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Rudolph G. Penner
Director

December 6, 1984

MEMORANDUM

TO: Jeanine Hull
Subcommittee on Energy Conservation and Power
House Committee on Energy and Commerce

FROM: Mollie Quasebarth MQ
John Thomasian JT
Natural Resources and Commerce Division

SUBJECT: Response to Chairman Ottinger's Request on the Economic Comparisons of the AGC and AVLIS Processes

This memorandum presents the results of CBO's update of its October 1983 study entitled, Uranium Enrichment: Options for the Long Term. It summarizes the recent changes that have affected the enrichment program and compares the enrichment costs of the two advanced technologies being considered by the Department of Energy (DOE). Our results are similar to those provided in the draft memo (September 14, 1984), but do include some changes and additional analyses.

It is important to note that DOE's comments (attached) on our September draft memo indicate that some of the data we used are being revised. These revisions will not be available to us until after the DOE submits its annual budget request to the Congress in early 1985. Thus, our comparisons reflect only the current published cost estimates for the two developing technologies, and will be subject to question until after the peer review on the advanced technologies is completed in May 1985. The effects of possible revisions are also discussed.

SUMMARY

We evaluated various uranium enrichment program options to determine the most cost-effective investment scheme for the federal government. The options examined reflect important changes that have occurred since CBO's October 1983 report. These include the following:

- Lower demand for DOE's enriched uranium product, by both domestic and foreign nuclear utilities; and

- Updated cost and production schedule estimates for the advanced enrichment technologies--Advanced Gas Centrifuge (AGC) and Atomic Vapor Laser Isotope Separation (AVLIS).

This analysis compares different enrichment programs under both the DOE's 1984 "most likely" enrichment demand scenario and a low-demand case prepared by the CBO. [1/] These options assume different combinations of enrichment technologies to meet the DOE's SWU (separative work unit) production requirements. Each program relies initially on production from the DOE's three gaseous diffusion plants; these are then replaced either partially or completely by the AGC or AVLIS process, whichever one the DOE selects in 1985.

Using currently available data supplied by the DOE, our results indicate that under both the DOE "most likely" and the CBO low-growth demand projections, replacing the three gaseous diffusion plants with the AVLIS process seems to offer the most cost-effective investment. The economic differences between the two proposed technologies is small, however, considering the uncertainties that are inherent in the long-term cost projections for both processes. Through the year 2025, discounted federal outlays for options introducing AVLIS would range from $23 to $25 billion under DOE's demand scenario. For options with AGC, the outlays would require $25 to $28 billion. These differences are small when measured over the 40-year period.

Under the CBO low-demand case, the results are similar. A program utilizing the AVLIS process to completely replace the diffusion technology would require about $2.5 billion less in federal outlays (from now through 2025) than would a similar program based on the AGC technology.

Based on the current DOE enrichment pricing formula, we estimated the SWU price that the DOE would be able to charge its customers under the different investment options. Our calculations suggest that through 2000, the DOE SWU price under an enrichment program using the AGC technology would be about $8 to $16 more than the price based on a program relying on

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1. The DOE 1984 SWU demand requirement and production projections reflect slight revisions to the 1983 "most likely" forecast for nuclear capacity growth, found in their March 1984, "Interim Working Scenarios." The DOE Office of Uranium Enrichment and Assessment provided us with the revised schedule in August 1984.

the AVLIS process. Use of either advanced process, however, should allow the DOE to greatly reduce the current SWU charge of $135 by the year 2000.

These results differ from those in our October 1983 study, which concluded that an eight-building AGC facility appeared to be the most economical choice. The main factors altering our previous results are:

- o Lower DOE SWU demand and production projections. Because of DOE's large SWU inventory and decreased demand for its enrichment services, future DOE SWU production from its gaseous diffusion plants is lower. Thus, the commercial development of AGC, which would displace the expensive diffusion production earlier than AVLIS, no longer would provide as great a savings as it previously did.

- o Updated cost projections for the two technologies. 2/ The cost rankings of the two advanced technologies have changed. Although AVLIS capital costs have been revised slightly upward by the DOE, the combined capital and operating cost estimates for AVLIS have fallen 34 percent from those used in our 1983 study. In contrast, available DOE estimates show the combined capital and operating costs for the advanced centrifuge technology have risen 15 percent.

The DOE is reviewing new information, and has indicated it plans to revise the AGC data used in this analysis, while altering the AVLIS projections somewhat less. It is likely that the AGC program will be ready for commercial operation sooner than we have assumed, with somewhat lower costs. Thus, the difference in total costs between the two enrichment programs may be even less than our results show. Most important, however, is that the differences that have occurred between this analysis and our previous study illustrate the inherent uncertainty of the economic comparisons between AGC and AVLIS at this time.

The remainder of this memo presents our analyses in more detail. The next section describes current demand projections for DOE enrichment services, since this issue is so crucial to the costs of the enterprise. The following sections then compare the technology options under various program and financial assumptions.

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2. These cost updates do not include the technology data revisions that the DOE is reviewing currently.

DEMAND FOR DOE'S ENRICHED URANIUM SERVICES

DOE's uranium enrichment program is quite sensitive to changes in SWU demand. Declining demand for its product over the last several years has seriously hurt DOE's position as the major world supplier and has affected the financial status of the DOE program. This decline in demand is due to essentially three factors:

- o A world glut in the enriched uranium market;
- o Strong competition from foreign producers of enriched uranium, aided by currency exchange rates that make the DOE's product relatively more expensive; and
- o Lower than projected growth in the nuclear electric utility industry, particularly in the United States.

The current world inventory of surplus enriched uranium is almost 40 million SWUs, according to recent DOE estimates. This surplus--if it was all available to the market--could supply almost two years of the world's enriched uranium needs, projected at 23.7 million SWUs in 1985 (excluding communist countries). [3/] A secondary SWU market exists that has been selling excess SWUs at greatly reduced prices--in 1983, secondary market SWUs sold as low as $90 per SWU, compared to the DOE's price of $139 to $150 per SWU. [4/] This world surplus of inexpensive enriched uranium could continue to repress demand for DOE's services, especially through the early 1990s when the quantity of SWUs available on the world market becomes more in balance with total SWU requirements.

In addition to the secondary market, foreign enrichment suppliers have been pricing their SWUs competitively against DOE's--their prices have been reported at $100 to $117 per SWU in 1983, compared to DOE's price ranging from $139 to $150 per SWU. Since 1979, the DOE has lost roughly $3.5 billion in enrichment sales from customers who have signed contracts

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3. This projection is taken from Department of Energy, World Nuclear Fuel Cycle Requirements 1983, Energy Information Administration (February 1984).

4. U.S. General Accounting Office, Information on DOE's Costing and Pricing of Uranium Enrichment Services, Report to the Chairman, Subcommittee on Energy Conservation and Power, April 25, 1984.

with foreign producers. 5/ The current exchange rates, which favor the U.S. dollar at the expense of most European currencies, account in part for the cheaper foreign SWU prices. Furthermore, the more flexible pricing and financing policies of foreign suppliers have provided them with a competitive edge in the world market.

Worsening the situation for DOE's enrichment program, electric utilities in the United States are not building the nuclear capacity that was previously expected. In 1982, the DOE projected that U.S. nuclear electricity capacity would reach 133 gigawatts-electric (Gwe) in the year 2000. In May 1983, DOE's Office of Uranium Enrichment and Assessment reduced this projection by 30 percent to just 119 Gwe. An additional CBO low-growth scenario lowers these projections to only 103 Gwe in the United States by the year 2000, based on recent trends in plant cancellations and lower projected new plant construction. In any case, the SWU market today may be characterized as "demand constrained," rather than "supply constrained," a predicament opposite to that projected just ten years ago.

These combined factors have produced a loss of enrichment contracts and fewer SWU sales by the DOE. In CBO's October 1983 report on the DOE's uranium enrichment program, projected SWU sales to both U.S. and foreign nuclear utilities totaled 18.7 million in 1985 and 26.8 million by the year 2000. The DOE's 1984 demand case reduces these projected sales to roughly 14 million SWUs in 1985, and only 18 million SWUs in 2000. Table 1 shows the projected world nuclear electric capacity and associated SWU requirements serviced by the DOE under the earlier and revised demand scenarios.

DOE's Response to Current Demand Conditions

In response to the declining demand for its services, the DOE has taken several steps to maintain its customer contracts and to reduce its uranium production costs. These include:

- Issuing a New Utility Services (U.S.) Contract in January 1984. This new contract offers several advantages to DOE customers compared to the two existing contracts, including a lower, long-term price ceiling of $135 per SWU (roughly $4 to $15 per SWU less than the 1983 price), an option to purchase up to 30 percent of its requirements from outside of the DOE, and more flexible

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5. U.S. General Accounting Office, Ibid.

TABLE 1. ALTERNATIVE PROJECTIONS FOR NUCLEAR-POWER CAPACITY AND ENRICHED URANIUM DEMAND SERVICED BY THE DEPARTMENT OF ENERGY

	1985	1990	1995	2000
World Nuclear Capacity Serviced by the DOE a/ (In gigawatts-electric)				
DOE 1982 Forecast b/	135	178	204	220
DOE 1983 Forecast c/	122	168	177	178
CBO Low-Growth Projection d/	113	146	153	150
Enriched Uranium Sales to Nuclear Electric Utilities e/ (In millions of SWUs)				
DOE 1982 Forecast b/	18.7	19.8	23.4	26.8
DOE 1984 Forecast f/	13.8	13.4	18.4	18.1
CBO Low-Growth Projection d/	10.9	9.3	15.3	14.3

SOURCE: Congressional Budget Office, based in part on data from the Department of Energy, Office of Uranium Enrichment and Assessment.

a. These projections include only nuclear capacity for which the DOE will provide enrichment services.

b. The projections for nuclear-power capacity and DOE SWU sales made in 1982 were used in the CBO 1983 study, Uranium Enrichment: Investment Options for the Long-Term.

c. These 1983 projections represent the DOE "most likely" case, used to develop the current enrichment production and sales schedules.

d. The CBO low-nuclear growth forecast was prepared in 1984.

e. These figures do not include DOE SWU sales to the U.S. government for military uses.

f. The DOE 1984 projections for SWU sales were based primarily on their 1983 projections of nuclear-power capacity, but were revised somewhat to reflect current world SWU inventories and decreased utility SWU requirements in the near term.

ordering and delivery provisions. The SWU demand and production schedule of DOE's enrichment operations will largely depend on the acceptance of this contract by current and potential DOE customers. By October of 1984, about 90 percent of DOE's current customers had either converted to this contract or verbally assured the DOE that they would do so. 6/

- o Cutting back on near-term SWU production from the gaseous diffusion plants by drawing down the DOE SWU and natural uranium feedstock inventories. The DOE is using its current stockpiles of both enriched uranium product and natural uranium feed to help meet its near-term contract commitments, thereby reducing the SWU production requirements from its three gaseous diffusion plants. The DOE will deplete its current SWU inventory of about 20 million SWUs to 7-8 million SWUs (its long-term minimum inventory requirement) by about 1988. The DOE currently has over 40 million kilograms of natural uranium feedstock, which it will use to overfeed the enrichment plants (operate them at a higher tails assay), thereby reducing the separative work requirements for a given amount of enriched uranium product. This feed stockpile will also be depleted by the late 1980s, when the DOE will have to begin purchasing natural uranium at the market price.

- o Reducing research funds for developing the Advanced Gas Centrifuge (AGC) and Atomic Vapor Laser Isotope Separation (AVLIS) Technologies, and choosing between these two processes in 1985 rather than 1988. The DOE has cut back its outlays for research and technology development of these two new processes because of its reduced revenues from SWU sales. By moving the decision deadline for choosing between these two technologies from 1988 up to 1985, the DOE should reduce its research budget substantially over the next few years.

THE CURRENT DOE OPERATING PLAN

In early 1984, the DOE developed an interim operating plan outlining its schedules for SWU demand and production, inventory utilization, and its plans for developing and bringing on line new enrichment capacity. This working plan was prepared before the DOE could fully incorporate the

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6. Inside Energy/with Federal Lands (October 8, 1984).

nuclear industry's response to the new U.S. contract--the DOE is now updating this interim plan, and will issue a new operating plan in the spring of 1985, with revised technology information and SWU sales and production schedules.

The interim operating plan describes two working scenarios: one has the AGC process being chosen in 1985, and the other, the AVLIS technology. The DOE SWU demand schedule assumes that 85 percent of DOE's current customers convert to the new contract, taking 85 percent of their total reactor SWU requirements from the DOE until 1992. 7/ Beginning in 1992, the DOE will supply 100 percent of their SWU requirements, but will lose about 10 percent of its projected contract commitments to foreign enrichment suppliers. (The associated DOE SWU production schedule is shown in Table 2, compared with the production schedule we assumed in our earlier study.) In 1984, the DOE will produce 11.1 million SWUs from its gaseous diffusion plants, but beginning in 1985 will reduce production by depleting the SWU and natural uranium feed inventories. The long-term DOE projections assume a production rate of 19.8 million SWUs per year after 2002, compared to the rate of 26.5 million SWUs per year the DOE projected in its 1983 operating plan.

The interim working scenarios include plans to incorporate one of the new technologies. The proposed deployment schedules of the AGC and AVLIS processes are described below, noting the changes in these schedules from the 1983 DOE operating plan.

The GCEP/AGC Program. The DOE has almost completed construction on the first two process buildings of the Gas Centrifuge Enrichment Plant (GCEP) in Portsmouth, Ohio. Through fiscal year 1983, the Congress had appropriated $2.13 billion for the GCEP project. 8/ Gas centrifuges (Set III) are now being purchased and installed into the first building, which will begin production in 1986 at a rate of 0.4 million SWUs. The DOE's interim working scenario proposes a four-building plant if the AGC process is chosen in 1985, finishing the facility by 1994.

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7. These SWU sales projections were made in mid-1984 by the DOE and are slightly higher over the next few years than the demand schedules assumed in the initial DOE interim working scenarios. The earlier estimates had projected that only 75 percent of DOE customers would convert and that they would take only 70 percent of their SWUs from the DOE.

8. U.S. General Accounting Office, Memorandum to the Hon. Richard L. Ottinger, Chairman, House Subcommittee on Energy Conservation and Power, August 10, 1984 (B-207463).

TABLE 2. DOE ANNUAL SWU PRODUCTION SCHEDULES UNDER ITS 1983 AND INTERIM 1984 DEMAND SCENARIOS, 1984-2000 (In millions of SWUs)

Year	DOE 1983 Operating Plan Scenario a/	DOE 1984 Revised Interim Working Scenario b/	Percent Difference 1983-1984
1984	12.1	11.1	-8.3
1985	16.7	10.6	-36.5
1986	18.2	8.4	-53.9
1987	19.2	8.7	-54.7
1988	19.6	12.9	-34.2
1989	20.3	14.9	-26.6
1990	22.3	17.1	-23.3
1991	24.4	18.3	-25.0
1992	25.2	17.8	-29.4
1993	22.9	20.3	-11.4
1994	25.0	22.8	-8.8
1995	26.3	19.8	-24.7
1996	26.4	19.7	-25.4
1997	26.5	19.8	-25.3
1998	26.5	18.8	-29.1
1999	26.5	18.8	-29.1
2000	26.5	18.8	-29.1

SOURCE: Congressional Budget Office, based on information from the Department of Energy, Office of Uranium Enrichment and Assessment.

NOTES: Figures reflect combined SWU production from total enrichment capacity.

a. This production schedule was used in CBO's 1983 study.

b. This schedule reflects slight revisions to DOE's 1983 "most likely" nuclear-power capacity growth projections.

The advanced gas centrifuges (Set V) are assumed to begin operation in 1989. If the AGC process is chosen, the four-building AGC facility will reach its annual enrichment capacity of 13.2 million SWUs by 1997. No additional AGC capacity is projected in this working scenario. The DOE estimates that total capital costs for the four-building AGC facility will be $4.75 billion (in fiscal year 1985 dollars). If the DOE does build all eight process buildings, as it assumed in the January 1983 Enrichment Operating Plan, the AGC machines could produce 26.4 million SWUs per year by 1997. The associated capital outlays would be $6.88 billion (in fiscal year 1985 dollars). By comparison, DOE's 1983 plan called for a GCEP facility fitted with Set IV centrifuges (with 150 percent of the efficiency of the Set III machines), with capital costs of $6.33 billion (in fiscal year 1984 dollars). 9/

The AVLIS Program. If the AVLIS process is chosen in 1985, DOE's interim working scenario assumes that AVLIS production would begin in 1993 at 1 million SWUs per year. Full production from the 14.2 million SWU capacity AVLIS plant would be ready by 1997. The estimated capital costs of the AVLIS plant are $1.67 billion (in fiscal year 1985 dollars).

The AVLIS program described in the January 1983 DOE Enrichment Operating Plan called for an AVLIS plant with a capacity of 9 million SWUs per year, with capital costs of $0.95 billion (in fiscal year 1984 dollars). AVLIS production would begin in 1994 and reach full capacity production by 1996.

DESCRIPTION OF ALTERNATIVE ENRICHMENT PROGRAMS USING THE ADVANCED TECHNOLOGIES

In addition to the two enrichment programs developed by the DOE for interim working scenarios, the CBO evaluated two alternative programs for meeting DOE's enriched uranium requirements through 2025, still using the DOE 1984 SWU production schedule presented in Table 2. All four program options are described below and summarized in Table 3.

Option I--Build Four-Building AGC Plant, Continue Gaseous Diffusion

This option reflects DOE's Scenario "A" from the March 1984 interim operating plan, based on the AGC process. A four-process building gas

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9. The DOE has cancelled any further development of the Set IV machines, instead going directly from the Set III machines to the Set V centrifuges with three times their efficiency.

TABLE 3. TECHNOLOGY COMPOSITION AND DEPLOYMENT/RETIREMENT SCHEDULES FOR EACH OPTION

Option	Gaseous Diffusion	Advanced Gas Centrifuge a/	Atomic Vapor Laser Isotope Separation
Option I AGC with Diffusion	Two plants decommissioned in 1995 and 1996, respectively; One plant operational through 2025	Set III machines operational in first building in 1986; Set V AGC machines operational in second building in 1989; Full 13.2 million SWU AGC annual capacity from the four-building plant reached in 1997	Not assumed
Option II AVLIS with Diffusion	Two plants decommissioned in 1995 and 1996, respectively; One plant operational through 2025	Not assumed	One AVLIS plant operational in 1993; Full 14.2 million SWU capacity reached in 1997
Option III Eight-Building AGC	All three plants decommissioned in 1991, 1993, and 1995	Set III machines operational in first building in 1986; Set V AGC machines installed in second building in 1989; Maximum 19.8 million SWU AGC annual capacity from the six-building plant reached in 1995	Not assumed
Option IV Two-Plant AVLIS	All three plants decommissioned, one in 1995 and two in 1996	Not assumed	Two AVLIS plants operational in 1993 and 1994, respectively; Maximum annual capacity of 20 million SWUs reached in 1997

SOURCE: Congressional Budget Office.

a. The AGC program assumes that the first building is partially filled with Set III gas centrifuges, which are retrofitted with ACG Set V machines beginning in 1989.

centrifuge plant would be built and completed by 1994. Production would begin in 1986 at a rate of 0.4 million SWUs per year, using Set III centrifuges that would fill half of the first building. AGC machines (Set V) would replace these machines, and be installed in building two and the rest of building one beginning in 1989; full AGC capacity would reach 13.2 million SWUs by 1997.

AGC SWU production would gradually replace most production from the three gaseous diffusion plants. Two plants would shut down in 1995 and 1996, respectively, and the last plant would continue operating through 2025, producing 6.6 million SWUs per year after 2003.

Option II--Build 14.2 Million SWU Capacity AVLIS Plant, Continue Gaseous Diffusion

This option is based on Scenario "B" from the DOE 1984 interim operating plan, and assumes that AVLIS is selected in 1985. A 14.2 million SWU capacity AVLIS plant would be built beginning in 1985 and would be completed by 1995. Beginning production in 1993 at a rate of 1 million SWUs per year, the AVLIS plant would reach full production by 1997.

While annual SWU production using the gaseous diffusion plants would be higher through 1995 under this program, compared to Option I, two diffusion plants still could be retired in 1995 and 1996, respectively. Annual SWU requirements from the remaining operating diffusion plant would be 5.6 million SWUs from 2003 through 2025.

Option III--Build Six-Building AGC Plant, Retire All Gaseous Diffusion Plants

Like Option I, the AGC process would be selected in 1985. However, this option assumes six process buildings instead of four would be constructed to supply all of DOE's annual SWU requirements and retire gaseous diffusion. Again, production using Set III machines would begin in 1986 at a rate of 0.4 million SWUs per year; maximum plant capacity would be 19.8 million SWUs per year, available by 1995.

Because additional AGC capacity would be installed beginning in the late 1980s, production from the three gaseous diffusion plants would be replaced sooner. All three diffusion plants would be retired under this program--in 1991, 1993, and 1995.

Option IV--Build Two AVLIS Plants, Retire All Gaseous Diffusion Plants

This option assumes the AVLIS technology is chosen and is built to fully retire gaseous diffusion. Under this option, two AVLIS plants would be required, with an annual production capacity of 20 million SWUs. The two buildings would have enrichment capacities of 14.2 and 5.8 million SWUs per year, and would begin production in 1993 and 1994, respectively. They would be able to provide DOE's projected SWU demand of 19.8 million SWUs by 1997.

The three gaseous diffusion plants would close later under this option as compared to Option III. One plant would shut down in 1995, and the other two plants would close in 1996.

COSTS OF THE ALTERNATIVE ENRICHMENT PROGRAMS

To compare the enrichment program costs under the four options, we examined three measures of cost performance over the period 1984 through 2025.

- **Government Outlays**--The discounted sum of annual federal outlays for the enrichment program (excludes customer feed costs and interest charges on capital investment). 10/

- **Enterprise Costs**--The total present value cost of enrichment services under each program, including the cost of the customers' uranium feed purchases, and the interest and depreciation charges for DOE's capital investment. 11/ We also calculate this measure on a "cost per SWU" basis, excluding customer feed costs, to indicate the unit production costs under the different investment programs.

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10. In addition to capital, operating, and research and development costs, outlays and enterprise costs include DOE purchases of additional natural uranium feedstock after its current inventory is depleted. The DOE is using its current feedstock to overfeed the diffusion plants (operating them at a higher tails assay to reduce power costs), and must also provide the feed to produce the U.S. military requirements for enriched uranium.

11. In calculating the capital charges that the DOE would have to recover through its SWU sales, we assumed that all capital construction costs would be depreciated over a 25-year period, including an interest charge of 6 percent per year.

- **Price Per SWU for DOE Enrichment Services**--The estimated price that the DOE would charge its enrichment customers, based on DOE's current pricing formula. This formula calculates the SWU price each year by summing DOE's costs (with interest) forward over a ten-year period, and dividing by the projected quantity of SWUs sold over that period.

For the first two measures, we discounted all future year costs (projected in fiscal year 1985 dollars), using a real annual discount rate of 6 percent. This rate reflects the CBO long-term projection of the nominal ten-year Treasury bond rate (11 percent) minus the annual rate of inflation (5 percent). The price projections are calculatetd in fiscal year 1985 dollars.

Comparisons of Option Costs

Our results indicate that the AVLIS technology seems to have a slight cost advantage compared to the AGC process (see Table 4). Both through the year 2000 and over the entire analysis period (through 2025), total federal outlays and enterprise costs for the enrichment program are lower when the AVLIS program is pursued. As was noted in the earlier CBO study, however, the total cost differences between the options is not large.

Option IV, deploying AVLIS to completely replace the three diffusion plants, would be the most economic program in terms of both federal outlays and total enterprise costs--projected at $23.2 billion and $67.1 billion, respectively, through 2025. The program relying on a six-building AGC facility to replace all gaseous diffusion capacity (Option III), however, would be only slightly more expensive, with federal outlays of $24.5 billion through 2025 (roughly 5 percent higher than Option IV). Alternatively, Option I, assuming a four-building AGC facility operating with one diffusion plant, would be the most expensive ($27.6 billion in outlays, and $71.8 billion in total enterprise costs). By 2025, DOE enrichment production costs (not the selling price) would be roughly $29 per SWU under Option IV, compared to $36 per SWU under Option 1.

The federal outlays required only through the year 2000 illustrate the major differences between the characteristics of the two technology cost schedules. Options using AVLIS would be cheaper than those with AGC, primarily because of the much lower capital investment requirements of the AVLIS project. Although AGC operating costs are lower than those projected for AVLIS, over the long term the cost difference persists, but tends to diminish. Comparing Options I and II, which the DOE developed in its interim working plan in March 1984, Option II (which assumes AVLIS)

TABLE 4. DISCOUNTED OUTLAYS AND ENTERPRISE COSTS UNDER EACH OPTION, 1984-2025

	Option I	Option II	Option III	Option IV
Discounted Federal Outlays (In billions of fiscal year 1985 dollars)				
Gaseous Diffusion	14.9	15.7	10.5	12.9
AGC a/	6.9	NA	8.2	NA
AVLIS	NA	3.4	NA	4.5
DOE Feed Purchases	5.8	5.8	5.8	5.8
Total, 1984-2025	27.6	24.9	24.5	23.2
1984-2000 Total	22.4	19.9	21.4	19.8
Discounted Enterprise Costs (In billions of fiscal year 1985 dollars)				
Gaseous Diffusion	14.9	15.7	10.5	12.9
AGC a/	6.7	NA	8.0	NA
AVLIS	NA	3.1	NA	4.0
DOE Feed Purchases	5.8	5.8	5.8	5.8
Customer Feed Costs	44.4	44.4	44.4	44.4
Total, 1984-2025	71.8	69.0	68.7	67.1
Production Cost per SWU in Fiscal Year 1985 Dollars				
Enrichment Charge Through 2000	74.0	67.3	69.3	65.8
Enrichment Charge Through 2025	35.5	31.8	31.5	29.4

SOURCE: Congressional Budget Office.

NOTES: The real discount rate assumption is 6 percent per year. In computing enterprise costs and enrichment charges, all capital costs are depreciated over 25 years at a real interest rate of 6 percent per year. Total production through 2025 is 772 million SWUs.

a. The AGC program assumes that only half the first GCEP building will be filled with Set III gas centrifuges, and that AGC (Set V) machines replace these beginning in 1989.

would save the federal government $2.5 billion over a 40-year period. Figure 1 shows annual federal outlays for these two options, illustrating the higher costs of the AGC program (Option I) through 1992 due to its large capital outlays. From 1993 to 1996, the AVLIS program costs would be somewhat higher because of greater reliance on the gaseous diffusion plants in that period. After 1996, the two programs would have similar cost schedules, Option II having a very slight cost advantage.

Comparing SWU Prices Under Alternative DOE Enrichment Investments

The major reason that the DOE is developing these new enrichment technologies is to lower its SWU prices to become more competitive in the world market. Using DOE's SWU pricing formula, cost data, and sales projections, we calculated the DOE SWU price under Options I and II, the programs that the DOE proposed in its interim working scenarios. Figure 2 shows the projected price patterns under these two options through the year 2000. Both options would allow prices to drop steadily from the $135 mark, starting in 1984. By 2000, the price would drop 49 percent (to $69 per SWU) under Option I (based on AGC), and would fall 61 percent (to $53 per SWU) under Option II (assuming AVLIS).

The pricing methodology follows DOE's program objective of recovering costs within ten years of initial investment. [12/] The price calculation uses the following equation:

$$\text{Price in year } n = \frac{\sum_{n}^{n+10} \text{costs}_n + \text{initial SWU inventory value}}{\sum_{n}^{n+10} \text{SWU sales}_n + \text{ending SWU inventory}_{n+10}}$$

12. Setting a price in one year based on recovering the next ten years' projected costs does not guarantee full cost recovery over that period, as future SWU sales and actual program costs can differ from their projections.

FIGURE 1.

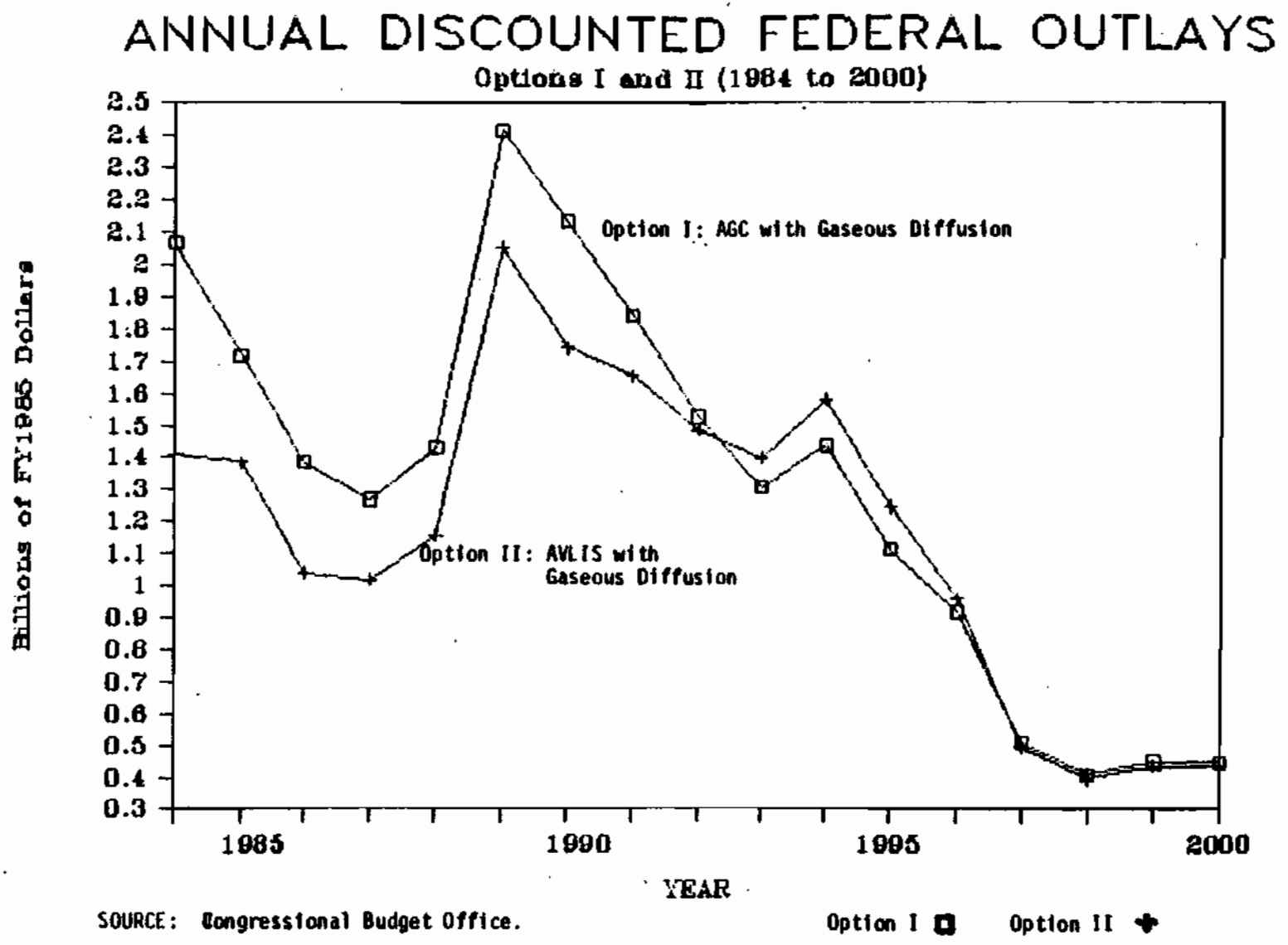
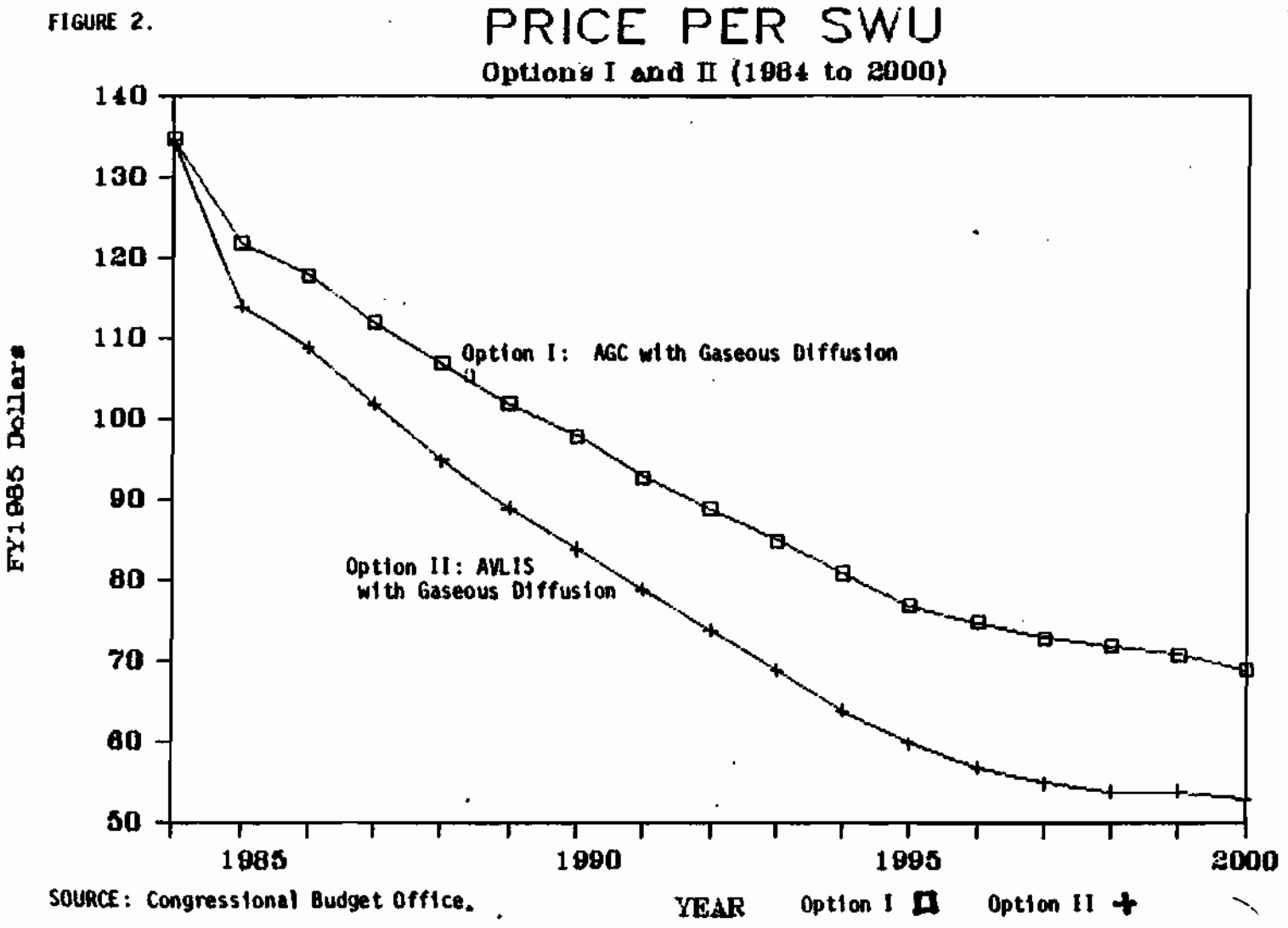

ANNUAL DISCOUNTED FEDERAL OUTLAYS
Options I and II (1984 to 2000)
Billions of FY1985 Dollars
2.5
2.4
2.3
2.2
2.1
2
1.9
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
1985
1990
1995
2000
YEAR
Option I: AGC with Gaseous Diffusion
Option II: AVLIS with
Gaseous Diffusion
SOURCE: Congressional Budget Office.
Option I
Option II

FIGURE 2.



SOURCE: Congressional Budget Office.

The ten-year's worth of forward costs include power, operating, administrative, and research and development costs, depreciation costs for capital investments (excluding interest charges), costs of DOE uranium feed purchases (needed to overfeed the diffusion plants in order to lower power costs), and interest costs on all unrecovered government investment. Unrecovered investment includes cumulative capital outlays less depreciation, plus the value of DOE's SWU and natural uranium feed inventories, minus any prior profits. 13/

While our projections would not replicate DOE's price calculations for these two programs exactly, due to different assumptions on feed costs and interest rates, the trends should be similar. Thus, the AVLIS program based on current data should enable the DOE to lower its SWU price more than the AGC process would, because of its lower capital investment requirements (and thus its substantially lower depreciation and interest charges).

Explanation of Changes from Last Year's Study

The five options evaluated in CBO's October 1983 study on the DOE enrichment program had federal outlay and total enterprise cost projections in the range of $28 to $41 billion and $82 to $87 billion (in discounted 1983 dollars), respectively. All five programs studied then were more expensive, under both cost measures, than any of the options studied in this update. Part of the decrease in the current cost projections reflects this study's higher discount rate (6 percent, compared to 4 percent in the last one), and lower uranium feed prices, which lower total enterprise costs substantially.

Most important, the comparative cost advantages between the AGC and AVLIS processes have changed since the earlier CBO study. Table 5 compares the costs of the AGC and AVLIS technologies from the earlier and the current analyses. Two key changes occurred.

First, both the projected unit operating and capital costs of the AGC facility have risen somewhat since the earlier report. Second, the unit

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13. The DOE is now excluding 60 percent of the remaining unrecovered capital investment for the diffusion plants from its pricing calculation, thus lowering both the annual depreciation costs and the interest charges on unrecovered investment. Our price estimates also assume this new DOE policy. DOE interest charges reflect a 10.5 percent real interest rate each year, however, while we assume a 6 percent real annual rate consistent with what we used in projecting our other cost measures.

TABLE 5. COST ASSUMPTIONS FOR THE AGC AND AVLIS TECHNOLOGIES USED IN THIS ANALYSIS AND THE CBO OCTOBER 1983 STUDY (In fiscal year 1985 dollars per SWU)

	CBO 1983 Report a/	CBO Update	Percent Change
	GCEP/AGC b/		
Capital Costs c/	8.0	8.8	10
Operating Costs d/	9.8	11.6	18
Combined Costs	17.8	20.4	15
	AVLIS e/		
Capital Costs c/	3.5	3.8	9
Operating Costs d/	22.9	13.6	-41
Combined Costs	26.4	17.4	-34

SOURCE: Congressional Budget Office, based on information from the DOE Office of Uranium Enrichment and Assessment.

a. All costs from the CBO 1983 study, Uranium Enrichment: Investment Options for the Long Term, were inflated to reflect fiscal year 1985 dollars.

b. The cost projections for the 1983 CBO study assume an eight-building GCEP/AGC plant, with a maximum annual capacity of 26.5 million SWUs. The updated analysis reflects a six-building GCEP/AGC facility with a lower annual production rate of 19.8 million SWUs.

c. Capital costs on a per SWU basis reflect total capital costs (excluding sunk capital outlays) divided by total SWU production through the year 2025.

d. Operating costs per SWU reflect the cost of operating the assumed plant at its maximum SWU production rate.

e. The 1983 AVLIS cost projections assume a 9 million SWU capacity plant. The 1984 AVLIS cost revisions reflect a 14.2 million SWU capacity plant.

operating costs for the AVLIS process have decreased by 41 percent since last year's projections (only somewhat offset by the 9 percent increase in capital costs). The lower operating cost per SWU reflects large reductions in the estimated feed conversion costs necessary for the AVLIS process. Between these cost changes, the combined unit costs for the AGC technology are now somewhat higher than the AVLIS costs, contrary to last year's projections.

Also, demand changes have affected rankings. The least costly program in the earlier CBO analysis assumed an eight-building GCEP facility, installed with AGC machines by 1999 (the AVLIS process was not assumed). This option was cheaper, mainly because it displaced reliance on production from the gaseous diffusion plants more quickly than did the AVLIS program. But DOE's current SWU demand schedule is lower, and the earlier deployment advantage of the AGC process is no longer significant enough to offset its higher capital outlays. 14/ With the reduced operating costs of the AVLIS process, the AVLIS options in this report appear more economical than the two AGC enrichment programs.

SENSITIVITY ANALYSIS--EXAMINING THE DOE ENRICHMENT OPTIONS UNDER DIFFERENT ASSUMPTIONS

To test the stability of our analysis findings, we compared the enrichment options under various changed assumptions. These include:

- A lower discount rate,
- A higher electricity inflation rate, and
- Process cost overruns.

To summarize, different discount and power escalation rates do not seem to affect the rankings--Option IV (with full AVLIS) remains the least expensive program, although Option III (the six-building AGC facility) is only slightly more costly. The outlay projections using these alternative assumptions are shown in Table 6.

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14. Production from the gaseous diffusion plants is greatly curtailed in the current DOE operation schedule, due to three factors: lower projected SWU sales, DOE's depleting of its SWU inventory in the next five years, and the overfeeding of the diffusion plants.

TABLE 6. DISCOUNTED FEDERAL OUTLAYS THROUGH 2025 UNDER EACH OPTION, WITH CHANGED FINANCIAL ASSUMPTIONS (In billions of discounted fiscal year 1985 dollars)

Alternative Assumption	Option I	Option II	Option III	Option IV
Discount Rate of 3 Percent	38.5	35.3	32.3	31.4
Real Increase in Electricity Prices of 2.5 Percent per Year a/	29.9	27.2	25.1	24.1
Capital Cost Overruns				
AVLIS: 100 percent, and AGC: 50 percent	30.4	27.3	27.9	26.5
AVLIS: 50 percent, and AGC: 0 percent	27.6	26.1	24.6	24.8

SOURCE: Congressional Budget Office.

a. This sensitivity analysis assumes that the gaseous diffusion power costs increase 2.5 percent annually in real terms. The original analysis assumes a 0.5 percent annual increase in real power costs.

A more important element to consider in evaluating the merits of the two new technologies is their level of risk. There are two types of risks that the DOE must address: the engineering uncertainties (such as the risk that the technology itself may not prove feasible) and the cost uncertainties. This study examines the economic comparisons of the technologies only--we do not attempt to evaluate the relative technological risks of AGC and AVLIS. We do, consider the uncertainties of the technology cost projections, however, by looking at the effects of cost overruns on the four options. We first assume that all AVLIS capital plant and equipment costs will be 100 percent greater than current estimates, while the AGC capital construction and machine costs are 50 percent greater. At this time, the AVLIS cost projections are considered more uncertain, since the AGC facility is already partially built, and Set III gas centrifuges are now operating. The associated outlay projections (see Table 6) again indicate that Option IV would be the most economic program, and that even Option II (AVLIS with continued diffusion reliance) would be marginally cheaper than Option III (the six-building AGC facility).

If we assume that the AGC program can actually meet its current cost projections, actual AVLIS process costs (under Option IV) would have to increase by 50 percent in order for Option III to be more economic, although Option IV would still have lower outlays through the year 2000.

The frequent nature of the revisions in the AGC and AVLIS cost schedules emphasizes the uncertainties inherent in any long-term technologically intensive program. When the DOE selects between the two technologies in May 1985, it must evaluate their relative economic risks along with the cost schedules that are projected at that time.

Advanced Deployment Schedule for the AVLIS Program

To respond to Chairman Ottinger's request to evaluate an accelerated development schedule of the AVLIS process (ready by 1990 instead of 1983), we asked DOE's Lawrence Livermore Laboratory to provide us with cost information on this alternative AVLIS schedule. Because these data have not received full DOE headquarters review, we must caution that this AVLIS deployment schedule and cost data are more uncertain than the DOE data assumed in the AVLIS programs in Options II and IV.

This AVLIS program assumes that two AVLIS plants provide DOE's long-term SWU requirements through 2025. These plants would operate at a lower tails assay than Options I to IV assumed, however, requiring less natural uranium feed but more separative work to produce equal amounts of

the enriched uranium product. 15/ The two plants would have an annual SWU capacity of 13 and 9 million SWUs, respectively, beginning production in 1990 and 1992.

This program would be less costly than the similar AVLIS program that assumes deployment in 1993 (Option IV), mainly because production from the diffusion plants could be displaced quicker. Through the year 2000, this alternative AVLIS program would cost roughly $18 billion in federal outlays, compared to almost $20 billion for Option IV. By 2025; its enrichment production cost would be $23.4 per SWU, instead of $29.4 per SWU if AVLIS would not begin production until 1993.

Sensitivity of Enrichment Options to Lower Demand Projections

Future demand for DOE's enrichment services largely depends on nuclear capacity growth and the response of DOE's customers to the new U.S. contract. We developed a lower SWU demand scenario to test the sensitivity of the two new technologies to lower than expected demand for DOE's enrichment services. The CBO low-demand case reflects both lower nuclear-power capacity growth (and thus lower enriched uranium fuel requirements), and a somewhat different customer response to DOE's new contract than DOE assumed in its revised interim plan. The CBO case projects a more dire forecast for the nuclear-power industry and DOE's enrichment services demand, but at this time, it is neither more nor less likely than the DOE projections.

Figure 3 shows the projected worldwide nuclear capacities that would use U.S. enrichment services under both DOE's interim plan and CBO's low-demand schedule. By the year 2000, the DOE would have enrichment contracts to service 178 Gwe and 150 Gwe under the DOE and CBO cases, respectively (refer to Table 1). The factor used to convert total gigawatt capacity to annual SWU requirements, based on a capacity utilization rate of 65 percent, is 110,000 SWUs per Gwe. Reactors are assumed to retire after 35 years of operation. The CBO case assumes that only nuclear reactor plants currently being built in the United States and abroad come on line by the year 2000. Furthermore, those projects in the United States currently less than 50 percent complete are assumed cancelled, and several

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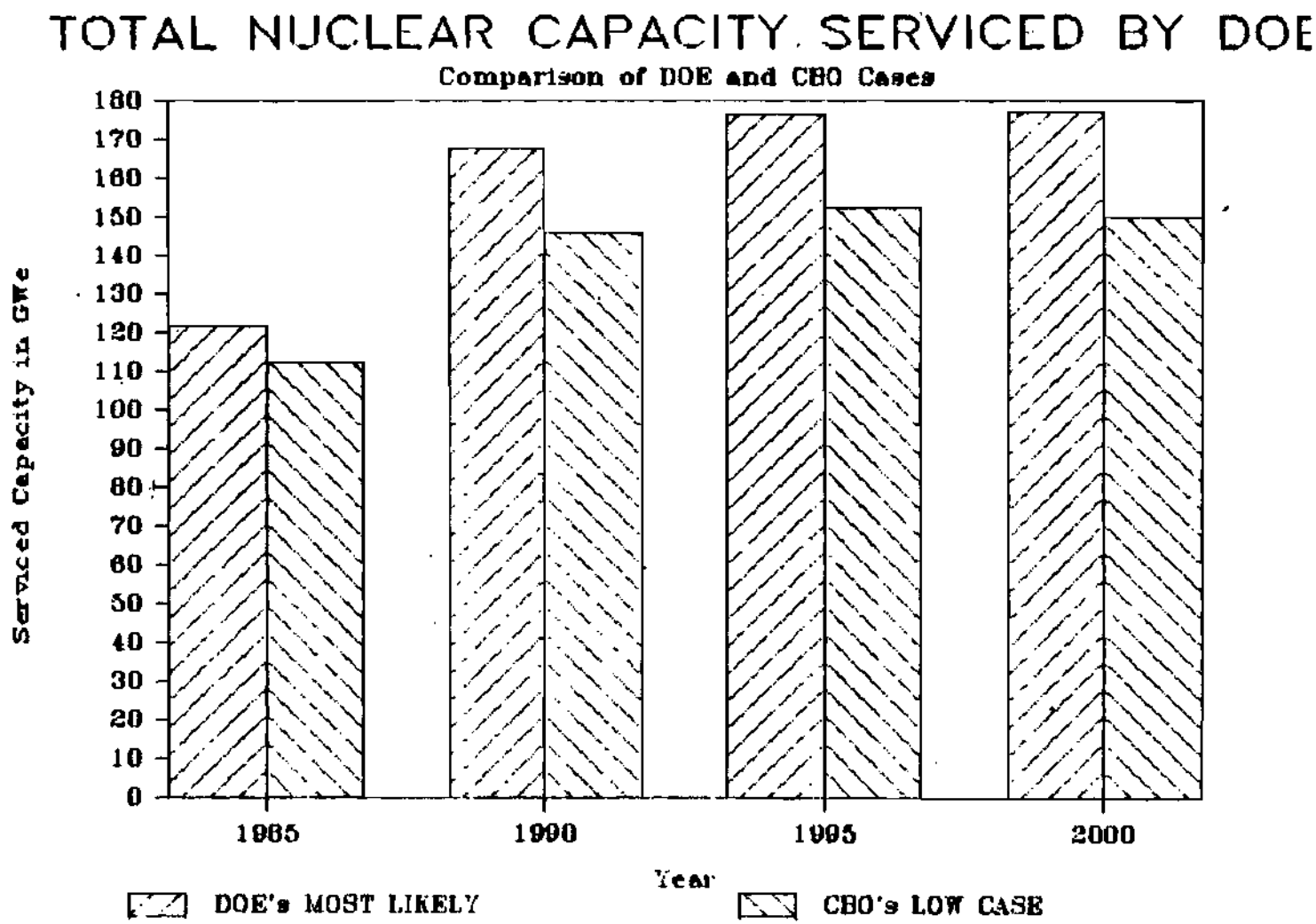
15. Options I through IV assumed that all enrichment facilities would operate at a tails assay of roughly 0.3 percent from 1985 to 1989 and at a tails assay of 0.235 percent thereafter. This program assumed the same tails schedule for the diffusion plants, but a 0.2 percent tails assay for the AVLIS plants.

FIGURE 3.



SOURCE: Congressional Budget Office.

others are delayed from entering service if the utility owner already has missed several projected operation schedules. 16/

New nuclear capacity after 2000 reflects assumptions about future electricity demand growth and the percent share that will be supplied by nuclear power. For the low case, we assumed that domestic electricity growth would average 2 percent per year through the year 2000, and 1 percent per year thereafter. The nuclear share would peak at 18 percent in 2000, and decline to a stable 12 percent share by 2012. The DOE would service all current and projected domestic utilities.

The DOE would maintain some limited contracts with European utilities through 2000, but after that the DOE would lose almost all these sales. After 2000, DOE's largest non-U.S. customers would be Japan, Korea, and Taiwan, although DOE sales to these countries are assumed to be lower than the DOE currently projects in its revised interim plan. (For the non-U.S. countries serviced by the DOE past 2000, electricity demand growth is derived from standard sources, and the nuclear share of projected electricity demand is held constant after 2025.) 17/

The CBO low SWU demand scenario assumes that 80 percent of DOE's current enrichment customers actually convert to the new U.S. contract, and that they purchase only 70 percent of their annual enrichment requirements from the DOE through 1993, when the world SWU inventory would be depleted. (In contrast, the DOE assumes that 85 percent of its current customers convert, purchasing 85 percent of their annual requirements from the DOE.) Figure 4 compares total DOE SWU sales to U.S. and non-U.S. utilities and to the U.S. government under the DOE "most likely" and the CBO low-demand cases.

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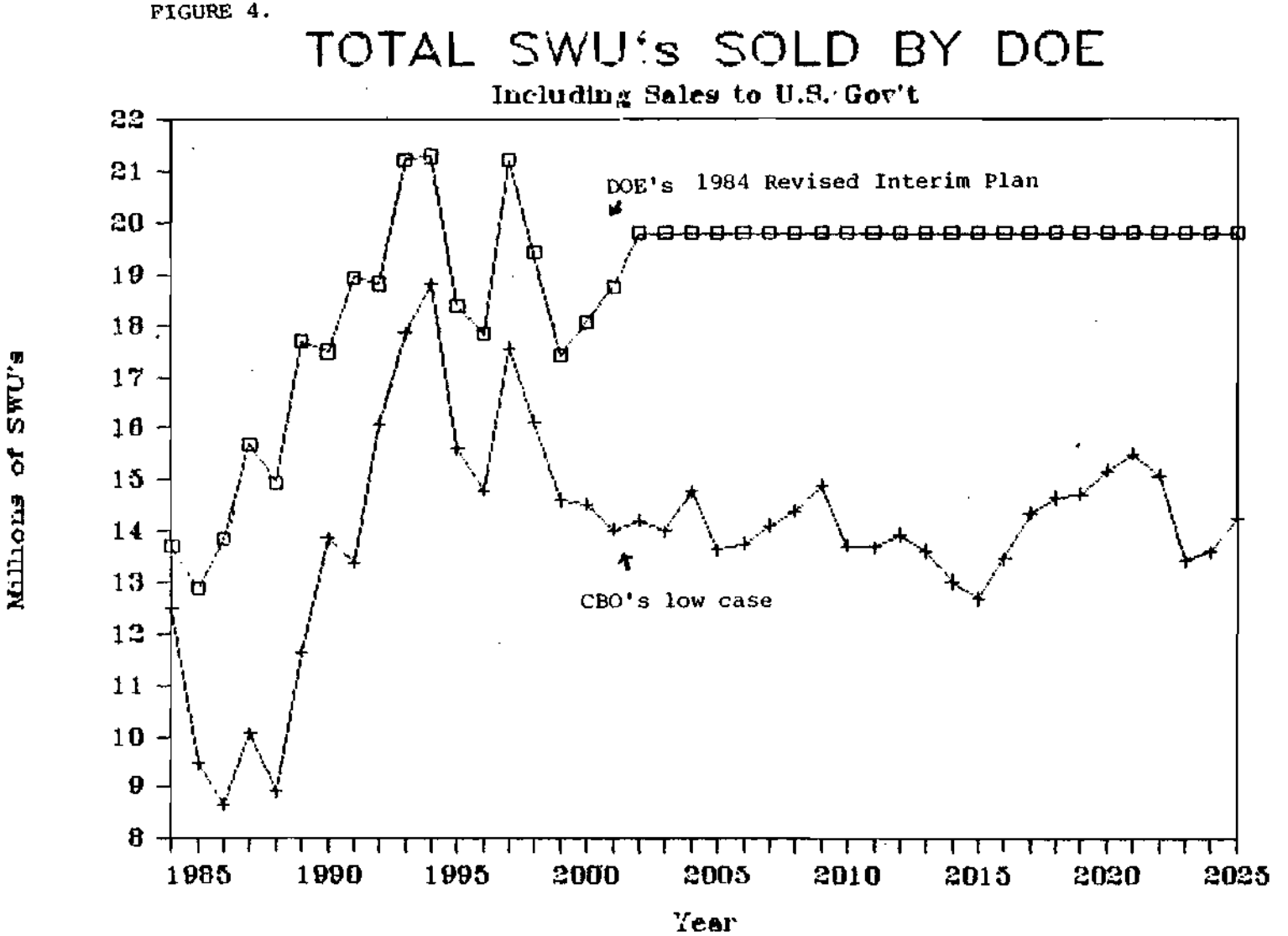
16. Since the DOE's "most likely" nuclear capacity case was developed in 1983, several nuclear plants have been deferred or cancelled (Midland, Zimmer, four TVA facilities, and Marble Hill), and a few utilities face acute financial difficulties (Consumers Power, LILCO, Public Service of Indiana). The choice of the 50 percent construction completion factor as a low-case cutoff reflects the expectation that rising financing costs for U.S. utilities (which have been exacerbated by these recent developments) may force cancellation of most plants that are now more than five years away from commercial operation. This assumption also reflects the recent trend by U.S. utilities to cancel the second plant of a twin facility as costs rise.

17. Sources include Organization for Economic Cooperation and Development, the World Bank, and the Department of Energy's Energy Information Administration.

FIGURE 4.


TOTAL SWU's SOLD BY DOE
Including Sales to U.S. Gov't
DOE's 1984 Revised Interim Plan
CBO's low case
Millions of SWU's
Year
22
21
20
19
18
17
16
15
14
13
12
11
10
9
8
1985
1990
1995
2000
2005
2010
2015
2020
2025

CBO evaluated two options for meeting the lower SWU demand requirements, assuming an annual production rate of about 14 million to 16 million SWUs after 1995, compared to the DOE schedule that requires production of roughly 19.8 million SWUs annually in 1995. The two programs are described below:

Option III-A--Build Five-Building AGC Plant, Retire All Gaseous Diffusion Plants. Similar to Option III, the AGC process is selected in 1985, and the DOE builds the capacity necessary to fully retire the three diffusion plants. This would require five process buildings with a total annual capacity of 16.5 million SWUs. The first building would be operational in 1986 (with Set III centrifuges), with full AGC capacity in 1998. The three diffusion plants would shut down in 1990, 1995, and 1997.

Option IV-A--Build Two AVLIS Plants, Retire All Gaseous Diffusion Plants. This option reflects the same assumptions of Option IV, but the two AVLIS plants would be built with less total capacity--only 16.3 million SWUs per year. The plants would begin production in 1993 and 1998. The three diffusion plants would be retired in 1994, 1995, and 1998.

Comparisons of These Low-Demand Program Options. The total enterprise cost and outlay projections of these two options would be lower than any of those under the assumed DOE demand projections, because of the reduced capital, operating, and feed cost requirements (see Table 7). Again, the AVLIS option would be the most cost-efficient program, with total federal outlays of $18.8 billion (in discounted fiscal year 1985 dollars), about 12 percent lower than those for the AGC-based option.

Enrichment production costs follow the same pattern. By the year 2025, Option IV-A's enrichment costs would be roughly $31 per SWU, compared to $36 per SWU for Option III-A.

CONCLUSIONS AND CAUTIONS

Both the AGC and AVLIS technologies promise to lower DOE's production costs and SWU prices in the future, thereby making DOE's services more attractive to enrichment customers. The most economic investment strategy for the DOE to undertake would be to replace all three diffusion plants with either AVLIS or AGC capacity: at this time, using data available to us, the AVLIS program appears to have a slight economic advantage over the AGC process through 2025. Under the revised data projections that the DOE is reviewing now, however, the relative rankings between these two programs may change.

TABLE 7. DISCOUNTED OUTLAYS AND ENTERPRISE COSTS UNDER EACH OPTION ASSUMING THE CBO LOW-DEMAND CASE, 1984-2025

	Option III-A	Option IV-A
Discounted Federal Outlays (In billions of fiscal year 1985 dollars)		
Gaseous Diffusion	9.9	11.3
AGC a/	7.5	NA
AVLIS	NA	3.6
DOE Feed Purchases	3.9	3.9
Total	21.3	18.8
1984-2000 Total	18.2	15.7
Discounted Enterprise Costs (In billions of fiscal year 1985 dollars)		
Gaseous Diffusion	9.9	11.3
AGC a/	7.7	NA
AVLIS	NA	3.7
DOE Feed Purchases	3.9	3.9
Customer Feed Costs	32.0	32.0
Total	53.5	50.9
Cost per SWU in Fiscal Year 1985 Dollars		
Enrichment Charge Through 1995	99.3	90.1
Enrichment Charge Through 2025	35.5	31.1

SOURCE: Congressional Budget Office.

NOTES: The real discount rate assumption is 6 percent per year. In computing enterprise costs and enrichment charges, all capital costs are depreciated over 25 years at a real interest rate of 6 percent per year. Total production through 2025 would be 605 million SWUs under all options.

a. The AGC program assumes that only half the first GCEP building will be filled with Set III gas centrifuges, and that AGC (Set V) machines replace these beginning in 1989.

Through the year 2000, incorporating the AVLIS process into DOE's enrichment operations to displace either some or all of the diffusion capacity should reduce DOE's program spending more than the AGC program would. As we mentioned before, the large capital costs of the AGC facility outweigh its earlier deployment advantage over the AVLIS process and thus would result in somewhat higher SWU prices. Even with more favorable data projections for AGC, it seems unlikely that the proposed AVLIS program would require greater total program outlays than will AGC over this time period.

Attachment

Department of Energy
Washington, D.C. 20545

NOV 13 1984

David L. Bodde, Assistant Director
Natural Resources and Commerce
Congressional Budget Office
U.S. Congress
Washington, DC 20515

Dear Mr. Bodde:

We appreciate your office sending us a copy of the Congressional Budget Office's (CBO) September 14, 1984, memorandum to Jeanine Hull on the preliminary results of a CBO study update at the request of Chairman Ottinger on the Economic Comparisons of the Advanced Gas Centrifuge (AGC) and the Atomic Vapor Laser Isotope Separation (AVLIS) processes. Further, we recognize that the data base used in the CBO analysis is the Department of Energy's (DOE) March 1984 Interim Working Scenario (IWS) including base Gas Centrifuge Enrichment Plant and AVLIS costs.

Our main comment on your analysis is that the data base used by CBO inadequately reflects the current situation. This is due, of course, to the length of time needed to perform these analyses and the rapid evolution of revised economic estimates for both technologies during the last 6 months. It was in January 1984 that the Department recommended the May 1985 technology decision to Congress. Immediately, the Department and the technology advocates began to reexamine the AGC and AVLIS technology research schedules and costs to make available adequate data for the May 1985 decision. As a part of this realignment, the deployment schedules were reexamined.

While this process was underway, DOE developed an IWS for our planning purposes. The separative work unit demand and technology deployment assumptions used in the IWS were those available as of January 1984. Since then, significant changes have occurred in the assumed technology deployment schedules as the technology advocates have developed their optimum economic case in support of process selection. For example, the IWS assumed Set V centrifuge machines were not available until 1989, while the current assumption is that Set V machines can be available in 1987, or 2 years earlier. The impact of such changes is significant enough to alter the conclusions of comparative economic analysis of AGC and AVLIS. In addition, the results of the recently completed contract conversion process indicate that demand for DOE enrichment services will be higher than that assumed in the IWS.

Accordingly, we are now updating our data base and will continue to do so as process proponents develop their best estimates in support of the May 1985 technology selection. Pending the selection, we will prepare an updated IWS by January 1985 and we will provide it for your use at that time. Of course, following the May 1985 selection, we will also provide our selection findings and supporting data to you and to the Congress. Given the availability of the more current data, you may want to defer completion of your study until 1985. Please call if I can be of assistance.

Sincerely,

John R. Longenecker

John R. Longenecker
Deputy Assistant Secretary
for Uranium Enrichment
Office of Nuclear Energy