APPENDIXES

APPENDIX A. DESCRIPTION OF ANALYTIC METHOD AND ASSUMPTIONS

To project total enterprise costs and outlays for the Base/DOE Plan and the options examined, the Congressional Budget Office used an accounting model for each of the three technologies--gaseous diffusion, both the gas centrifuge enrichment plant and advanced gas centrifuge, and the atomic vapor laser isotope separation process. The costs included those associated with research and development, capital investment, operation and maintenance, and uranium feedstock. Those corresponded with each technology's production schedule under the options. The total costs and SWU production figures from each technology were combined in a larger model, which reports on total option costs and production schedules.

As described in Chapter IV, the initial analysis applied a SWU production level designed to meet the Department of Energy's medium-level demand projections. Each option thus provides a cumulative production of 1.06 billion SWUs over the period 1983 to 2025. For each option, the production schedule for the technologies was assigned as follows:

- The three gaseous diffusion plants would be relied on only while production from the advanced technologies is insufficient to meet demand, and they are phased out of commercial operation as soon as the new processes can be brought on-line to replace them.

- For the Base/DOE Plan and Option I, production from the eight-building GCEP complex is based on the deployment schedule outlined in the DOE's operating plan (January 1983), beginning in 1988 at 0.4 million SWUs a year, eventually operating at full capacity of 13.2 million SWUs a year, through 2025.

- For Option II, production from the two-building GCEP complex (as under Option I) would also begin in 1988, producing 0.4 million SWUs, and would eventually run at maximum capacity of 3.3 million SWUs from 1997 through 2025.

- For Options I, II, and III, AVLIS plants would be brought on-line in consecutive years as required to phase out the gaseous diffusion plants, either with or without the GCEP. The AVLIS technology would be first introduced in 1994 at an annual rate of 0.9 million SWUs.

- For Option IV, production from the GCEP/AGC complex would begin in 1988 at 0.4 million SWUs, using the Set III machines and, in 1990, improved Set IV machines. Set V centrifuges would be phased in beginning in 1994, eventually providing a maximum capacity of 26.5 million SWUs per year from 1999 to 2025.

- The DOE SWU inventory is used as needed in meeting annual SWU requirements, after assuring that it could provide at least one-third of the next year's requirements. Under all options, the stockpile is drawn down from its 1982 level of 24.7 million SWUs to 8.8 million SWUs by the year 2002, where it remains through 2025. The drawdown from the DOE inventory is not accounted for in enterprise costs, since the stockpile is considered a "sunk cost," while enterprise costs consist only of yearly outlays expended over the period 1983 through 2025. 1/

Under all options, total enterprise costs represent the feed and system costs of enriching uranium. In determining enterprise costs, the real interest rate on capital was assumed to be 4 percent, and initial costs were fully depreciated over 25 years. The capital recovery factor accounts for the interest and depreciation on capital investment that would be reflected in the SWU prices charged to DOE customers. The federal outlay schedules for each option were also calculated; these do not include feed costs nor capital interest and depreciation expenses, since the actual appropriation levels would be made each year.

The amount of natural uranium feed each technology requires ranges between 1.3 and 1.6 kilograms of uranium (kgU) per SWU produced. 2/ Since

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1. Total enterprise costs represent the combined option costs both to the DOE and to the enrichment customers, including depreciation and interest on capital, and feed charges. Not included in enterprise costs are the still unrecovered outlays expended before 1983, costs associated with carrying the existing DOE natural uranium feed and SWU inventories, and the administrative costs of running the DOE enrichment program. These costs would be reflected in actual DOE SWU prices, however, since by law all costs associated with the federal enrichment program must be recovered from sales.

2. The amount of natural uranium feed required to produce a given amount of enriched product is dependent on the U-235 concentration in the feed, enriched product, and depleted uranium waste stream left after enrichment. The concentration remaining in the depleted uranium tails, called the tails assay, is an operating tool set by the (Continued)

equal cumulative SWU production levels would be produced under all options, the costs of natural uranium feed are not a decisive factor in determining the least-cost enrichment program. However, the feed costs under each option are included in total enterprise costs, which represent the combined enrichment costs both to the DOE and to its customers. 3/ The unit price for natural uranium used in the CBO analysis--$134 per kgU through the year 2025-- was the price set by the DOE in its program cost analyses as published in the January 1983 operating plan.

The three algorithms that calculate the costs of uranium enrichment under the different technologies are described below.

The Gaseous Diffusion Subroutine

The gaseous diffusion model calculates the annual costs of operating the three gaseous diffusion plants at given SWU production levels. The costs include feed, operating and maintenance, power, capital, and plant decommissioning costs.

The DOE has power contracts with the following utility companies for operating the gaseous diffusion plants: the Tennessee Valley Authority (TVA) for the Oak Ridge (Tennessee) and Paducah (Kentucky) plants; Electric Energy, Incorporated (EEI) for the Paducah plant; and the Ohio Valley Electric Corporation (OVEC) for the Portsmouth (Ohio) plant. In 1983, the unit power charges to the DOE were 4.11 cents per kilowatt hour for TVA, 2.79 cents per kilowatt hour for EEI, and 2.96 cents per kilowatt hour for OVEC. Future power costs were determined using a DOE schedule that estimates yearly total power cost projections for different gaseous diffusion production levels. This schedule incorporates DOE's current and projected contract commitments with the three utilities, and includes

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2. (Continued)
DOE. All technologies are assumed to operate under the same tails assay at the same time. Until 2000, all technologies operate at a tails assay of 0.2 percent; from 2000 to 2025, all technologies are assumed to operate at a tails assay of 0.25 percent. This is consistent with the tails assay assumptions in the DOE's current operating plan. Appendix B contains the results of an analysis of program costs assuming that all technologies operate at a tails assay of only 0.10 percent from the year 2000 to 2025.

3. The feed costs are not included in the federal outlay figures or enrichment charges for each option.

demand penalties that the DOE would incur for using less than the full committed power levels under the current contracts. For each option, power charges are adjusted upward using a 0.5 percent real annual rate for electricity. Over the 1983-2025 period, the combined operating and power costs for this process range from $50 to $82 per SWU, varying with the production schedule for gaseous diffusion assumed for each option. 4/

The capital expenditure projections for maintaining the three gaseous diffusion plants were obtained from DOE, totaling roughly $600 million under all options except the Base/DOE Plan, the only program that would continue to use gaseous diffusion through the year 2025. The estimated capital expenditures associated with maintaining the gaseous diffusion plants through the year 2025 in the Base/DOE Plan are $760 million.

The last cost item in the gaseous diffusion subroutine is the decommissioning cost incurred in the year production is discontinued for each plant. The DOE does not currently provide a specific figure for closing down the gaseous diffusion plants, but it has estimated a wide range of costs. The model assumes a mid-range estimate of $700 million for each plant closed down. Whatever portion of the plant is not fully depreciated at the time of decommissioning is still included in enterprise costs.

The GCEP Subroutine

The cost of the GCEP program includes research and development, capital, feed, and operating and maintenance. The system costs used in the GCEP subroutine are based on projections prepared at the Oak Ridge Laboratory where the development and performance testing for this project are under way. Cost estimates were provided for the eight-building GCEP (Set III-Set IV) complex (Base/DOE Plan and Option I), the two-building GCEP (Option II), and AGC (Option IV). 5/

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4. The outlays for the operating and maintenance costs, in addition to the power costs, were obtained from the DOE Office of Uranium Enrichment and Assessment. The cost figures cited in this Appendix represent discounted outlays in constant 1983 dollars assuming a real discount rate of 4 percent.

5. The GCEP and AGC cost data were in part reported in the DOE operating plan. The rest were obtained from the DOE Office of Uranium Enrichment and Assessment.

The discounted operating costs for the GCEP/AGC complex average $5 per SWU over the analysis period, including the operating costs of the less advanced Sets III and IV machines before the introduction of the Set V (AGC) advanced machines. This $5 per SWU average is about one-half the cost per SWU of operating the eight-building GCEP complex. The total discounted capital costs for the GCEP and AGC programs are very similar, $5.5 billion and $5.7 billion, since both would use the same eight buildings; the incremental capital costs for AGC are associated with the more efficient Set V machines. The discounted research and development costs for the AGC process are $0.8 billion, more than 50 percent higher than research costs for GCEP. It is important to note that there is still a large degree of uncertainty concerning the advanced centrifuge machine design, performance, and project costs; thus, total AGC costs could be much higher.

There is a significant trade-off between the two-building GCEP proposal (Option II) and the eight-building GCEP project (Base/DOE Plan and Option I). Through the capital costs for the two-building GCEP ($2.6 billion) would be about 53 percent lower than those for the full eight-building plant ($5.5 billion), the operating costs per SWU would be more than twice as high. Furthermore, before AVLIS became operational in the early 1990s, a two-building GCEP complex would require greater reliance on the gaseous diffusion plants, further increasing total production costs.

If the GCEP program were discontinued entirely after 1983, as in Option III (AVLIS only), the DOE would still incur GCEP-related outlays of $1.4 billion associated with current commitments to procure and build centrifuge machines.

The AVLIS Subroutine

The AVLIS program enterprise costs--for research and development, capital, feed, and operating and maintenance--depend on the number and capacity of the AVLIS plants brought on-line. Under Options I, II, and III, total AVLIS capacity is designed to enable the three gaseous diffusion plants to be phased out by the late 1990s.

The DOE deployment schedule for one AVLIS plant assumes an annual production rate of nine million SWUs, with production of 0.9 million SWUs beginning in 1994, 6.3 million SWUs in 1995, and the full nine million SWUs from 1996 on. In the CBO analysis, the number of plants built and the total annual AVLIS capacity for each option using that process is given below:

- Under Option I (eight-building GCEP and AVLIS), two AVLIS plants would be built with a combined annual capacity of 15.3 million SWUs;

- Under Option II (two-building GCEP and AVLIS), three AVLIS plants would be built with a combined annual capacity of 25 million SWUs;

- Under Option III (AVLIS only), three AVLIS plants would be operated with a total annual capacity of 27 million SWUs.

The deployment schedule for each AVLIS plant is based on the DOE schedule detailed above and displayed in Chapter IV, Table 7.

The AVLIS algorithm projects capital expenditures based on the DOE undiscounted cost estimate of $947 million for a nine million SWU capacity plant. [6] The CBO analysis assumes that the maximum plant capacity would be nine million SWUs a year but that smaller plants could be built. Such smaller plants' capital construction costs are calculated without a decreasing-return-to-scale factor. [7] The total discounted capital costs for the two-plant AVLIS program (Option I) would be $1.12 billion; under Options II and III, the capital costs for three AVLIS plants would be $1.76 billion and $1.93 billion, respectively. The discounted research and development costs to support AVLIS would be $0.63 billion. The discounted operating and maintenance costs for the AVLIS complex are roughly $8 per SWU over the 1983-2025 period, including the cost of converting natural uranium feed into a solid form, a requirement unique to the AVLIS process.

Combined Technology Costs for Each Option

To compute the enterprise costs and outlays for each option, the production and cost figures from the relevant technologies are combined and

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6. The research and development, capital, and operating and maintenance cost schedules for the AVLIS technology are projected on the basis of information prepared for DOE at the Lawrence Livermore Laboratory, where the AVLIS developmental work is being done. The AVLIS capital and operating costs and production figures are reported in the DOE operating plan (January 1983). The research and development cost data were obtained directly from the DOE Office of Uranium Enrichment and Assessment.

7. The major portion of the capital costs for an AVLIS plant represents the machinery expenditures directly related to SWU capacity; thus the DOE advised against using a decreasing-return-to-scale factor when projecting capital costs for a plant with an annual capacity of less than nine million SWUs.

discounted using a real annual rate of 4.0 percent. Tables A-1 through A-5 show the annual SWU production schedules, total enterprise costs, and outlay trends for the base plan and the four options under the initial medium SWU demand schedule. Enterprise costs and federal outlays are shown in 1983 dollars. Appendix B discusses the model results based on alternate sets of assumptions, including projected SWU demand.

In all tables, outlays represent annual government expenditures, which exclude feed costs, discounted at a real rate of 4.0 percent. These outlays do not take into account the offsetting government revenue from the enrichment services customers, which must recover the full cost to the federal government of running the enrichment program, over a ten-year period.

TABLE A-1. BASE/DOE PLAN--ANNUAL SWU PRODUCTION, ENTERPRISE COSTS, AND FEDERAL OUTLAYS, 1983-2025

Year	Annual SWU Production (In millions of SWUs)			Discounted Enterprise Costs (In millions of	Discounted Federal Outlays 1983 dollars)
	Gaseous Diffusion	GCEP	Total		
1983	9.8	0.0	9.8	2,971	1,926
1984	12.1	0.0	12.1	3,602	2,202
1985	16.7	0.0	16.7	4,660	2,447
1986	18.2	0.0	18.2	4,831	2,394
1987	19.2	0.0	19.2	4,908	2,361
1988	19.2	0.4	19.6	4,828	2,292
1989	19.2	1.1	20.3	4,809	2,238
1990	19.2	3.1	22.3	4,866	2,078
1991	19.2	5.2	24.4	4,888	1,859
1992	17.9	7.3	25.2	4,749	1,710
1993	13.3	9.6	22.9	4,495	1,752
1994	13.3	11.7	25.0	4,089	1,052
1995	13.3	13.0	26.3	4,048	896
1996	13.3	13.1	26.4	3,913	864
1997	13.3	13.2	26.5	3,774	834
1998	13.3	13.2	26.5	3,633	805
1999	13.3	13.2	26.5	3,497	777
2000	13.3	13.2	26.5	3,918	749
2001	13.3	13.2	26.5	3,771	723
2002	13.3	13.2	26.5	3,629	698
2003	13.3	13.2	26.5	3,493	673
2004	13.3	13.2	26.5	3,361	650
2005	13.3	13.2	26.5	3,235	627
2006	13.3	13.2	26.5	3,113	605
2007	13.3	13.2	26.5	2,996	584
2008	13.3	13.2	26.5	2,866	563
2009	13.3	13.2	26.5	2,740	544
2010	13.3	13.2	26.5	2,622	525
2011	13.3	13.2	26.5	2,510	506
2012	13.3	13.2	26.5	2,403	489
2013	13.3	13.2	26.5	2,300	472
2014	13.3	13.2	26.5	2,202	455
2015	13.3	13.2	26.5	2,108	439
2016	13.3	13.2	26.5	2,020	424
2017	13.3	13.2	26.5	1,936	409
2018	13.3	13.2	26.5	1,856	395
2019	13.3	13.2	26.5	1,784	381
2020	13.3	13.2	26.5	1,717	368
2021	13.3	13.2	26.5	1,652	355
2022	13.3	13.2	26.5	1,590	342
2023	13.3	13.2	26.5	1,530	330
2024	13.3	13.2	26.5	1,472	319
2025	13.3	13.2	26.5	1,417	308

SOURCE: Congressional Budget Office.

TABLE A-2. OPTION I--ANNUAL SWU PRODUCTION, ENTERPRISE COSTS, AND FEDERAL OUTLAYS, 1983-2025

Year	Annual SWU Production (In millions of SWUs)				Discounted Enterprise Costs (In millions of 1983 dollars)	Discounted Federal Outlays (In millions of 1983 dollars)
	Gaseous Diffusion	GCEP	AVLIS	Total		
1983	11.2	0.0	0.0	11.2	3,349	2,056
1984	12.4	0.0	0.0	12.4	3,752	2,294
1985	17.5	0.0	0.0	17.5	4,922	2,591
1986	16.5	0.0	0.0	16.5	4,587	2,423
1987	18.9	0.0	0.0	18.9	4,967	2,452
1988	17.8	0.4	0.0	18.2	4,641	2,299
1989	19.2	1.1	0.0	20.3	4,888	2,305
1990	20.6	3.1	0.0	23.7	5,186	2,259
1991	19.6	5.2	0.0	24.8	5,020	2,059
1992	16.8	7.3	0.0	24.1	5,069	2,318
1993	12.3	9.6	0.0	22.0	3,852	1,396
1994	10.6	11.7	0.9	23.2	3,777	1,120
1995	6.2	13.0	7.2	26.4	4,219	1,202
1996	0.0	13.1	13.8	26.9	3,924	827
1997	0.0	13.2	13.2	26.4	3,308	310
1998	0.0	13.2	15.3	28.5	3,412	324
1999	0.0	13.2	14.4	27.6	3,186	301
2000	0.0	13.2	12.0	25.2	3,345	262
2001	0.0	13.2	13.7	26.9	3,417	271
2002	0.0	13.2	14.2	27.4	3,342	266
2003	0.0	13.2	13.3	26.5	3,115	246
2004	0.0	13.2	13.3	26.5	2,995	237
2005	0.0	13.2	13.3	26.5	2,880	228
2006	0.0	13.2	13.3	26.5	2,769	219
2007	0.0	13.2	13.3	26.5	2,663	211
2008	0.0	13.2	13.3	26.5	2,543	202
2009	0.0	13.2	13.3	26.5	2,427	195
2010	0.0	13.2	13.3	26.5	2,319	187
2011	0.0	13.2	13.3	26.5	2,216	180
2012	0.0	13.2	13.3	26.5	2,118	173
2013	0.0	13.2	13.3	26.5	2,024	166
2014	0.0	13.2	13.3	26.5	1,934	160
2015	0.0	13.2	13.3	26.5	1,848	154
2016	0.0	13.2	13.3	26.5	1,764	148
2017	0.0	13.2	13.3	26.5	1,684	142
2018	0.0	13.2	13.3	26.5	1,607	137
2019	0.0	13.2	13.3	26.5	1,537	131
2020	0.0	13.2	13.3	26.5	1,473	126
2021	0.0	13.2	13.3	26.5	1,414	122
2022	0.0	13.2	13.3	26.5	1,360	117
2023	0.0	13.2	13.3	26.5	1,308	112
2024	0.0	13.2	13.3	26.5	1,257	108
2025	0.0	13.2	13.3	26.5	1,209	104

SOURCE: Congressional Budget Office.

TABLE A-3. OPTION II--ANNUAL SWU PRODUCTION, ENTERPRISE COSTS, AND FEDERAL OUTLAYS, 1983-2025

Year	Annual SWU Production (In millions of SWUs)				Discounted Enterprise Costs (In millions of 1983 dollars)	Discounted Federal Outlays (In millions of 1983 dollars)
	Gaseous Diffusion	GCEP	AVLIS	Total		
1983	11.2	0.0	0.0	11.2	3,347	2,054
1984	12.4	0.0	0.0	12.4	3,747	2,271
1985	17.5	0.0	0.0	17.5	4,931	2,544
1986	16.5	0.0	0.0	16.5	4,575	2,256
1987	18.9	0.0	0.0	18.9	4,920	2,189
1988	17.8	0.4	0.0	18.2	4,577	1,937
1989	19.2	1.1	0.0	20.3	4,781	1,857
1990	21.4	2.3	0.0	23.7	5,091	1,833
1991	22.3	2.4	0.0	24.7	5,069	1,881
1992	21.5	2.6	0.0	24.1	4,739	1,842
1993	19.2	2.8	0.0	22.0	4,163	1,675
1994	19.4	2.9	0.9	23.2	4,182	1,671
1995	15.5	3.1	7.2	25.8	4,547	1,828
1996	7.2	3.3	16.2	26.7	4,137	1,295
1997	0.0	3.3	24.3	27.6	3,813	863
1998	0.0	3.3	25.0	28.3	3,354	378
1999	0.0	3.3	24.0	27.3	3,120	351
2000	0.0	3.3	22.0	25.3	3,324	315
2001	0.0	3.3	23.7	27.0	3,397	322
2002	0.0	3.3	24.0	27.3	3,300	312
2003	0.0	3.3	23.2	26.5	3,086	292
2004	0.0	3.3	23.2	26.5	2,967	281
2005	0.0	3.3	23.2	26.5	3,853	270
2006	0.0	3.3	23.2	26.5	2,743	260
2007	0.0	3.3	23.2	26.5	2,638	250
2008	0.0	3.3	23.2	26.5	2,519	240
2009	0.0	3.3	23.2	26.5	2,405	231
2010	0.0	3.3	23.2	26.5	2,298	222
2011	0.0	3.3	23.2	26.5	2,200	214
2012	0.0	3.3	23.2	26.5	2,109	205
2013	0.0	3.3	23.2	26.5	2,024	197
2014	0.0	3.3	23.2	26.5	1,945	190
2015	0.0	3.3	23.2	26.5	1,868	183
2016	0.0	3.3	23.2	26.5	1,792	176
2017	0.0	3.3	23.2	26.5	1,717	169
2018	0.0	3.3	23.2	26.5	1,644	162
2019	0.0	3.3	23.2	26.5	1,572	156
2020	0.0	3.3	23.2	26.5	1,503	150
2021	0.0	3.3	23.2	26.5	1,440	144
2022	0.0	3.3	23.2	26.5	1,383	139
2023	0.0	3.3	23.2	26.5	1,330	133
2024	0.0	3.3	23.2	26.5	1,279	128
2025	0.0	3.3	23.2	26.5	1,230	123

SOURCE: Congressional Budget Office.

TABLE A-4. OPTION III--ANNUAL SWU PRODUCTION, ENTERPRISE COSTS, AND FEDERAL OUTLAYS, 1983-2025

Year	Annual SWU Production (In millions of SWUs)			Discounted Enterprise Costs	Discounted Federal Outlays
	Gaseous Diffusion	AVLIS	Total	(In millions of 1983 dollars)	
1983	11.2	0.0	11.2	3,820	1,965
1984	12.4	0.0	12.4	3,955	1,975
1985	17.5	0.0	17.5	4,980	2,189
1986	16.5	0.0	16.5	4,515	1,953
1987	18.9	0.0	18.9	4,657	1,810
1988	18.2	0.0	18.2	4,319	1,686
1989	20.3	0.0	20.3	4,561	1,724
1990	23.7	0.0	23.7	5,007	1,879
1991	24.8	0.0	24.8	5,102	2,038
1992	24.1	0.0	24.1	4,765	2,002
1993	22.0	0.0	22.0	4,145	1,793
1994	22.3	0.9	23.2	4,209	1,836
1995	18.6	7.2	25.8	4,192	1,607
1996	10.5	16.2	26.7	4,161	1,448
1997	2.8	24.3	27.1	3,712	941
1998	1.2	27.0	28.2	3,278	408
1999	0.0	27.0	27.0	3,350	691
2000	0.0	26.5	26.5	3,364	299
2001	0.0	26.5	26.5	3,235	288
2002	0.0	26.5	26.5	3,110	277
2003	0.0	26.5	26.5	2,991	266
2004	0.0	26.5	26.5	2,876	256
2005	0.0	26.5	26.5	2,765	246
2006	0.0	26.5	26.5	2,659	237
2007	0.0	26.5	26.5	2,556	227
2008	0.0	26.5	26.5	2,455	219
2009	0.0	26.5	26.5	2,357	210
2010	0.0	26.5	26.5	2,265	202
2011	0.0	26.5	26.5	2,177	194
2012	0.0	26.5	26.5	2,092	187
2013	0.0	26.5	26.5	2,011	180
2014	0.0	26.5	26.5	1,934	173
2015	0.0	26.5	26.5	1,857	166
2016	0.0	26.5	26.5	1,782	160
2017	0.0	26.5	26.5	1,707	154
2018	0.0	26.5	26.5	1,633	148
2019	0.0	26.5	26.5	1,561	142
2020	0.0	26.5	26.5	1,492	137
2021	0.0	26.5	26.5	1,429	131
2022	0.0	26.5	26.5	1,371	126
2023	0.0	26.5	26.5	1,318	121
2024	0.0	26.5	26.5	1,267	117
2025	0.0	26.5	26.5	1,218	112

SOURCE: Congressional Budget Office.

TABLE A-5. OPTION IV--ANNUAL SWU PRODUCTION, ENTERPRISE COSTS, AND FEDERAL OUTLAYS, 1983-2025

Year	Annual SWU Production (In millions of SWUs)			Discounted Enterprise Costs	Discounted Federal Outlays
	Gaseous Diffusion	AGC	Total	(In millions of 1983 dollars)	
1983	11.2	0.0	11.2	3,314	2,021
1984	12.4	0.0	12.4	3,675	2,221
1985	17.5	0.0	17.5	4,843	2,498
1986	16.5	0.0	16.5	4,483	2,316
1987	18.9	0.0	18.9	4,880	2,398
1988	17.8	0.4	18.2	4,596	2,287
1989	19.2	1.1	20.3	4,840	2,269
1990	20.3	3.5	23.8	5,166	2,213
1991	18.4	6.3	24.7	4,932	1,899
1992	14.4	9.6	24.0	4,879	1,993
1993	8.0	13.9	21.9	3,625	999
1994	4.3	19.0	23.3	3,786	976
1995	3.5	22.3	25.8	3,470	386
1996	3.2	23.5	26.7	3,419	327
1997	2.5	24.7	27.2	3,278	263
1998	3.1	25.8	28.9	3,345	269
1999	0.0	26.5	26.5	3,252	509
2000	0.0	26.5	26.5	3,320	130
2001	0.0	26.5	26.5	3,192	125
2002	0.0	26.5	26.5	3,070	120
2003	0.0	26.5	26.5	2,952	115
2004	0.0	26.5	26.5	2,838	111
2005	0.0	26.5	26.5	2,729	107
2006	0.0	26.5	26.5	2,624	103
2007	0.0	26.5	26.5	2,523	99
2008	0.0	26.5	26.5	2,408	95
2009	0.0	26.5	26.5	2,298	91
2010	0.0	26.5	26.5	2,194	88
2011	0.0	26.5	26.5	2,096	84
2012	0.0	26.5	26.5	2,002	81
2013	0.0	26.5	26.5	1,912	78
2014	0.0	26.5	26.5	1,827	75
2015	0.0	26.5	26.5	1,745	72
2016	0.0	26.5	26.5	1,667	69
2017	0.0	26.5	26.5	1,594	67
2018	0.0	26.5	26.5	1,526	64
2019	0.0	26.5	26.5	1,464	62
2020	0.0	26.5	26.5	1,406	59
2021	0.0	26.5	26.5	1,352	57
2022	0.0	26.5	26.5	1,299	55
2023	0.0	26.5	26.5	1,249	53
2024	0.0	26.5	26.5	1,201	51
2025	0.0	26.5	26.5	1,155	49

SOURCE: Congressional Budget Office.

APPENDIX B. SENSITIVITY ANALYSIS--DETAIL

The sensitivity analysis summarized in Chapter IV resulted from five principal changes in the underlying assumptions:

- o Project delays of the AGC and AVLIS technologies,
- o Capital cost overruns in the GCEP, AGC, and AVLIS projects,
- o Higher and lower real discount rates,
- o A higher real power esclation factor, and
- o Lower projected demand for enrichment services.

The first portion of this appendix details the rationales behind and the results of these changed assumptions (see Tables B-1 through B-12, pages 65 through 76). To supplement the sensitivity tests, the remainder of the appendix reviews the analysis with a changed assumption regarding the tails assay in the enrichment process.

In each sensitivity test, all assumptions but the one under scrutiny are held constant with those in the initial analysis. The uniform assumptions include cumulative production for all options at 1.06 billion SWUs, a real discount rate of 4 percent, a real power escalation rate of 0.5 percent, and a 4 percent real return on capital investment when calculating enterprise and SWU costs and enrichment charges. The same 1983-2025 projection period is examined in all cases. Natural uranium feed costs are treated as part of total costs, but they are not included in federal outlays and enrichment charges. All figures are expressed in 1983 dollars, treated by CBO as equal to the fiscal year 1984 dollars used in DOE's projections. In the option that calls for ultimate reliance on the AVLIS technology--Option III--a cost of $1.4 billion is assigned to the gas centrifuge process for the decommissioning of the GCEP facility already partly built.

With both the AGC and AVLIS processes still in the early stages of development, there is considerable uncertainty about their project introduction schedules. The options were examined with the following timetable changes. Under Option III, AVLIS production would come on-line in 1997 instead of 1994; the GCEP project would still be discontinued. Under Option IV, production from the initial GCEP operation would begin in 1988 with 0.4

million SWUs, but incorporation of the AGC (Set V) technology would occur in 1996 instead of in 1993. Under this schedule, the AGC project would reach its maximum annual production rate of 26.5 million SWUs in the year 2002 instead of 1999.

If either or both of the advanced technologies were not available for commercial production until three years later than current projections specify, the rankings of options reported in Chapter IV would not be affected. Option IV, relying ultimately on AGC though introducing it three years behind schedule would offer the lowest enterprise costs ($125.9 billion) over the projection period. This would hold true even if the AVLIS system could be introduced on its current schedule with the enterprise costs of Option III remaining at $128.2 billion. If the AVLIS technology were developed and brought on-line three years late, however, the costs of Option III would be $132.2 billion, $8.7 billion more than the $123.5 billion projected for Option IV in the initial analysis and $6.3 billion higher than the delayed version of Option IV. The enrichment charge for Option IV delayed AGC is also cheaper than under Option III--$29.10 per SWU compared to $31.30. (These comparisons are displayed in Table B-1).

As noted in Chapter IV, the capital cost overrun factors applied for the advanced technologies in the sensitivity analysis are as follows:

- An 8 percent cost overrun factor for the GCEP machine and building costs,
- A 100 percent cost overrun factor for the capital plant and equipment portion of AVLIS, and
- A 100 percent cost overrun factor for AGC machine and a 60 percent factor for the building costs of the GCEP/AGC complex.

The cost overrun factor of 100 percent for the capital equipment portion for both the AVLIS and AGC technologies reflects the considerable uncertainty surrounding the early developmental stage of each. Since the AGC construction phase is now under way, however, an increase of 60 percent was applied to the AGC plant costs, compared to a 100 percent cost overrun in the AVLIS plant capital costs. The 100 percent cost overrun figure applied to the AVLIS capital plant and equipment costs reflects the greater uncertainty associated with this technology. (In fact, the AVLIS process may be improved by "learning-by-doing" effects associated with new technologies; in some instances, real costs can fall below intial estimates, as experience points to improved efficiencies. This analysis, however, does not consider this possibility.)

The much lower cost overrun factor of 8 percent used for the GCEP complex reflects the later developmental stage of Sets III and IV centrifuge machines. In fact, judging from experience to date on construction of the first two buildings and support facilities, actual costs may be just at or below current projections.

The results suggest that, if the above cost overrun factors occurred in all advanced projects, Option IV would still be the least expensive choice, with enterprise costs of $130.2 billion over the projection period. If the AGC program did experience the cost overruns while the AVLIS program costs remained on schedule, Option III would become the least expensive--$128.2 billion for Option III compared to $130.2 billion for Option IV. But again, the total cost differences between the options remain rather small considering the uncertainty of the technology cost projections. (See Table B-2.)

Alternative Discount Rates

The choice of a discount rate can significantly affect decisions about the appropriate timing of expensive capital projects. Thus the sensitivity of the enrichment option costs to different discount rate assumptions was measured. The analysis in Chapter IV discounted the projected enterprise costs and federal outlays using a real annual discount rate of 4 percent (see Chapter IV, Table 7). This appendix displays both the results of a 6 percent real discount rate and a zero percent rate. The results show that, although absolute costs would be different under higher and lower discount rate assumptions, the effect on the comparisons of the options would be insignificant. Compared to the initial analysis, the higher discount rate results in lower total costs across all options, but the relative rankings do not change. Option IV is again the least expensive over the 1983-2025 period, with projected enterprise costs of $92.9 billion and a lifetime enrichment charge of $22.60 per SWU. Option III is the next cheapest choice, with total enterprise costs of $96.4 billion and an eventual enrichment charge of $25.90 per SWU. (See Table B-3.)

With no discounting of future costs, all options appear to require much higher outlays compared to the initial analysis (see Table B-4). For instance, the least expensive choice, again Option IV, would result in a lifetime enrichment charge of $41.10 per SWU using undiscounted costs, compared to $26.70 per SWU using a real discount rate of 4 percent. Option III is still the second cheapest, with total enterprise costs of $268.6 billion and an overall enrichment charge of $51.60 per SWU.

A Higher Inflation Rate for Electricity

The rate at which electricity prices rise will affect the costs of enrichment operations--especially in the short term, when the existing energy-intensive gaseous diffusion plants would still be heavily used. The initial analysis assumed that power costs would escalate at a real annual rate of 0.5 percent; this appendix shows the results of applying an annual 2 percent escalation factor for power costs instead (see Table B-5). As in the other sensitivity analyses, Option IV (AGC) remains the cheapest, costing $124.5 billion and with an eventual enrichment charge of $27.70 per SWU. However, the total costs of the AVLIS programs either with or without the eight-building GCEP--that is Options I and III--are now roughly equal, with total enterprise costs of about $130 billion. Since the inclusion of GCEP in Option I allows for less gaseous diffusion production, and thus lower power costs, the AVLIS-alone program, Option III, loses the advantage it had in the initial analysis.

Lower Projected Demand

The initial analysis reported in Chapter IV is based on DOE's 1983 projections of SWU demand, which assume that the United States would provide enrichment services for 220 gigawatts of nuclear power worldwide by the year 2000. Of this total, 133 gigawatts would represent domestic nuclear generating capacity and 87 gigawatts would be foreign capacity. These DOE medium-case gigawatt totals have been consistently revised downward from previous annual operating plans, reflecting lower estimates of worldwide and domestic nuclear capacity growth and diminishing success in obtaining new foreign contracts for U.S. enrichment services. The CBO has therefore performed this sensitivity analysis reflecting lower demand: one in which full capacity is built but operated at lower levels, and one in which capacity itself is scaled down.

Scaled-Down Use of Full Capacity. In modeling this analysis, CBO assumed that enrichment facilities would be built to provide the full annual complement of 26.5 million SWUs throughout the projection period; capital costs would therefore remain as in the initial analysis. After 1995, however, SWU demand would slow, leveling off after the year 2005 at an annual rate of 19.6 million SWUs. This represents a total capacity use factor of approximately 75 percent.

Again, the cost trends among the options remain the same: Option IV would provide the lowest enterprise ($102.5 billion) and enrichment ($32.10 per SWU) costs. Likewise, Option III would be the second least expensive program, with enterprise costs of $106.0 billion and enrichment costs of $36.20. (See Table B-6.)

To model the effects of the decreased use of the fully constructed enrichment buildings, the following adjustments were made regarding the options:

- The Base/DOE Plan would use the GCEP complex fully, but it would require less production from the gaseous diffusion plants through 2025.

- The programs that include both GCEP and AVLIS (Options I and II) would continue to use GCEP fully but would cut back on AVLIS SWU production levels. The construction of the GCEP and AVLIS plants would have been fully completed by 1995, and it would be cheapest to operate GCEP fully and cut back on AVLIS use (operating costs are $21 per SWU for the GCEP complex, compared to $22 per SWU for AVLIS.)

- Options III and IV would cut back on production from the AVLIS and GCEP/AGC plants uniformly.

Scaled-Down Capacity. In this sensitivity test, capacity is assumed to be built to service 147 gigawatts of installed generating capacity by the year 2000, rather than 220 gigawatts under the medium-demand initial scenario. Of these, 114 gigawatts would be domestic generating capacity and 33 gigawatts would be foreign capacity. (There are currently 59.7 gigawatts of domestic capacity in operation, and 54.3 gigawatts would be added by the year 2000, all to be serviced by the DOE's enrichment program.) Corresponding to the 147 gigawatts of nuclear capacity, the analysis assumes a steady civilian enrichment demand of 18 million SWUs a year after the year 2000 (plus 1.55 million SWUs of military demand).

Since less capacity is built and fewer SWUs produced over the analysis period, all options are less costly compared to the initial analysis. The option trends are the same, however. Option IV would be least expensive, costing $93.4 billion for the total enterprise costs and $31.80 per SWU for enrichment charges, followed closely by Option III, costing $95.8 billion for the enterprise costs and $34.60 per SWU for enrichment charges. (See Table B-7.)

Under these same low-growth demand assumptions, any foreign nuclear plants now categorized as planned but not yet authorized by their governments would be either cancelled or serviced by other enrichment suppliers. Through 1992, DOE would retain all foreign non-firm enrichment contracts except for eight adjustable fixed commitment contracts with Japan (reflecting current over-contracting on Japan's part) and two Taiwanese contracts that are cancelled after 1988 and serviced thereafter

by Eurodif. After 1992, all of DOE's enrichment contracts for European nuclear capacity are assumed lost except for those for three German, one Yugoslavian, and four Swedish units.

Tables B-8 through B-12 display the annual production and cost figures for each option under projected low SWU demand. Total enterprise costs, expressed in 1983 dollars, represent annual expenditures, which exclude feed costs, and are discounted at a real rate of 4.0 percent. Outlays represent annual government expenditures, which exclude feed costs, discounted at a real rate of 4.0 percent. These outlays do not take into account the offsetting government revenue from sales, which must recover the full cost to the federal government of running the enrichment program over a ten-year period. In modeling the five option costs under this low-demand schedule, the following adjustments were made regarding the production capacities and schedules described in Chapter IV.

- The Base/DOE Plan would continue to use two gaseous diffusion plants along with the eight-building GCEP, but the one gaseous diffusion plant would be decommissioned in 1992, rather than in 1993 as in the initial analysis.

- Under Option I only one AVLIS plant would be built, rather than two, with an annual capacity of 6.4 million SWUs; in addition, the three gaseous diffusion plants would be shut down by 1995 instead of 1996.

- Option II would use the two-facility GCEP building with an annual production rate of 3.3 billion SWUs; only two rather than three AVLIS plants would be required, with an annual capacity of 9 and 7.3 million SWUs each. The three diffusion plants would still be decommissioned by the year 1996.

- Option III would initially use three AVLIS plants along with the gaseous diffusion technology, phasing out the latter process entirely by 1997. Two of the three AVLIS plants would each provide 9 million SWUs a year, and the third would have an annual production rate of 2 million SWUs.

- Option IV would use only a six-building GCEP/AGC complex rather than the original eight-building project. An annual production rate of 19.6 million SWUs would be reached by 2001, and production from the gaseous diffusion plants would stop after 1996.