incremental unit of output--and such prices lead to the most efficient use of resources. As long as price exceeds marginal cost, society forgoes benefits because consumers are paying more for the additional unit of service than the value of the resources committed to producing it. This suggests that the prices set for government enterprises should be based on marginal cost to the extent that efficiency considerations apply.

This option would exclude all fixed or "sunk" costs which have already been spent through 1984. It would allow the DOE to forgive all earlier GDP and AGC capital investments, recovering only those made from 1985 on. This option would be aimed at lowering U.S. enrichment prices in order to maximize U.S. enrichment sales, and would achieve the most efficient use of resources. Because this policy would never recover DOE's past investments, it might require a change in the statutes--the Atomic Energy Act and the Uranium Enrichment Services Criteria--governing enrichment pricing.

A marginal cost pricing formula would allow DOE's price to be considerably more competitive since it would not include depreciation or interest charges on the $4.5 billion GDP and AGC capital investments made through fiscal year 1984. The price would still include all new capital, power, and other operating costs; research and development expenditures; administration costs; and interest on new program debt. This long-term marginal cost pricing structure would assume an annual imputed interest charge of 5 percent, as in Option II. The price in a given year would reflect the 10-year sum of the above marginal costs divided by the total SWUs available for sale over this period. 7/

Alternatively, the Congress could allow the DOE to postpone recovering the sunk capital investment until an AVLIS plant is operational, at which time DOE's operating costs would be much lower. This would enable the DOE to begin recovering its past investments while still maintaining a competitive price. This alternative marginal cost pricing strategy might or might not require an amendment to the current pricing law.

7. By still using the 10-year averaging period for recovering depreciated new capital and operating expenses, this formula would not reflect true marginal cost pricing. Such a "true" formula would involve pricing SWUs at their individual production costs, which change depending on how many are made. Such an approach, of course, is administratively impractical.

Option IV--Maximize Short-Term Revenues and Long-Term Competitiveness

If the Congress wanted to maximize the revenues generated from the enrichment program in the short term, it could require the DOE to charge the $135 contract ceiling price through the early 1990s. Because DOE's current customers are locked into their contracts for 10 years, unless they are willing to pay a termination penalty, the DOE should not lose signficant sales over this period because of its high, uncompetitive price. After that time, however, many current customers would probably terminate their contracts, possibly resulting in a very large decline in U.S. enrichment revenues. 8/ To minimize the loss in market share and to attempt to sign new customers, the DOE could alter its pricing strategy in 1992 by offering prices based on its marginal costs, as in Option III. These prices, beginning in 1992, would no longer include capital or interest charges for any outstanding AGC or GDP investment.

Since this option would be aimed at achieving maximum price competitiveness in the long term, it assumes that the DOE would deploy an AVLIS plant in 1995 in order to reduce further its operating costs and prices. All AVLIS capital investment would be recovered through depreciation charges, beginning in 1995, and any GDP capital costs incurred from 1992 on would be fully recovered. These marginal cost prices would be very competitive with those projected for either Eurodif or Urenco.

Alternatively, if the Congress intended to maximize program receipts in the short term and was willing to lose significant market share in the long term, the DOE could maintain the pricing structure described under Option IV but forgo the additional program outlays associated with deploying the AVLIS process. While net program receipts would be quite large through the early 1990s, prices under the GDP-only program would not be competitive in the long run, even under marginal cost pricing. The DOE would likely see a large decline in its enrichment sales if it pursued this program strategy. Thus, this program is not a viable strategy to achieving the goals of Option IV, and is not fully evaluated in this report.

---

8. Because the termination charge is small if DOE customers give seven- or eight-year termination notices, it was assumed that the DOE would not suffer significant sales losses through 1991 under the $135 price. Many of DOE's current customers signed their contracts in good faith, however, fully expecting DOE prices to fall gradually in the future with the development of the AVLIS program and DOE's emphasis on becoming a competitive supplier. If prices remain artificially high at $135 per SWU, it is quite possible that many customers will soon begin signing long-term contracts with other suppliers, and begin accepting deliveries from them in 1992.

PROJECTED PRICES UNDER DIFFERENT PRICING AND TECHNOLOGY OPTIONS

Using the four pricing options outlined above, CBO has projected future U.S. enrichment prices for the GDP-only program and for the program assuming an AVLIS plant is built in the 1990s. In general, DOE's current pricing policy (Option I) would require higher SWU charges than either Option II (the revised current policy) or Option III (marginal pricing policy), but lower charges than Option IV, which maintains the $135 SWU charge through 1991. Option I would not allow the U.S. enrichment program to offer long-term competitive prices under either of the two technology programs.

Prices would fall considerably--to the $80 to $110 per SWU range in the next several years--under either Options II or III. Option III would provide the lowest long-term prices, roughly $63 per SWU by the year 2000 using the AVLIS technology. Option II would provide somewhat less competitively priced SWUs, with prices falling to about $72 per SWU by the end of the century under the AVLIS program. If the DOE continues to rely only on the GDP technology in the long term, however, it would not be able to offer competitive prices during the late 1990s, even under Option III. Under Option IV, DOE's price would remain well above those of Eurodif and Urenco until 1992. At that time, its price would fall dramatically to the competitive level of almost $60 per SWU by the year 2000, assuming the AVLIS program is deployed.

Finally, it should be noted that future prices depend ultimately on both production costs, including capital investments, and on the level of projected SWU sales. The CBO price forecasts reflect the level of sales implied by DOE's current long-term contracts, and exclude the additional 5 million SWUs that the DOE has recently contracted to sell from 1987 to 1990 as a result of its new incentive pricing offer. It is likely that future prices will affect DOE's market demand, however, which in turn will alter DOE's future production costs and revenues. Chapter IV evaluates the effects of potential market responses to future U.S. enrichment prices in terms of net program revenues and DOE's ability to recover its past investments. It also includes a discussion on DOE's ability to make payments directly to the U.S. Treasury for unrecovered government costs, based on projections of net revenues under the different pricing options.

Prices Under Option I--Current DOE Pricing Policy

The current U.S. enrichment pricing policy should result in gradually declining prices over the next decade, even if the AVLIS program is not pursued.

In fact, prices would be lowest through 1993 under the GDP-only program, because all further AVLIS development and capital costs would be forgone. (The $2.3 billion sunk AGC costs still would be fully recovered, however.) The AVLIS program would offer lower prices in the long term, however, falling to $80 per SWU by the year 2000.

By 1990, prices should drop to $101 per SWU under the GDP-only program, and to about $106 per SWU under the AVLIS program. This price decline stems partly from DOE's plans to sell off a large portion of its existing SWU inventory in the next few years, rather than utilizing its expensive GDP capacity. Also, the DOE has been able to lower its operating costs significantly by increasing the efficiency of the diffusion plants and by purchasing cheaper off-peak power when available.

Figure 6 shows projected prices for the two technology programs under Option I. Prices under the AVLIS program should fall below those of the GDP-only program by 1994 because of its lower operating costs--assuming an AVLIS plant is deployed in 1995. (Because the DOE sets contract prices based on production costs over the next ten years, the potential AVLIS savings are included in the SWU price before AVLIS is deployed.)

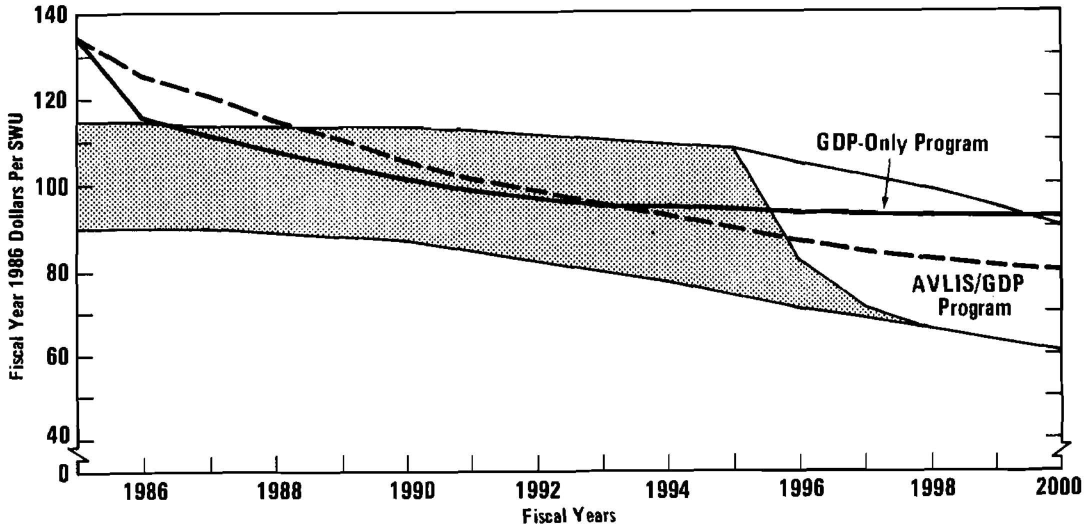
The shaded area in Figure 6 shows the projected range of prices that Eurodif and Urenco will offer in competition with the DOE. Under current pricing practices, DOE would not be able to compete strongly against either supplier in the long term, although its prices might be below those of Eurodif through the mid-1990s. Thus, it is likely that these prices would result in some market losses for the U.S. enrichment program, particularly after the mid-1990s.

Prices Under Option II--Revised Current Pricing Option

The price projections for the two technology programs under Option II are shown in Figure 7. Compared with the price paths in Figure 6 based on current policy, prices would be lower because of the lower imputed interest charge. The price would drop considerably in 1986, and would continue falling under the AVLIS program to about $72 by the year 2000. Prices under the GDP-only program would be higher during the 1990s and beyond, leveling off at about $87 per SWU after 1992.

The AVLIS program would enable the DOE to offer fairly competitive prices by the early 1990s. By the late 1990s, the DOE might have to introduce additional AVLIS capacity to replace the remaining GDP production in

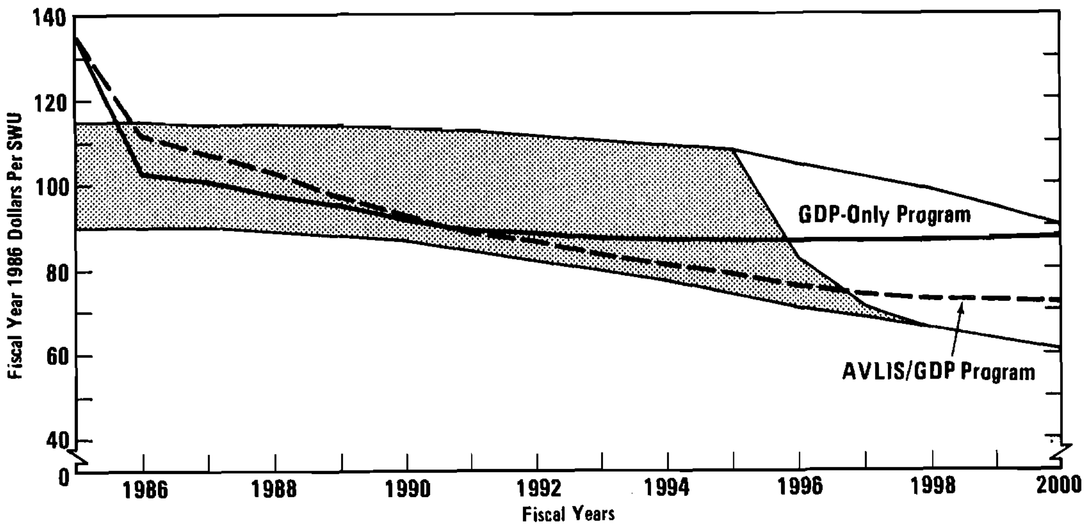
Figure 6.
Prices Under Option I



SOURCE: Congressional Budget Office.

NOTE: The shaded area represents the range of projected Eurodif and Urenco prices, based on their projected production costs.

Figure 7.
Prices Under Option II



SOURCE: Congressional Budget Office.

NOTE: The shaded area represents the range of projected Eurodif and Urenco prices, based on their projected production costs.

order to remain competitive in the next century. The GDP-only program would put the DOE in an unfavorable marketing position beyond the early 1990s.

Prices Under Option III--Marginal Cost Pricing

The U.S. enrichment program would be in a very competitive position in the world enrichment market during the next decade if the Congress allowed the DOE to sell its enrichment services at their marginal costs. Figure 8 shows the projected price paths under Option III for the GDP-only and AVLIS programs. As expected, marginal cost pricing would reduce DOE's prices below those of either Option I or Option II, which are both based on average cost pricing and full capital recovery. Even prices under the GDP-only program would remain competitive until 1995, but over the long term they would increase above those projected for the DOE's major competitors. Under the AVLIS program, however, prices should drop to $67 per SWU by 1995, well below the market prices of DOE's competitors . Again, the DOE might have to increase its AVLIS capacity and replace most GDP production in order to remain competitive past the year 2000.

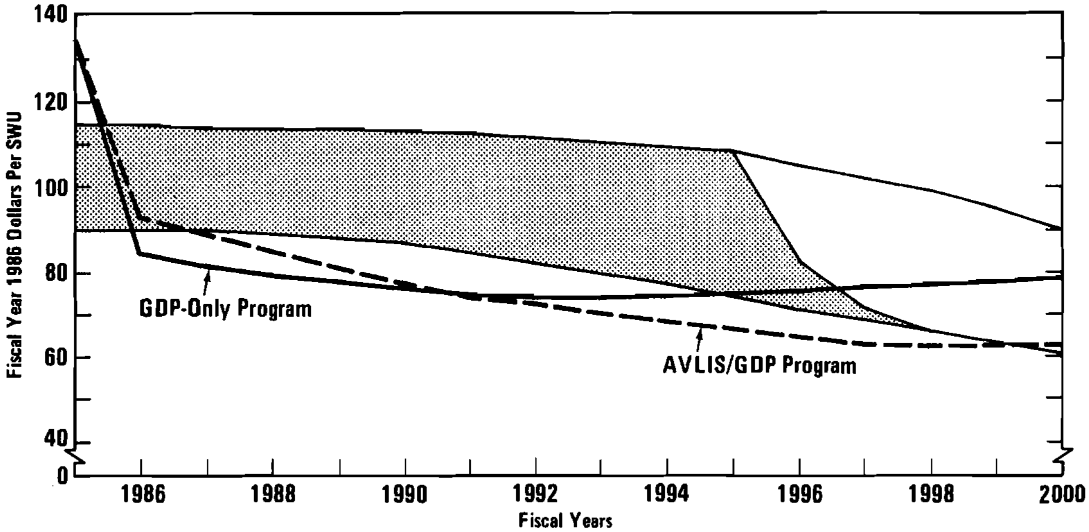
Prices Under Option IV--Maximize Short-Term Revenues and Long-Term Competitiveness

If the DOE charged the artificially high $135 ceiling price through 1991, it would greatly exceed the prices of DOE's competitors, and probably cause a large decline in DOE's sales beginning in 1992. If, at this time, the DOE altered its pricing strategy to strive for maximum price competitiveness and market share, it might offer prices based on its marginal cost, as described in Option III.

In 1992, the U.S. enrichment price would drop significantly to about $71 per SWU, assuming the AVLIS program (see Figure 9). Prices would remain very competitive, falling to roughly $62 per SWU by the year 2000. These low prices would probably bring in new U.S. sales, but it is very uncertain whether current DOE customers would maintain or terminate their contracts after 1992, if the DOE kept its price at $135 per SWU until that time.

Again, if the DOE abandoned the AVLIS program while adopting this pricing strategy, near term program spending would be reduced. U.S. enrichment prices would not be competitive in the long term, however, estimated at about $78 per SWU in the year 2000.

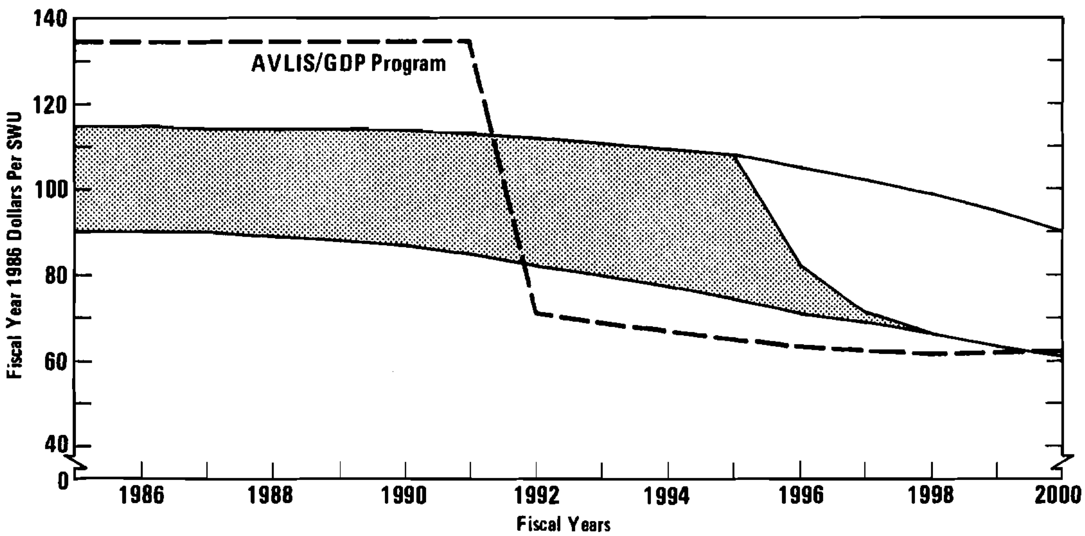
Figure 8.
Prices Under Option III



SOURCE: Congressional Budget Office.

NOTE: The shaded area represents the range of projected Eurodif and Urenco prices, based on their projected production costs.

Figure 9.
Prices Under Option IV



SOURCE: Congressional Budget Office.

NOTE: The shaded area represents the range of projected Eurodif and Urenco prices, based on their projected production costs.

As stressed earlier, the price projections under the different options reflect the level of U.S. demand projected by the DOE based on its current contracts. Future prices will affect DOE's contract commitments and sales, however, which in turn will alter prices. Chapter IV will discuss potential market responses to the price schedules projected under the four pricing options and the budgetary effects of the federal enrichment program under the different price schedules and market demand scenarios.

OTHER ALTERNATIVES

The DOE could adopt other variations of pricing policy in an effort to achieve a more competitive enrichment program. The DOE is currently evaluating a market-based pricing system, whereby it would set its price according to what the competitive market would bear. This system would require the DOE to determine the level of sales it would like to achieve, and decide what price it would have to offer in order to capture this demand. In setting target sales goal and price, the DOE would have to balance its production costs and expected revenues, so that it would recover at least its operating costs. In order to achieve significant market penetration, the DOE might have to stretch out or write off the recovery of some past capital investments.

Another alternative for lowering enrichment prices would be to postpone imputed interest charges on capital investments until the facilities become operational. The DOE now begins imputing interest on all capital outlays as soon as they are spent, while the depreciation charges do not begin until the plant starts commercial operation. This change might significantly reduce prices in the next decade, especially if the DOE decides to build an AVLIS plant during this time. Also, prices would decline because the interest charges now being included on the $2.3 billion outstanding AGC investment would be dropped.

This report does not include projected price, market, and budgetary effects associated with these other pricing strategies. It is important to note, however, that there are numerous methods of pricing U.S. enrichment services, depending on the goal that the program is meant to serve.

CHAPTER IV

POTENTIAL BUDGETARY EFFECTS OF ALTERNATIVE PRICING POLICIES

A choice exists between enhancing the price competitiveness and net receipts of the enrichment enterprise in the long term and maximizing net revenues in the short term. Essentially, the more competitive the Department of Energy's pricing strategies are, the lower its revenues will be in the next decade, possibly requiring net program spending if the AVLIS program is deployed. In the long term, however, this strategy should increase annual net enrichment receipts because of higher sales. Alternatively, if the DOE maintains its high, uncompetitive prices, it will earn substantial net revenues through the year 2000, but could lose a large share of its market eventually.

If the Congress wanted to maximize the program's net revenues through the year 2000, so as to eliminate any additional net federal spending and to allow for significant cost recovery of past program investments, the DOE could maintain its current pricing policy (Option I) and cancel all further development of the AVLIS program. Even assuming a moderate loss in customer sales as a result of uncompetitive prices, net federal revenues would still be the largest of all options for this period. In contrast, adopting the revised pricing strategy of Option II and deploying an AVLIS facility in 1995 might best achieve price competitiveness and long-term budgetary income.

The marginal cost pricing policy (Option III) would result in the most competitive prices and the largest U.S. market share of all the alternatives. Because the potential market of uncommitted world demand that is price-sensitive is not large, however, the additional revenues from the higher sales might not offset the loss in revenue from lower prices. Thus, over both the short and long run, total program net revenues might be lower than those of Option II.

Option IV, in which the DOE would maintain its $135 ceiling price through 1991 and adopt a marginal pricing schedule thereafter, would achieve maximum net program revenues only through 1991. Over the 1985 through 2000 period this option would produce lower net revenues than would Option I because of its significantly lower prices in the 1990s. Because of the initially high price under Option IV, however, DOE sales would be considerably lower during most of the 1990s, and the potential sales increase resulting from its very competitive prices beyond the early 1990s might not compensate for this lost revenue.

POTENTIAL MARKET RESPONSES TO ALTERNATIVE PRICING OPTIONS

The four pricing options would result in different levels of demand for U.S. enrichment services, depending on how price-sensitive the world market is. The market response also would affect the program's revenues and cash flows. To estimate the budgetary effects of the different pricing strategies on the U.S. enrichment program and their ability to recover all costs (including past and future capital investments), CBO examined different demand schedules that might best reflect the potential market responses to changes in DOE pricing.

The price projections presented in Chapter III reflect the annual sales and production levels associated with DOE's current forecast of demand, which is based on current DOE contracts. Thus, this demand forecast does not represent any potential market response, either negative or positive, to changes in future DOE prices. This "base-case" demand assumes that the share of the world market that the DOE will supply--between 45 percent and 47 percent--will remain fairly steady through the 1990s. It also assumes that current customers will purchase between 70 percent and 75 percent of their annual requirements from the DOE through 1990, and about 85 percent thereafter. Under these assumptions, annual civilian sales would be about 9.9 million SWUs in 1985 and 12 million SWUs in 1990, gradually increasing to 18 million SWUs by the year 2000.

If an alternative pricing policy were adopted, most of the market effects would be felt during the 1990s and beyond. Before 1990, even if DOE prices remained uncompetitive, most current customers would not terminate their contracts because of the significant penalty charges they would incur. Moreover, if DOE prices were to fall significantly, U.S. enrichment sales would not increase considerably before 1990 because most uncommitted world demand during this period would be supplied by the secondary SWU market.

In addition to the DOE base-case demand schedule, Figure 10 shows four alternative civilian demand scenarios based on the options presented in Chapter III:

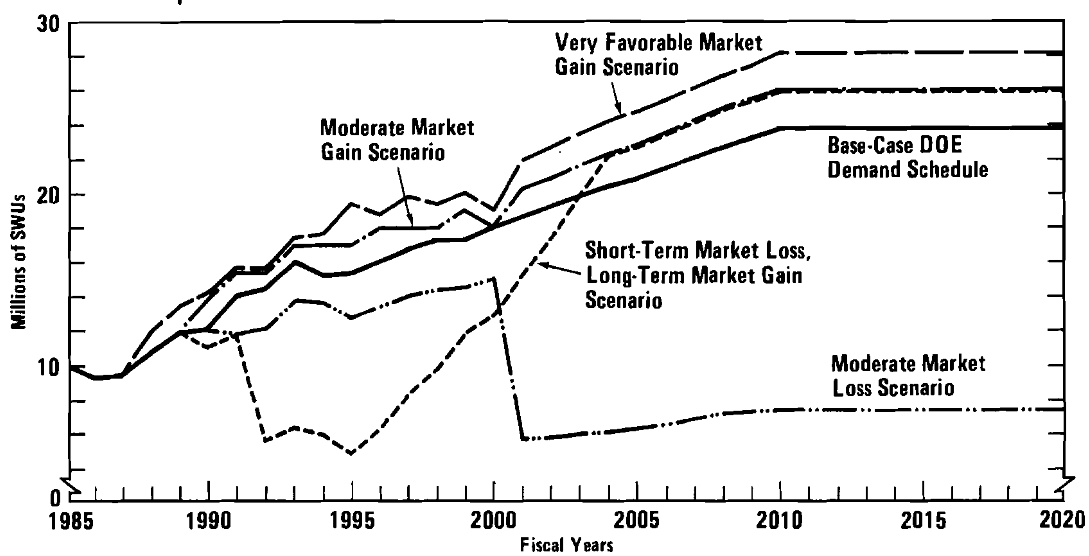
- o Under Option I--moderate market loss;
- o Under Option II--moderate market gain;
- o Under Option III--very favorable market response; and
- o Under Option IV--market loss in the 1990s and significant gain thereafter, assuming AVLIS deployment.

Because of the nature of the market--which is an oligopoly--it is difficult to estimate specific price elasticities of demand, and thus various assumptions must be made, as shown in Table 8.

Demand Scenario Under Option I--Moderate Market Loss

If future DOE prices were to remain above those of its competitors, U.S. enrichment sales probably would be less than the base-case schedule assumes, especially from the mid-1990s on. Under Option I, enrichment prices would be well above those projected for Urenco through 1995, and above those of both Eurodif and Urenco thereafter, even if the AVLIS program

Figure 10.
Alternative DOE Civilian Sales Projections Under Different Market Response Scenarios



SOURCE: Congressional Budget Office.

TABLE 8. ASSUMPTIONS USED TO DEVELOP FOUR SCENARIOS FOR MARKET RESPONSE, BY SALES PERIOD (In fiscal years)

Sales Period	Market Response
	Moderate Market Loss
1985-1990	None; customers take their currently contracted amounts, averaging 75 percent of their annual requirements.
1991-1994	DOE services between 70 percent and 75 percent of its current customers' annual requirements, compared with roughly 80 percent assumed in the DOE base-case demand schedule.
1995-2000	The DOE services 90 percent of the domestic demand assumed in the DOE base-case demand schedule, and about 75 percent of the foreign demand. The DOE's share of the world market will fall to roughly 40 percent, compared with 47 percent under the base-case demand schedule.
2001-2020	The DOE services only 50 percent of the domestic demand currently assumed, and loses all its foreign contracts.
	Moderate Market Gain
1985-1989	None; customers are assumed to purchase any uncommitted SWU requirements from the secondary SWU market or other suppliers.
1990-2000	The DOE services 50 percent to 55 percent of world market demand, compared with roughly 47 percent under the base-case demand schedule.
2001-2020	The DOE services 60 percent of world market demand.
	Very Favorable Market Gain
1985-1987	None.
1988-2000	The DOE services between 50 percent and 60 percent of world market demand.
2001-2020	The DOE services 65 percent of world market demand.
	Short-Term Market Loss, Long-Term Market Gain
1985-1989	None.
1990-1991	The DOE services 70 percent of its current customers' annual requirements.
1992-1995	The DOE services 50 percent of the domestic demand assumed in the DOE base-case demand schedule, and about 25 percent of the foreign demand. The DOE's share of the world market will fall to 15 percent in 1995.
1996-2000	The DOE's world market share increases gradually to 40 percent.
2001-2020	The DOE services between 45 percent and 60 percent of world market demand.

SOURCE: Congressional Budget Office.

were pursued. The potential market response to Option I assumes that the DOE would suffer a small loss in sales in the mid-1990s, with a more significant loss in later years. U.S. enrichment sales would be 12.8 million SWUs in 1995 and 15.1 million SWUs in 2000, compared with the base-case projections of 15.3 million and 18 million SWUs, respectively. Table 9 shows the total civilian SWU sales projections under the alternative demand projections.

TABLE 9. DOE CIVILIAN SWU SALES UNDER ALTERNATIVE DEMAND PROJECTIONS (By fiscal year, in millions of SWUs)

Year	DOE Base-Case Demand	Moderate Market Loss	Moderate Market Gain	Very Favorable Market Gain	Short-Term Market Loss, Long-Term Market Gain
1985	9.9	9.9	9.9	9.9	9.9
1986	9.3	9.3	9.3	9.3	9.3
1987	9.4	9.4	9.4	9.4	9.4
1988	10.7	10.7	10.7	12.0	10.7
1989	11.8	11.8	11.8	13.5	11.8
1990	12.0	12.0	14.0	14.2	11.1
1991	14.0	11.8	17.0	15.7	11.8
1992	14.4	12.1	17.0	15.7	5.7
1993	16.0	13.8	18.0	17.4	6.4
1994	15.2	13.6	17.0	17.6	6.1
1995	15.3	12.8	17.0	19.3	4.9
1996	16.0	13.4	18.0	18.8	6.4
1997	16.8	14.1	18.0	19.8	8.4
1998	17.2	14.5	18.0	19.5	9.9
1999	17.3	14.6	19.0	20.0	11.9
2000	18.0	15.1	18.0	19.0	12.9

SOURCE: Congressional Budget Office.

NOTE: The base-case demand estimates reflect the DOE projections provided to the Congressional Budget Office by the Office of Uranium Enrichment and Assessment on March 5, 1985. They do not include the market responses to DOE's recent incentive pricing offer, which will increase sales by about 5 million SWUs from 1987 to 1990.

CBO developed the alternative demand schedules based on projected customer response to future DOE prices under the four pricing options discussed in Chapter III. U.S. military SWU sales, which are not included, would remain the same under all demand schedules.

Demand Scenario Under Option II--Moderate Market Gain

If the DOE adopted Option II, reflecting a lower imputed interest rate, SWU prices would be marginally competitive with both Eurodif and Urenco by the early 1990s, assuming an AVLIS plant was deployed in 1995. To assess the potential budgetary effects of this program, it was assumed that the DOE would capture roughly 50 percent to 55 percent of the world market during the 1990s and 60 percent of that market beyond the year 2000, compared with the base-case projections of 45 percent to 47 percent. It was also assumed that DOE sales would not increase significantly under the GDP-only program because U.S. enrichment services still would cost significantly more than their competitors, especially after the mid-1990s.

This moderate market gain schedule assumes sales of 17 million SWUs in 1995 and 18 million SWUs in 2000 (see Tables 9 and 10). By the year 2000, the difference between DOE's base-case projections and this demand schedule becomes smaller. The base-case projections assume that current customers will take about 85 percent of their annual demand from the DOE at that time. This relatively high level of continued customer demand, however, probably would not be achieved unless the DOE offered the more competitive prices provided by Option II.

Demand Scenario Under Option III--Very Favorable Market Response

Under Option III, U.S. enrichment prices would be very competitive using the AVLIS technology. The potential market response to these prices would increase DOE's annual civilian sales to about 19 million SWUs between 1995 and 2000.

This scenario of a very favorable market gain, based on the AVLIS program, assumes that the DOE would service 55 percent to 60 percent of the world enrichment market by the late 1990s, and 65 percent beyond the year 2000 (see Table 8). It was assumed that there would be no significant market response under the GDP-only program because, while prices would be competitive through the early 1990s, prices would not be competitive after 1995, when most of the market response would occur.

Demand Scenario Under Option IV--Market Loss in the 1990s and Significant Market Gain Thereafter

If the DOE pursued the two-tiered pricing strategy of Option IV, the United States probably would lose a large share of both its domestic and foreign customers beginning in the early 1990s. The market demand scenario developed in response to this pricing option assumed that U.S. sales would fall to only 4.9 million SWUs in 1995, compared with the base-case demand projection of 15.3 million SWUs (see Table 9). At this time, the U.S. share of the world enrichment market would be about 15 percent, but it would gradually increase in the following years in response to lower prices achieved through marginal cost pricing and deployment of an AVLIS plant (see Table 8).

Beyond the year 2000, DOE's market share would increase steadily from 45 percent to 60 percent, which would be considerably larger than current long-term projections of about 47 percent. U.S. enrichment sales would not, however, be as large as the demand projected under Option III. It was assumed that some current DOE customers who would terminate their contracts in the early 1990s because of the $135 price would not re-sign with the DOE in later years, even though U.S. prices would be lower than other suppliers by then. This reflects the belief that many DOE customers would resent being charged the artificially high $135 ceiling price while they were locked into their contracts, and would seek long-term contracts with Eurodif or Urenco in spite of potentially lower U.S. prices in the long term.

CASH-FLOW PROJECTIONS FOR THE ENRICHMENT PROGRAM UNDER THE FOUR PRICING OPTIONS

CBO projected net program revenues under the four alternative pricing options. Net revenues reflect the difference between annual revenues from both civilian and military SWU sales and program outlays. (Negative net revenues would reflect net federal spending for the program.) Annual net revenues were discounted, using a real annual discount rate of 5 percent. 1/ The cash-flow projections represent the summed net revenue streams, beginning in fiscal year 1985. 2/

1. Discounting is a way to calculate, in today's dollars, the value of a future expenditure or future stream of annual expenditures. The result is called present value. A future expenditure is discounted to its present value using the following formula:

$$\text{Present Value} = \text{Future Value}/(1 + i)^n,$$

where n = the number of years between the present year and the year in which the expenditure is made, and i = the discount rate.

2. While revenues include charges for depreciation on past capital investments and imputed interest, program outlays simply reflect annual operating and capital expenses incurred by the federal government. Thus, it would be expected that net revenues would be positive in years in which there is little new capital spending and negative when the federal government is building a new facility, such as an AVLIS plant, when capital outlays may be large.

The DOE SWU price is based on combined civilian and military DOE sales. The price that DOE charges for military SWU production is considerably less than this price, however, because it excludes capital recovery and imputed interest charges. The CBO net revenue projections assume these lower military SWU prices for their associated portion of total DOE sales.

The analysis suggests that, because only a small portion of the world market is open to price competition, a GDP-only program with current pricing might accrue the greatest revenues between now and the year 2000. But, pricing options that maximize program cash flow through the year 2000 might not produce the largest net budgetary receipts between 2000 and 2020 for two reasons. First, the most significant market response to DOE price changes probably would not occur until the mid-1990s. Thus, options that maintain relatively high prices would produce higher revenues throughout the next decade than those options that would have lower, more competitive prices. The more competitively priced options, however, would probably gain greater sales after the 1990s than would the higher priced options, resulting in higher annual net revenues in the long term.

Second, if the DOE decided to build an AVLIS plant in the early 1990s, program outlays would be quite large, possibly outweighing annual receipts until the benefits of this new technology were felt. Thus, even though the plant would begin operation in 1995, total net revenues through the year 2000 might be negative or only slightly positive. Because the new plant should operate for at least 25 years, however, evaluating net program revenues through the year 2020 would better reflect the potential budgetary returns of pursuing the AVLIS program. Carrying the period of analysis beyond 2000 does suggest that AVLIS might be economic, since annual net revenues for the later period would be greater than those under the GDP-only program.

Pricing Options That Maximize Net Revenues Through Year 2000

Through the year 2000, the DOE could enhance its net receipts by continuing to use its current pricing policy, Option I. Program cash flow would be largest during this period if the federal government did not fund the AVLIS project, thus keeping program spending at a minimum.

Prices under Option IV would achieve the largest program cash flow through 1991, even if AVLIS were deployed, but through the year 2000 total net revenues would be smaller than those projected under Option I. Options II and III, which would offer more competitive prices in the short term, would have significantly lower cash balances, and, in fact, would require net federal spending through 2000 if the AVLIS program were fully developed.

Table 10 shows the discounted net receipts for the four pricing options through the year 2000 under both the DOE base-case demand schedule and the alternative scenarios based on market demand response. Even assuming that the DOE suffers a moderate drop in sales (the moderate market loss scenario) because of the uncompetitive prices associated with Option I, net revenues through the year 2000 would be $2,740 million for the GDP-only program, and $950 million for the AVLIS/GDP program. By comparison, the AVLIS/GDP program under Options II and III would require $19 million and $1,970 million in net federal spending, respectively, even assuming the higher DOE sales projected for the respective market gain scenarios.

Option IV pricing, assuming that AVLIS is deployed to lower long-term prices, would result in net revenues of $304 million through the year 2000, assuming lower U.S. enrichment sales during the 1990s because of the $135 SWU price charged through 1991. Alternatively, if the DOE followed this pricing strategy but abandoned the AVLIS program in order to maximize program receipts through 1991, program cash flow during this period would be $2,551 million (compared with $1,898 million assuming AVLIS), under the base-case demand schedule. Over the 1985 through 2000 period, however, total program revenues would be lower than those projected for the option that would maximize net revenues over this period (the GDP-only program under Option I), stemming from lower sales during the 1990s because of the initially high $135 ceiling price.

Figures 11 through 14 present the annual net program revenue (or net spending) projections for the four pricing options, both with and without the projected market demand response scenarios. In general, yearly net receipts will be larger under the GDP-only program until about 1997 or 1998, under the different pricing options. The figures illustrate, however, that the AVLIS program will achieve larger annual net revenues beyond this time.

Pricing Options That Maximize Long-Term Net Revenues

If the Congress was primarily concerned with the long-term budgetary goals of the U.S. enrichment program, the most economic program strategy might be to deploy the AVLIS technology and to make U.S. enrichment prices more competitive. Although the net revenues might still be highest over the 1985 through 2020 period under Option I, assuming the GDP-only program, net program receipts over the 2001 through 2020 period would be significantly larger under Option II. Thus, if the analysis period were extended beyond

TABLE 10. SHORT-TERM NET RECEIPTS OF THE ENRICHMENT PROGRAM UNDER FOUR PRICING OPTIONS AND TWO INVESTMENT STRATEGIES, FISCAL YEARS 1985-2000
(In millions of discounted fiscal year 1986 dollars)

Pricing Policy Market Scenario	Investment Strategy GDP-Only	AVLIS/GDP
Option I		
Base-case demand	2,910	1,335
Moderate market loss	2,740	950
Option II		
Base-case demand	1,755	-291 b/
Moderate market gain	NA a/	-19 b/
Option III		
Base-case demand	-168 b/	-2,169 b/
Very favorable market gain	NA a/	-1,970 b/
Option IV		
Base-case demand	NA c/	645
Market loss in 1990s, market gain thereafter	NA c/	304

SOURCE: Congressional Budget Office.

NOTES: The cash-flow estimates assume an annual discount rate of 5 percent.
NA = not applicable.

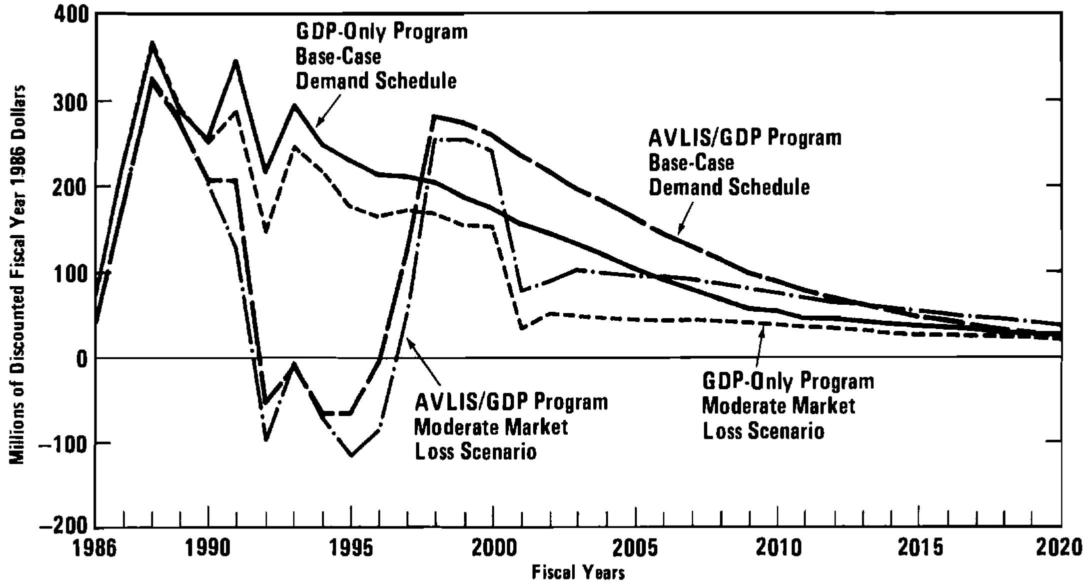
a. Market response scenarios were not developed for the GDP-only program under Options II and III, in which prices would be competitive in the short-term, but not beyond the mid-1990s. Most likely, net program revenues would be lower than those assumed under the base-case demand schedule, since any significant market response should occur after the mid-1990s, when the DOE enrichment sales probably would fall.

b. Negative program cash flows represent discounted net federal spending requirements.

c. Option IV assumed that the AVLIS program would be pursued to enable DOE prices to be very competitive in the long term. If Option IV were adopted while continuing to rely on the GDP-only capacity, net program revenues would be maximized through 1991 ($2,551 million). But over the 1985 through 2000 period, net receipts would be $2,874 million, assuming the base-case demand schedule, less than those projected for the GDP-only program under Option 1. Furthermore, actual net revenues would probably be significantly smaller because of contract cancellations in the 1990s resulting from the high $135 charge through 1991.

Figure 11.

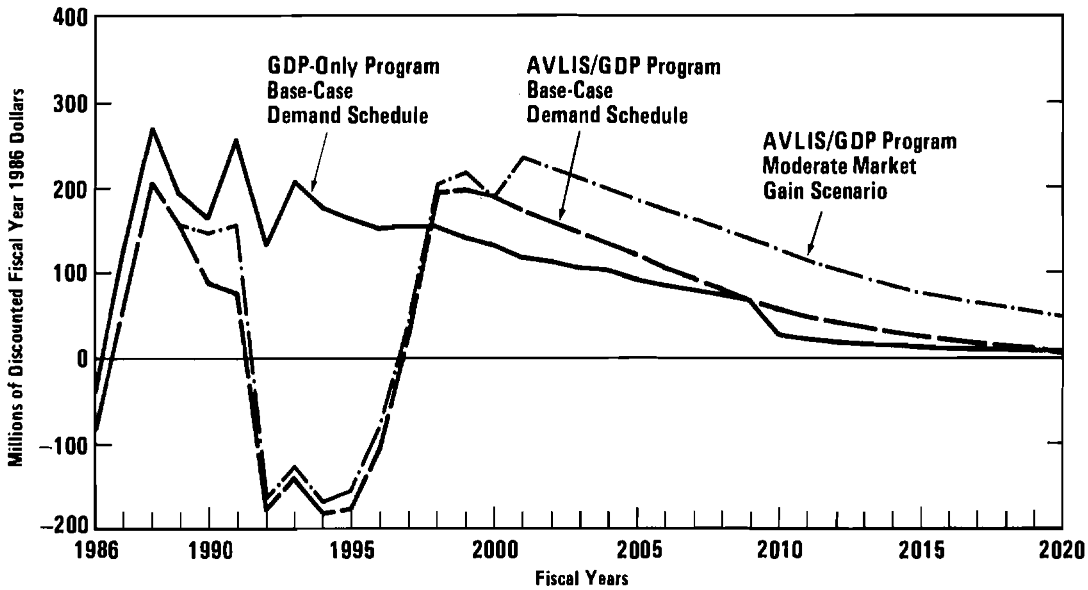
Annual Net Revenues Under Option I



SOURCE: Congressional Budget Office.

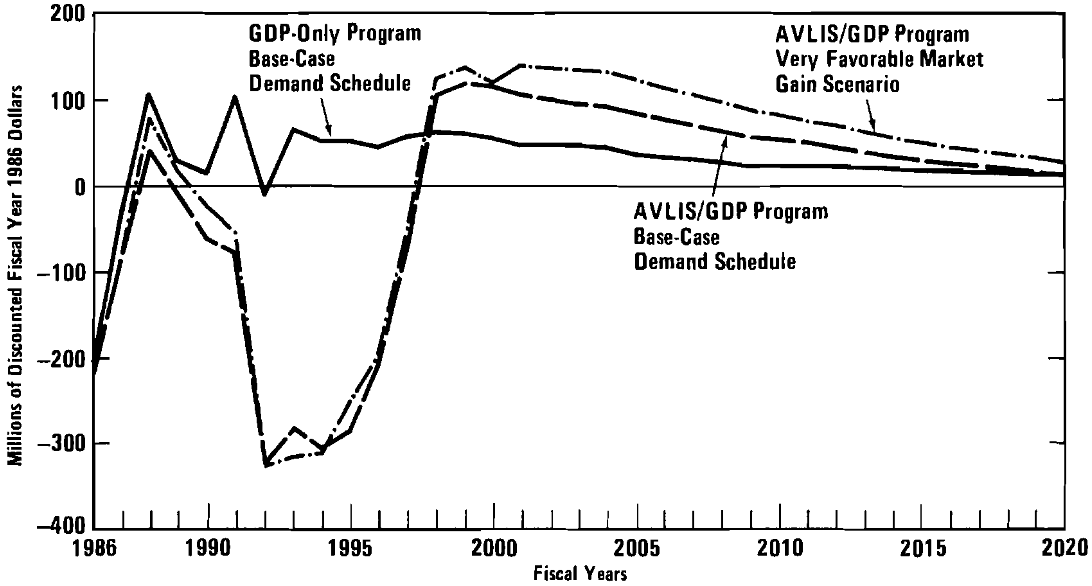
Figure 12.

Annual Net Revenues Under Option II



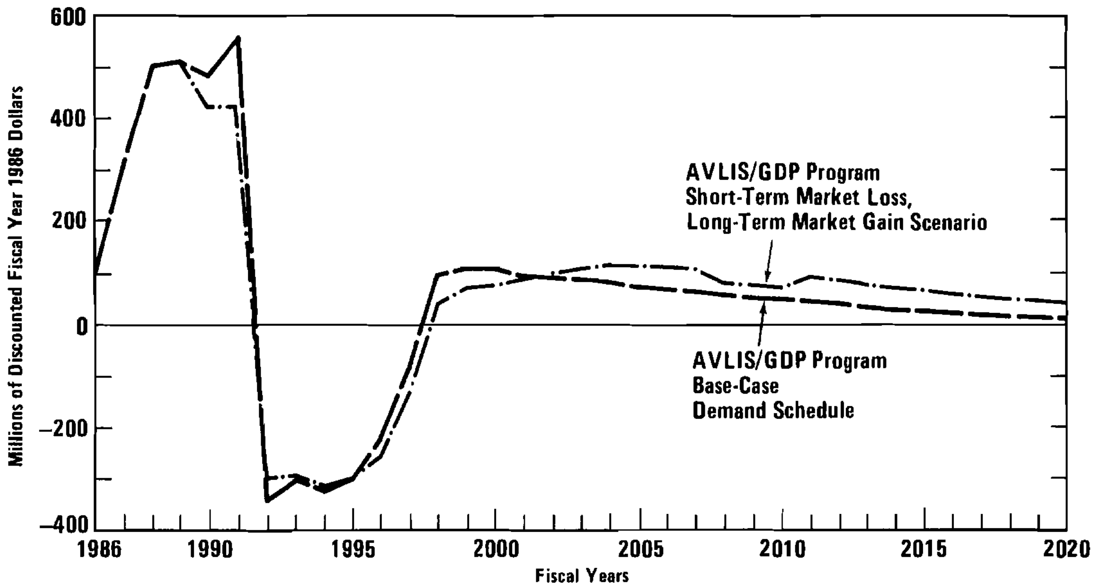
SOURCE: Congressional Budget Office.

Figure 13.
Annual Net Revenues Under Option III



SOURCE: Congressional Budget Office.

Figure 14.
Annual Net Revenues Under Option IV



SOURCE: Congressional Budget Office.

2020, the economic benefits of both lower prices and AVLIS probably would outweigh those of the GDP-only program under Option I, because of the higher annual net revenues of the AVLIS program in future years.

Table 11 presents the discounted net revenues for the enrichment program for fiscal years 1985 through 2020. Over this period, Option I under the GDP-only program would achieve a program balance of $3,179 million, even assuming a drop in U.S. enrichment sales. Option II, assuming that AVLIS is deployed, would result in a slightly smaller program cash flow, $2,587 million, over this period. Option IV would produce considerably smaller net revenues ($1,936 million), even assuming the associated increases in sales, and Option III would require net federal spending of $294 million.

Net receipts during the 2001 through 2020 period demonstrate the merits of pursuing the AVLIS program. Over this time frame, the DOE would realize the largest budgetary benefits by adopting Options II or III ($2,606 million or $1,676 million, respectively), assuming the positive market response scenarios projected for the AVLIS program. The GDP-only program, on the other hand, would produce much lower net revenues under any pricing strategy, even without considering the likely drop in sales that might occur.

The marginal cost pricing strategy, Option III, would provide the most competitive prices and probably achieve the largest world market share for the U.S. enrichment program in the long run. The higher sales, however, probably would not offset the very low SWU prices, and thus the overall net proceeds of this program would be smaller than the Option II pricing strategy.

REPAYING CAPITAL INVESTMENTS

The Office of Management and Budget (OMB) recently has recommended that the DOE should begin to repay the U.S. Treasury for past investments in the uranium enrichment program. Legally, the DOE is required to recover the full costs of the program through its receipts, but the pricing statutes do not stipulate that the DOE is obligated to make repayments on capital investments, including interest payments, to the Treasury. While under current law the DOE must charge an enrichment price that assures long-run full cost recovery--that is, revenues must offset program spending--the department legally has no outstanding debt to the Treasury. The program has not fully recovered its past investment costs, however, so OMB has suggested that the DOE be put on a fixed repayment schedule.

TABLE 11. LONG-TERM NET RECEIPTS OF THE ENRICHMENT PROGRAM UNDER FOUR PRICING OPTIONS AND TWO INVESTMENT STRATEGIES, FISCAL YEARS 1985-2020
(In millions of discounted fiscal year 1986 dollars)

	Investment Strategy			
	1985-2020		2001-2020 a/	
Pricing Option/ Market Scenario	GDP-Only	AVLIS/ GDP	GDP-Only	AVLIS/ GDP
Option I				
Base-case demand	4,261	3,370	1,351	2,035
Moderate market loss	3,179	2,351	709	1,401
Option II				
Base-case demand	2,736	1,084	981	1,375
Moderate market gain	NA b/	2,587	NA b/	2,606
Option III				
Base-case demand	395	-1,058c/	563	1111
Very favorable market gain	NA b/	-294c/	NA b/	1,676
Option IV				
Base-case demand	NA d/	1,662	NA d/	1,017
Market loss in 1990s, market gain thereafter	NA d/	1,936	NA d/	1,632

SOURCE: Congressional Budget Office.

NOTES: The cash flow estimates assume an annual discount rate of 5 percent.
NA = not applicable.

a. Net revenues over the 2001 through 2020 period are broken out to show the likely budgetary advantage of pursuing more competitive prices in the long run, which are not clearly evident when examining the net revenue projections over the entire 1985 through 2020 period.

b. Market response scenarios were not developed for the GDP-only program under Options II and III, in which prices would be competitive in the short-term, but not beyond the mid-1990s. Most likely, net program revenues would be lower than those assumed under the base-case demand schedule, since any significant market response should occur after the mid-1990s, when the DOE likely would see a drop in its enrichment sales.

c. Negative program cash flows represent discounted net government spending requirements.

d. Option IV assumed that the AVLIS program would be pursued to enable DOE prices to be very competitive in the long term. If Option IV were adopted while continuing to rely on the GDP-only capacity, long-term prices would not be competitive, and U.S. enrichment sales would probably be lower than those assumed in the moderate market loss scenario. In the long term, net revenues for this program would be lower than those under Option I, assuming the GDP-only program.

Under the repayment plan, part of the enrichment program's annual revenues would be paid directly to the Treasury to recover outstanding investments. 3/ In years when repayment plus outlays exceed revenues, the Congress might have to provide net appropriations to the program. If the Congress maintains its current budgetary policy of zero net program appropriations, however, while requiring the DOE to apply part of its revenues toward Treasury repayment, the department might have to cut back its level of spending and possibly delay the AVLIS program. Alternatively, it could charge higher SWU prices to earn additional revenue for repayment; in the long term, however, this would reduce DOE's demand and net receipts.

The streams of annual net revenues shown in Figures 11 through 14 illustrate the amount of money that the DOE could pay to the Treasury in each year, without requiring annual net program appropriations. (Under some of the pricing options, the program would need net federal spending in some years, even without any repayment requirements.) In general, those options that would enhance net receipts in the short term would allow the highest repayment plan in the near future (assuming the Congress continues its zero net appropriations policy). Alternatively, if the repayment schedule was stretched far into the future, the DOE might be better able to to repay its capital investments under options that maximize long-term net revenues through more competitive pricing policies.

SUMMARY

The budgetary comparisons of the four pricing options point out trade-offs between achieving competitive U.S. enrichment prices and minimizing the short-term budgetary costs of this program. Those program strategies that would allow the DOE a much more favorable marketing position in the long term would not achieve the largest net revenues over the next decade.

The GDP-only program would maximize the net proceeds of the federal enrichment program through the year 2000, especially under current pricing policy, Option I. Under this option, U.S. enrichment prices still would be uncompetitive, however, and the DOE might lose a large share of its domestic and foreign sales. Program policies aimed at increasing the U.S. enrich-

3. The OMB and DOE have not yet reconciled differences over how much money the DOE will be required to pay the Treasury. In part, these differences include whether the full AGC investment must be recovered, whether the proposed Treasury payments should include interest charges on the program's unrecovered investments, and the time period over which the DOE will be able to make these payments.

ment market share--adopting the more competitive pricing structure under Options II or III and fully deploying the AVLIS program--could require substantial net federal spending through the mid-1990s, but probably would achieve larger annual net revenues over the next century than would the current program. Thus, pursuing a more competitive enrichment program to increase U.S. sales might be most economic if the program's budgetary effects are considered well into the next century.

APPENDIX

APPENDIX

ALTERNATIVE RECOVERY SCHEDULES FOR THE OUTSTANDING AGC INVESTMENT AND EVALUATION OF THE AGC PROGRAM

In June 1985, the Secretary of the Department of Energy (DOE) announced plans to discontinue any further development of the Advanced Gas Centrifuge (AGC) process, and to devote all future research and development funding for the enrichment program to the AVLIS technology. The DOE has cancelled many of its AGC contracts, essentially terminating the program. Through fiscal year 1984, however, the DOE had already invested $2.3 billion (in fiscal year 1986 dollars) in the initial construction of the Gas Centrifuge Enrichment Plant (GCEP), the facility that would have housed the AGC machines if that process had been commercially deployed. In addition, $0.6 billion in AGC costs will be spent through fiscal year 1987, primarily to close down the GCEP facility.

The DOE has not yet determined how it will recover the outstanding AGC capital investment. The CBO analysis in Chapters III and IV assumed that under the current pricing (Option I) and revised current pricing (Option II) policies, based on full program cost recovery, the DOE would recover this past investment over a 25-year period beginning in 1986. This appendix evaluates several other treatments of this capital investment repayment, including full forgiveness of the debt.

This section also presents the AGC cost data used by the Process Evaluation Board (PEB), a group appointed by the Secretary of Energy to compare the engineering and economic aspects of the AVLIS and AGC programs for the June 1985 advanced technology selection decision. Based on these AGC program cost and deployment schedules, CBO estimated associated price paths and net program revenues under the four pricing options. These projections compare the relative merits of the AVLIS and AGC programs at the time of the June 1985 selection decision, in terms of their ability to achieve competitive U.S. enrichment prices and maximum net revenues. Because the AGC project has been partially terminated and would be more costly to restart at this time, the PEB cost estimates for this program are no longer current.

ALTERNATIVE OPTIONS FOR RECOVERING OUTSTANDING AGC CAPITAL INVESTMENTS

DOE's price for enrichment services will be considerably higher if it is required to recover the full $2.9 billion AGC investment, plus interest payments, through its enrichment revenues over the next 25 years. Under the current program, the AGC capital and interest charge would account for 20 percent of CBO's projected 1986 enrichment price of $116 per SWU (under the GDP-only program). Under Option II, this AGC charge would reflect roughly 15 percent of the projected 1986 SWU price of $103. Option III does not include any capital or interest charges for this outstanding AGC investment, since those would be forgiven under the marginal cost pricing policy. Option IV, which would artificially maintain the $135 price until 1991 and assume marginal cost pricing thereafter, would not reflect any AGC recovery charges in its prices explicitly. Its high net revenues through 1991, however, should allow at least partial AGC investment recovery.

This appendix evaluates three alternatives for treating the outstanding AGC investment under the Option I and II pricing strategies. These alternatives include total forgiveness of the investment debt; a delayed repayment schedule whereby the DOE would begin recovering the AGC investment if and when an AVLIS plant is deployed (at which time DOE's operating costs would fall considerably); and recovery of the capital investment, but not the imputed interest charges, through future enrichment revenues beginning in 1986.

Full Forgiveness of the Outstanding AGC Investment

DOE enrichment prices would drop considerably under both the GDP-only and AVLIS programs if the AGC capital recovery and interest charges were dropped. Under current pricing (Option I), the GDP-only program price would fall to $81 per SWU by 1995, compared with $94 per SWU if the full AGC debt were recovered over 25 years beginning in 1986. The AVLIS program price would fall to $77 per SWU by 1995, compared with $90 per SWU under full AGC cost recovery. These prices would be marginally competitive if AVLIS were deployed, while GDP-only program prices would still not be competitive beyond the mid-1990s.

If the revised current pricing strategy (Option II) were adopted, prices would decrease to $78 per SWU under the GDP-only program and $69 per SWU under the AVLIS program in 1995, compared with $87 and $79 per SWU, respectively, assuming full AGC cost recovery. Either technology would enable the DOE to offer very competitive prices through the mid-1990s, but only the AVLIS program would maintain the program's competitiveness in the long term.

Again, the trade-off between lower SWU prices and short-term net program revenue is evident. If AGC recovery charges were not included in the prices, the DOE would receive net program revenues of about \$0.74 billion through the year 2000 under Option I, assuming the GDP-only program and the DOE base-case demand schedule (see Table A-1). If the AGC investment were fully recovered through the higher prices, net program receipts under the same program assumptions would be much higher, about \$2.91 billion through 2000. Comparable budgetary estimates for the AVLIS program would be -\$0.84 billion, assuming AGC debt forgiveness, and \$1.34 billion under full AGC cost recovery.

Similarly, if AGC recovery charges were not required, net revenues under Option II would be considerably lower for both the GDP-only and AVLIS programs. Net revenues through the year 2000 would be about \$0.22 billion and -\$1.76 billion for these two programs, respectively, compared with \$1.76 billion and -\$0.29 billion, respectively, assuming full AGC cost recovery.

If the AGC investment were forgiven, DOE's total net revenues over the 1985 through 2020 analysis period would still be largest for Option I under the GDP-only program. Net receipts would be \$1.78 billion for this program, compared with \$0.89 billion for the AVLIS program under Option I. Again, the cash flow for the AVLIS program over the 2001 through 2020 period would be much larger than that of the GDP-only program. Furthermore, the AVLIS prices would be fairly competitive in the long term, probably resulting in higher U.S. enrichment sales. Thus, the AVLIS program under Option I might be the most economic in the very long term, if the AGC debt is completely forgiven.

Delayed Repayment of the AGC Investment

If the DOE were allowed to delay recovering its outstanding AGC investment until 1996, when an AVLIS plant would be in commercial operation, U.S. enrichment prices would fall somewhat in the next decade. Since prices reflect program charges incurred over the next 10 years, however, prices from 1987 on would reflect the AGC recovery charges, and thus the price decline would not be large. In fact, prices from the mid-1990s on might be larger under the delayed recovery schedule, since the interest payments on the unrecovered AGC investment remaining at this time would be greater. (This analysis assumed that the DOE would charge neither AGC capital nor interest payments in its prices until 1996, and then would begin to recover the full outstanding AGC investment over 25 years, with interest.)

TABLE A-1. DISCOUNTED NET PROGRAM REVENUE UNDER VARIOUS AGC INVESTMENT RECOVERY ALTERNATIVES (By fiscal year, in billions of fiscal year 1986 dollars)

Recovery Alternative	GDP-Only		AVLIS/GDP	
	Option I	Option II	Option I	Option II
Recover Full AGC Capital and Interest Costs, Beginning in 1986				
1985-2000	2.91	1.76	1.34	-0.29
1985-2020	4.26	2.74	3.37	1.08
Forgive AGC Capital and Interest Costs				
1985-2000	0.74	0.22	-0.84	-1.76
1985-2020	1.78	0.78	0.89	-0.65
Delay AGC Capital and Interest Recovery Until 1996				
1985-2000	NA	NA	0.75	-0.76
1985-2020	NA	NA	3.44	1.09
Recover AGC Capital Costs, But Do Not Impute Interest				
1985-2000	1.64	1.12	0.06	-0.93
1985-2020	2.90	1.90	2.01	0.40

SOURCE: Congressional Budget Office.

NOTES: All net revenue projections reflect U.S. enrichment sales assumed in the DOE base-case demand schedule. The revenues assume an annual real discount rate of 5 percent.

NA = Not applicable.

AVLIS program prices under Option I would be roughly $96 per SWU in 1990 and $93 per SWU in 1995, compared with prices of $106 and $90 per SWU, respectively, if the AGC investment were recovered beginning in 1986. (The delayed AGC repayment alternative was evaluated only for the AVLIS program.) These delayed recovery schedule prices would still be above those projected for Urenco and would not be competitive with either of the two European enrichment suppliers beyond the mid-1990s.

If Option II were followed, assuming a delay in the AGC investment recovery, AVLIS prices would be quite competitive with both Urenco and Eurodif in the next decade, with prices of $87 and $80 per SWU in 1990 and 1995, respectively. Beyond that time, if U.S. prices are to remain competitive, the DOE may have to deploy additional AVLIS capacity to replace more GDP production.

Through the year 2000, net program receipts would be lower if AGC costs were not charged until 1996, under either Option I or II (see Table A-1). Total net receipts would be $0.75 billion and -$0.76 billion, respectively, compared with $1.34 billion and -$0.29 billion under the AGC recovery schedule beginning in 1986. Over the long term, however, the program cash flow between these two recovery schedules would be roughly equal. The price decline in the next decade associated with delaying this repayment might well attract additional U.S. enrichment customers, however, achieving higher net revenues under this program strategy.

Recover AGC Capital Investment Beginning in 1986, But Do Not Impute Interest

If the DOE did not include imputed interest charges on unrecovered AGC costs, while still recovering the capital costs beginning in 1986, U.S. enrichment prices would be about $2 to $10 per SWU lower through the year 2000. In 1995, the program price under Option I would be $87 per SWU under the GDP-only program and $83 per SWU under AVLIS, compared with $94 and $90 per SWU, respectively, if imputed interest were included. Similary, prices under Option II would be $84 and $75 per SWU for the two programs, respectively, compared with $87 and $79 per SWU, respectively, assuming both AGC capital and interest charges. Under Option I, prices still would not be strongly competitive under either technology program. Under Option II and this AGC investment recovery plan, however, prices for the AVLIS program would be very competitive.

Without charging interest on unrecovered AGC investment, program cash flow would be lower both in the short and long terms, especially under Option I, which otherwise would have charged a 10 percent annual interest rate on this investment. Through the year 2000, net program receipts under Option I would be $1.64 billion for the GDP-only program and $1.12 billion for AVLIS, almost $1.3 billion lower for each program than the net revenue projections under full AGC capital and interest repayment (see Table A-1). Under Option II, net program revenue would be about $64 million lower over this period for both technology programs compared with the alternative that includes interest charges.

AGC PROGRAM: COST SCHEDULE, PRICE, AND BUDGETARY PROJECTIONS

Up until June 1985, to enhance future U.S. price competitiveness in enrichment, the DOE had been developing two advanced enrichment technologies to replace the gaseous diffusion process. The costs of continuing to develop both the AGC and AVLIS programs would be very high, however, and thus the DOE decided to choose one program for further development, demonstration and potential deployment. The selection of the AVLIS program in lieu of continuing any further AGC development was based on the technical and economic merits of the two processes evaluated by the PEB. This section presents an economic assessment of the AGC program, and compares it with the pricing and budgetary impacts of the AVLIS program based on the data used by the PEB for the June 1985 selection decision.

The AGC Technology Program

The federal government has been developing the gas centrifuge enrichment process for about 25 years. The advanced centrifuge machines were designed to replace the previously demonstrated "Set III" gas centrifuge, an earlier prototype of the process. The PEB deployment schedule for the AGC process assumed that these machines would be commercially operational by the early 1990s, and full production from the proposed 11.7 million SWU capacity plant would be reached by 1996. Under this schedule, the DOE would continue to operate two diffusion plants at least through the year 2000, with the Oak Ridge plant remaining in standby status.

Annual program outlays through the year 2000 would be quite high, including both AGC and gaseous diffusion related costs (see Table A-2). Total annual outlays would range from about $1.4 billion to $1.9 billion

TABLE A-2. PROGRAM OUTLAYS UNDER THE AGC/GDP PROGRAM (By fiscal year, in millions of fiscal year 1986 dollars)

	GDP Outlays			AGC Outlays				
Years	Capital	Power a/	Other Operating	Capital Construction	Research & Development	Operating	Other Program Outlays b/	Total
1985-1990	352	4,878	1,055	2,222	630 c/	288	162	9,587
1991-1995	125	2,782	815	3,150	125	710	135	7,842
1996-2000	125	1,728	815	1	125	1,340	135	4,269
Total	602	9,388	2,685	5,373	880	2,338	432	21,698

SOURCE: Congressional Budget Office, based on technology cost projections used by the Process Evaluation Board of the Department of Energy, obtained from the Office of Uranium Enrichment and Assessment in June 1985. These data no longer reflect the true costs of the AGC program, since it has been partially terminated and would be more expensive to restart.

NOTE: The AGC program assumes that two diffusion plants remain operational, with the Oak Ridge plant on standby. The AGC facility would have an annual capacity rate of 11.7 million SWUs, and would begin production in 1986 (using the Set III gas centrifuges). Production from the Set V advanced gas centrifuges would begin in the early 1990s, and full production would be reached in 1996.

a. The GDP power costs are based on DOE's assumption that they can continue to purchase some off-peak power to run the diffusion plants. Estimates based on DOE's power costs assuming only firm power contracts would increase total power costs by about $18 million through the year 2000. Also included are demand penalty charges for power that DOE has contracted for, but will not use.

b. Other program costs reflect the administration costs of managing the enrichment program.

c. About $80 million of the research and development costs were allocated for the AVLIS process in fiscal year 1985.

through 1994, most of which would be composed of GDP power costs and AGC capital outlays. Capital costs would run from $300 million to $800 million per year through 1995, totaling $5.4 billion over the period (not including the $2.3 billion DOE has already spent through fiscal year 1984). Program outlays would decline steadily to about $900 million a year by the late 1990s as the AGC facility reaches full production and replaces substantial diffusion capacity. Remaining program outlays include research and development expenditures, AGC and other GDP operating costs, minor GDP capital costs, and program administration expenses.

Important differences exist between the outlay schedules of the AGC and AVLIS programs in the next decade. In general, AGC would entail much higher capital costs than AVLIS (see Table A-2 and Table 7 in Chapter III), but their operating costs would be similar--about $26 per SWU. Through 1992, the AGC program would require higher annual outlays because of its high capital expenditures. In contrast, the AVLIS program would be more expensive during the mid-1990s as a result of AVLIS construction costs and high SWU production in these years using the expensive GDP capacity. By the late 1990s, the marginal difference in program outlays between the AGC and AVLIS options would reflect differences in the assumed capacity of each plant. Being smaller, the AVLIS plant would be supplemented by greater, more expensive GDP production. Total capital and operating costs would be about $47.3 per SWU for the AGC technology (not including GDP-related program costs), compared with $39.3 per SWU for the AVLIS process.

PRICE PROJECTIONS FOR THE AGC PROGRAM UNDER THE FOUR PRICING OPTIONS

In general, the AGC program would require higher prices than the AVLIS program because of the higher AGC capital and imputed interest charges. Under Option I, the current pricing formula, AGC program prices would be slightly higher in the late 1980s and early 1990s; from 1994 on, AGC program prices would remain roughly $10 per SWU higher than those charged under the AVLIS program. 1/ AGC program prices also would remain higher

1. Under both Options I and II, the DOE would recover the full $5.4 billion in future AGC capital costs, plus the $2.3 billion outstanding AGC investment. Under Option III, the marginal cost pricing structure, the DOE would recover only the additional $5.4 billion AGC capital investment. Option IV, which begins charging marginal cost prices in 1992, would recover only AGC capital costs from 1992 on, roughly $2.4 billion.

than those charged under the GDP-only program until the late 1990s. In the year 2000, the U.S. enrichment price would be about $89 per SWU for the AGC program, compared with $80 per SWU and $92 per SWU under the AVLIS and GDP-only programs, respectively.

Similarly, beginning in 1994, AGC prices would exceed those of the AVLIS program under both Options II and III. The price differential between the two technology programs would be smaller, however: about $2 to $5 per SWU. In the year 2000, prices under Option II would be $75 per SWU and $72 per SWU for the AGC and AVLIS programs, respectively. Under Option III, prices would be $68 per SWU and $63 per SWU, respectively. Under both pricing options, AGC program prices would fall below projected GDP-only program prices by the early 1990s. By the year 2000, AGC prices would be more than $10 per SWU cheaper.

Under Option IV, the U.S. enrichment price would remain at $135 per SWU through 1991. After that, prices under the AGC program would be lowest, primarily because most of the AGC capital investment would be forgiven, while full AVLIS capital costs would be paid off beginning in 1995. In the year 2000, U.S. enrichment prices would be $61 per SWU under the AGC program, compared with $62 per SWU under the AVLIS program.

Budgetary Effects of the AGC Program Under the Four Pricing Options

In both the short and long terms, the AGC program would achieve higher net revenues than would the AVLIS program if the Option I pricing policy were maintained. These higher revenues result primarily from the significantly higher AGC prices that would be charged under this option. Under the three alternative pricing options, net AGC program revenues would be somewhat smaller than those projected for both the AVLIS and the GDP-only programs. (For this analysis, net program receipts were projected assuming the DOE base-case demand schedule.)

Under Option I, net receipts for the U.S. enrichment program would be $4.5 billion for the AGC program through the year 2020; net revenues for the GDP-only and AVLIS programs would be $4.3 billion and $3.4 billion, respectively (see Table A-3). These estimates probably are somewhat optimistic, however, since prices under Option I would not be competitive in the long term, thus resulting in less demand for U.S. enrichment services than the base-case demand schedule assumes.

Under Options II, III, and IV, the AGC program would require net program spending through the year 2000. Under Option III, AGC program outlays would exceed projected revenues by $2.5 billion over this period, compared with net spending requirements of $2.2 billion under the AVLIS program (see Table A-3). Annual net receipts for the AGC program would be large by the late 1990s, however, and thus the financial status of the AGC program would improve over the long term. By the year 2020, net AGC program revenues would be $0.7 billion, -$1.1 billion, and $0.8 billion under Options II, III, and IV. These budgetary projections are roughly $20 million to $900 million less than the net revenues associated with the AVLIS program under these options.

Generally, the AGC program option would require greater program outlays over the next decade than would the AVLIS program, resulting in higher SWU prices, particularly if the current pricing strategy were maintained. Under this program plan, the DOE might in fact receive larger net revenues under the AGC program, depending on how sensitive the world market is to future U.S. enrichment prices. If the DOE were to adopt an alternative pricing option in order to offer more competitive prices in the long term, however, the AVLIS program should be better able to achieve both lower U.S. enrichment prices and higher net program revenues for the federal government, thus allowing for larger cost recovery of past and future program investments.

TABLE A-3. SHORT- AND LONG-TERM NET RECEIPTS OF THE ENRICHMENT PROGRAM UNDER THE FOUR PRICING OPTIONS (In millions of discounted fiscal year 1986 dollars)

	Net Reciepts 1985-2000 Investment Option		Net Receipts 1985-2020 Investment Option	
Pricing Policy	AVLIS/GDP	AGC/GDP	AVLIS/GDP	AGC/GDP
Option I	1,335	1,656	3,370	4,538
Option II	-291	-919	1,084	738
Option III	-2,169	-2,533	-1,058	-1,078
Option IV	645	-307	1,662	756

SOURCE: Congressional Budget Office.

NOTES: The cash flow estimates assume an annual real discount rate of 5 percent.

Negative program cash flows represent discounted net government spending requirements.

All net revenue projections assume the DOE base-case demand schedule.

402

CONGRESSIONAL BUDGET OFFICE
Second and D Streets, S.W.
Washington, D.C. 20515